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

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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 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.

Keywords: Energy efficiency, Energy rebates, Energy tax credits, Energy subsidies, Distributional effects, Energy policy

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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.

Partly as a result of these policies, energy efficiency has been linked to major economic and environmental changes. Globally, about $250 billion were invested in energy efficiency in 2017 (IEA, 2018). This investment has spurred job growth in certain sectors. For example, in the United States alone, energy efficiency has been linked to the creation of 2.5 million jobs (NASEO, 2019). From an environmental perspective, some simulations indicate that policies that aggressively sup-

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port investment in energy efficiency could lead to an 1,830 MMT carbon dioxide decrease in U.S. greenhouse gas emissions by 2050 (Gowrishankar and Levin, 2017).

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 a key element in analyses of many environmental and energy policies (e.g., Grainger and Kolstad, 2010; Bento et al., 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 are often of direct interest to utility managers and policymakers (Wichman et al., 2016).

In this paper, I investigate an important component related to the distributional effects of energy efficiency policy: how energy efficiency 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, spending on incentives for energy efficiency is expected to be about $10 billion annually in the United States, doubling relative to 2010 levels (Barbose et al., 2015).[2]

The analysis focuses on a uniquely well-suited version of the Residential Energy Consumption Survey (RECS) from 2009 that includes a large set of detailed questions related to energy efficiency incentives.[3] Using a variety of empirical techniques, I evaluate how the probability of receiving an incentive 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 always present in residences, such as dishwashers and clotheswashers, are more concentrated than are incentives for equipment that tends to be universally-owned, such as refrigerators. The levels of concentration that are estimated are substantial. For example, regression models indicate that a household with an income of $80*k* is three times more likely than a household with an income of $20*k* to receive an incentive. The concentration of incentives in higher-income households is

1. Effectiveness refers to whether the policies created a change in outcomes, such as consumption levels, whereas efficiency refers to whether the policy was optimal relative to alternative policy options. Examples of work related to the efficiency and effectiveness of energy efficiency policies include studies on labeling programs, especially the certification of high-efficiency Energy Star products and buildings (Walls et al., 2017; Jacobsen, 2015; 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, 2016; Jacobsen, 2016; Jacobsen and Kotchen, 2013); and studies on appliance rebates (Houde and Aldy, 2017; Datta and Gulati, 2014).

2. Other regions of the world have also enacted policies related to expanding investment in energy efficiency. For example, due in part to the Energy Performance of Buildings Directive and the Energy Efficiency Directive, spending on energy efficient building technology in Europe is expected to grow from $83.5 billion in 2017 to $111.9 billion in 2026 (Navigant, 2017).

3. I also analyze data from the 2015 RECS, although the 2015 dataset is not as rich as the 2009 version.

driven by differential rates across income groups in equipment presence and turnover, willingness to purchase Energy Star models, and homeownership. Utility rebates are no longer concentrated in higher-income households after controlling for these factors, but manufacturer / retailer rebates and tax credits remain concentrated.

The results are helpful for informing how energy efficiency incentives should be structured. As I describe in Section 3, many policies lead to the provision of energy efficiency incentives. The main implication of the results for policymakers is that incentives are more likely to go to lower-income households if policies are structured such that the incentives are provided through utility rebates and such that 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 receives incentives are an important factor as policymakers evaluate policy options and the associated trade-offs across multiple different criteria.[4] It should further be noted that the analysis is descriptive in nature and focuses on capturing tendencies with respect to the average distributional effects of different types of energy efficiency incentives. The analysis is not necessarily predictive of distributional effects of any individual program, which will depend on a large variety of factors which are not embedded in the present analysis.

2. RELATED LITERATURE ON THE DISTRIBUTIONAL EFFECTS OF ENERGY EFFICIENCY POLICIES

This paper contributes to the literature on the distributional effects of energy efficiency policies. In this section, I describe earlier studies in this area. I focus especially on four studies that have provided evaluations related to the distributional effects of energy efficiency incentives, although I also briefly describe work on the distributional effects of other policies related to energy efficiency.

Borenstein and Davis (2016) use U.S. tax return data to examine the socioeconomic characteristics of individuals who recently received federal tax credits for a variety of "clean energy" investments, including residential energy investments for energy efficiency and renewable energy. They find that the bottom three income quintiles received only about 10 percent of all credits. They conclude that tax credits are less attractive on distributional grounds than other market-based policies that could reduce emissions.

In another study using tax return data, Neveu and Sherlock (2016) find that federal tax credits for residential energy investments are distributed inequitably across groups. In addition to finding that tax credits are more likely to go to higher-income households, they also find that taxpayers in colder climates and in areas with higher electricity costs are more likely to take advantage of tax credits.

Sutherland (1994) presents survey evidence from 1990 that higher-income households are more likely to participate in demand-side management (DSM) programs, including utility rebates. Households with newer homes and newer heating and cooling equipment are also more likely to participate in utility programs. Additionally, participants in utility DSM programs are more likely to undertake conservation measures other than those incentivized through rebates, indicating that rebate programs may serve as substitutes for other conservation investments.

Using a discrete choice-model, Bruegge (2017) analyses a refrigerator and clotheswasher rebate program offered by a large utility. He focuses especially on the role that fundraising plays

4. Another distributional consideration is how the costs of energy efficiency incentives are distributed and I address this issue briefly in Section 6.4.

in utility-based programs. The results indicate that price changes induced by the rebate program enhance the energy savings attributable to the program yet reduced its welfare effects. Overall, the program created a loss in consumer surplus and the loss was greatest for low-income households.

Other studies have evaluated the distributional effects of other types of policies related to energy efficiency, including carbon taxes, gasoline taxes, fuel economy standards, and building energy codes. Grainger and Kolstad (2010) use data from the consumer expenditure survey and an input-output model to present evidence that a carbon price is regressive. Bento et al. (2009) evaluate the gasoline tax and find that the distributional impacts differ substantially depending on how the revenue is recycled. Davis and Knittel (2016) evaluate fuel economy standards and present evidence that the implicit tax imposed by the policy, measured as a share of income, is greater for lower-income households. Levinson (2019) focuses on a comparison of fuel economy standards to gas taxes and presents theory and evidence that both are regressive, but that taxes are less so. Bruegge et al. (2019) evaluate building energy codes and find that they result in more undesirable distortions for lower-income households, partly because codes lead to the construction of smaller residences.

The primary contribution of this paper relative to existing work on the distributional effects of energy efficiency incentives 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 comparisons of various types of incentives, I also evaluate types of incentives that have not previously been examined. 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. The findings do not reveal the overall welfare effects of different types of energy efficiency incentives, but they should be helpful for future studies with respect to setting parameters and simulating counterfactual outcomes as part of broader evaluations.

3. BACKGROUND ON ENERGY EFFICIENCY INCENTIVES AND CONCEPTUAL FRAMEWORK

3.1 Background on Energy Efficiency Incentives

Energy efficiency incentives are primarily offered through rebates or tax credits. In order to be eligible for an incentive, products that are supported must meet certain efficiency standards (e.g., Energy Star standards). The incentives typically cover only a portion of the costs and are often capped at maximum dollar amounts. Incentives can be structured either as a fixed dollar amount or as a percentage of the purchase price.[5]

Energy efficiency rebate 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] Rebate programs are typically operated by

5. See dsireusa.org and energy.gov/savings for recent examples of energy efficiency incentives.

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

utilities and funded by ratepayers through a surcharge. Two types of rebate programs are common. First, utilities can provide consumers with rebates directly ("utility rebate programs"). Alternatively, utilities can provide manufacturers or retailers with funding to administer a rebate program ("manufacturer / retailer rebate programs"). The primary difference between the two options is how the rebates are marketed and disseminated.

Utility rebate programs typically require customers to complete a mail-in application, which is sent to the utility. For advanced installations, such as those related to the HVAC system, the work may have to be completed by a program-certified contractor. For relatively simple goods (e.g., refrigerators), the application may only require a mail-in rebate form with an itemized receipt that includes the model number. Utility rebates are typically marketed predominantly through mailings and on the utility's web site.

Manufacturer / retailer rebate programs are typically implemented through a partnership between the utility and a major manufacturer or retailer (e.g. Lowe's, Home Depot) such that the rebate is instantly applied at the time of purchase. With respect to marketing, 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.

The main alternative to utility rebates or manufacturer / retailer rebates are energy efficiency tax credits, which also provide incentives for the purchase of high-efficiency goods and have been in place periodically over the last several decades at various levels of government. Tax credits require individuals to claim the credit during their annual taxes, thereby reducing the amount owed to the government. Tax credits for energy efficiency have typically been non-refundable, which means they cannot lower an individual's total tax bill once it is equal to or less than zero dollars. Tax credits that are non-refundable therefore have no value to households with zero income liability.

A prominent example of a tax credit related to energy efficiency is the Nonbusiness Energy Property Credit (NEPC), which was recently 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.

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 types of incentives 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 U.S. Department of Energy 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

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.

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.

3.2 Conceptual Framework

While a formal model related to the distribution of energy efficiency incentives is beyond the scope of this paper,[8] it may still be helpful to briefly discuss some reasons why the distribution of energy efficiency incentives could differ across income groups. As a starting point for this discussion, one can conceptualize decisions related to investment in energy efficiency as a two-stage process. First, a household evaluates whether to purchase equipment. This decision can be a function of whether the equipment is provided for them by a landlord; expectations regarding improved energy services from the equipment (e.g., using a dishwasher vs. hand-washing dishes or, for those that are upgrading, using a new dishwasher with a faster run-time); expected changes in energy costs resulting from the equipment; and whether the equipment is affordable based on the household's savings, income, and access to credit. Secondly, conditional on choosing to replace the equipment, the household chooses a level of efficiency for the equipment. This decision depends, in part, on a household's assessment of how the elevated upfront costs of high-efficiency models compare to the discounted future stream of benefits in the form of energy savings.

Based on this framework, there are two prominent reasons why lower-income households may be less likely to buy equipment, thereby preventing them from receiving an incentive. First, lower-income households are more likely to be renters, and thus more likely to have equipment provided for them by a landlord. Secondly, lower-income households may find it harder to afford to buy or replace equipment, especially high-efficiency models that are more expensive, when it is difficult or expensive for households to acquire small loans. Regardless of the reason, if lower-income households are less likely to purchase equipment than they will also be less likely to receive incentives.

Even among households that choose to buy equipment, lower-income households may be less likely to purchase high-efficiency models. As above, one reason for this is that high-efficiency units are often more expensive than low-efficiency units and lower-income households will tend to have less disposable income. Additionally, discount rates are often higher in lower-income households (Becker and Mulligan, 1997; Haushofer et al., 2013). Higher discount rates will reduce the discounted future stream of benefits from energy efficiency, which will limit household adoption of high-efficiency equipment. If lower-income households are less willing to adopt high-efficiency units for any reason, then they will be less likely to receive an incentive.

Even among households that have an interest in purchasing high-efficiency equipment, the structure, marketing, and salience of incentives could lead to distributional differences across income groups. Regarding structure, tax credits that are non-refundable may not be of interest to low-income household because they are only valuable if the household has tax liability. With respect to marketing, lower-income household may have less access to rebate incentives because retailers that are selected to implement rebate programs may operate in higher-income areas where consumers are expected to be more responsive to incentives. Additionally, rebate programs directly administered by utilities may be marketed through mailings or web sites in ways that are more

8. See Allcott and Greenstone (2012) for a model of investment in energy efficiency.

likely to reach higher-income households.[9] Finally, the "salience effect," which refers to consumers making decisions based on the most easily observable factors, could play a role in how incentives are distributed. Salience has been shown to play a major role in consumer decision-making related to energy efficiency (Gillingham et al., 2009). If lower-income household are more susceptible to the salience effect and incentives are less salient than the upfront costs of high-efficiency equipment, then the salience effect could contribute to distributional differences across income groups.

4. 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 and 2009. 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 homeowners 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.[10] In contrast, the 2015 wave of the survey only includes six questions about energy efficiency assistance, all with simple yes/no response options. 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.

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, 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,

9. Utilities might target mailings and other forms of advertisements at educated, higher-income households because these groups are often most responsive to environmental initiatives (e.g., Conte and Jacobsen, 2016).

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

subsidized loans, and the weatherization assistance program.[11] 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 go to 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,[12] 2) a variable indicating whether the household has replaced or installed the equipment since moving-in,[13] 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 the three source-specific variables.[14] All incentive variables equal one if the household indicated they 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 \$2.5*k*, \$5*k* or \$10*k* 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 "\$120*k* 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 \$10*k* and \$60*k*. 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 the 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

11. It is possible that some respondents mistakenly treat a dealer discount or other form of promotion as a manufacturer / retailer rebate, however any associated measurement error should be small because the survey prompts respondents to think specifically about support provided by "government or energy supplier assistance" prior to asking them to identify the type of assistance they received. Nonetheless, potential for measurement error constitutes one of the limitations of the empirical setting.

12. 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.

13. 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).

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

Table 1: Means for Variables Related to Equipment or Incentives

					Type of Subsidy		
Equipment	Presence	Post Move-In	Energy Star	Any Incentive	Manuf. / Retail Rebate	Utility Rebate	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.

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.

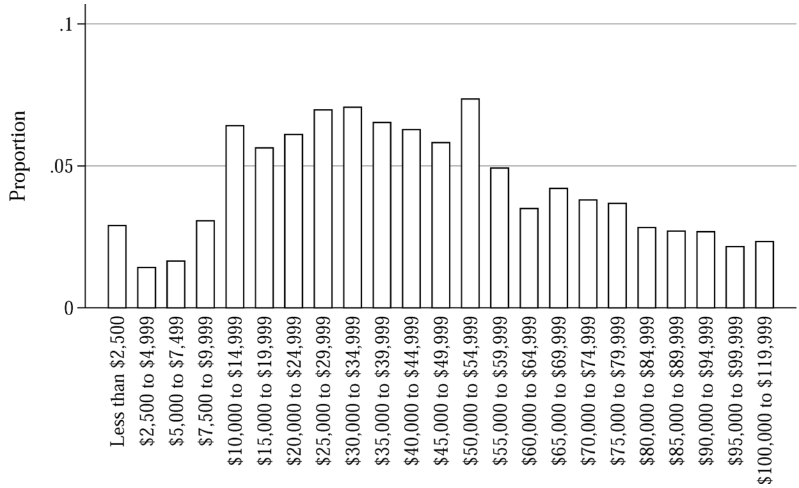
5. DISTRIBUTIONAL MEASURES

In order to more concisely describe how energy efficiency incentives are distributed across income groups, I compute two overall distributional measures.[15] The first measure is 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. This ratio is calculated by estimating a linear regression model of the receipt of an energy efficiency incentive on income and then obtaining the predicted probabilities for households with the corresponding incomes (i.e. \$80*k*, \$20*k*). 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 \$20*k* was chosen because it is near the 2009 federal poverty line for households with three members (\$18.3*k*) or four members (\$22.1*k*). The top figure, \$80*k*, 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 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 to the lowest-income

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

Figure 1: Histogram of 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.[16] I report both the $80*k*-to-$20*k* 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. Comprehensive data on rebate size is not available, but Datta and Gulati (2014) report average rebate sizes of $69, $34, and $48, for clotheswashers, dishwashers, and refrigerators, respectively, based on U.S. data from 2001 to 2006. 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 and incentives are often structured to cover a percentage of the purchase price, 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

16. 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.

the dollar-based concentrations across types of incentives will be greater than the differences in the take-up-based concentrations.

6. RESULTS

6.1 Primary Results

In this section, I evaluate how energy efficiency incentives are distributed across income groups. I focus on the full sample, thereby allowing the analysis to capture overall distributional patterns that occur through any channel, which is the primary goal of the paper. For example, the estimates can be driven by differences across income groups in rates of homeownership or willingness to replace equipment.[17]

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). In this analysis, I use the overall likelihood of a household receiving an incentive across all equipment types as the dependent variable. The likelihood of receiving an incentive is measured for each household as the fraction of equipment types for which the household has received an incentive of the corresponding type.[18] Figure 2 presents means in the likelihood of receiving an incentive across income groups and shows that the likelihood 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.

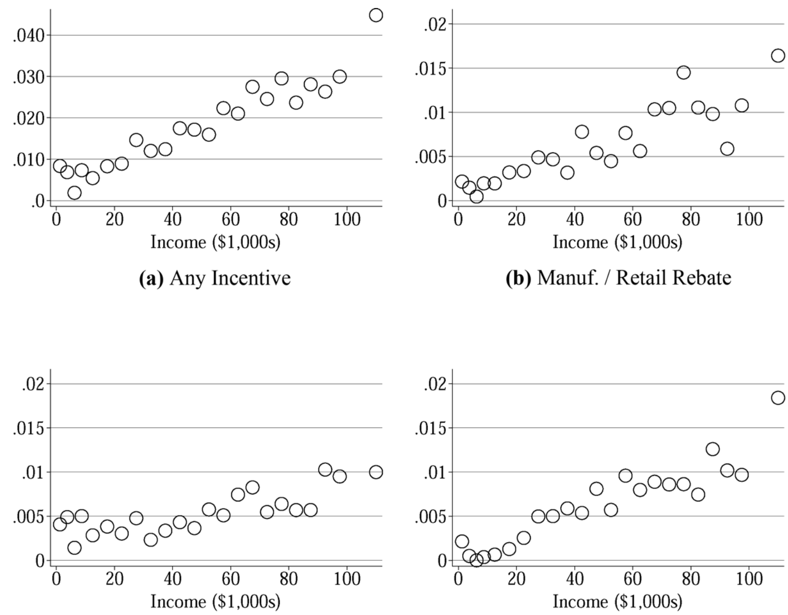
I characterize the distribution of incentives more precisely using Table 2, which reports results from linear regressions of the likelihood of receiving an incentive on income. Along with this regression output, the table also reports the two distributional measures described earlier. Note that in the regression output, 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.[19] Both distributional measures reported in the table indicate incentives are substantially more likely to go to higher-income households. The ratio measure indicates that a household with an income of $80*k* 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 $80*k*-household is about three times more likely to receive some form of incentive than the $20*k*-household. The overall concentration index is .30 and subsidy-specific values range between .20 (utility rebate) and .36 (tax credit).

17. Accordingly, the primary estimates are not expected to capture the relationship between income and incentive uptake in settings where all households have recently had a direct opportunity to receive an incentive (i.e. when all households are homeowners who have recently replaced their equipment). Results from Section 6.2 are more appropriate for inferring this relationship, especially Tables 6 and 7.

18. There are eight appliances, so if a household, for example, had received a utility rebate for a refrigerator and a tax credit for windows, then the "Any Incentive" likelihood would be .25, the utility rebate likelihood would be .125, and the tax credit likelihood would be .125.

19. 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 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.

Figure 2: Mean Likelihood of Household Receiving an Incentive by Income—By Type of Subsidy.



(a) Any Incentive **(b)** Manuf. / Retail Rebate **(c)** Utility Rebate **(d)** Tax Credit

Table 2: Regressions of Likelihood of Receiving an Incentive on Income by Type of Subsidy

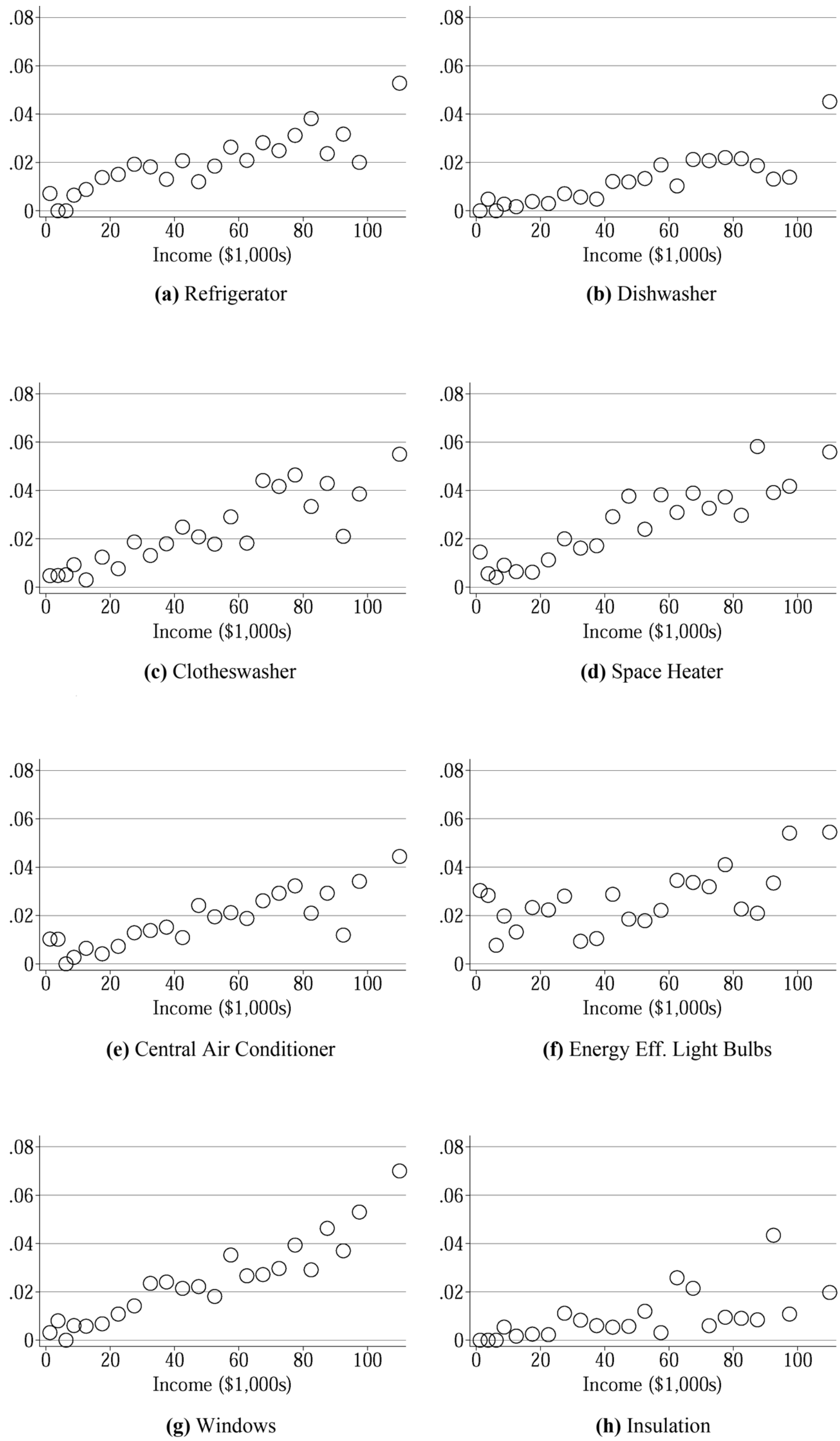
	Any Incentive (1)	Man./Ret. Reb. (2)	Util. Reb. (3)	Tax. Cred. (4)
Income ($10,000s)	0.0032***	0.0012***	0.0006***	0.0014***
	(0.0002)	(0.0001)	(0.0001)	(0.0002)
Constant	0.0026***	0.0006	0.0022***	–0.0001
	(0.0009)	(0.0005)	(0.0005)	(0.0006)
$80*k*-to-$20*k* Rat.	3.123**	3.423**	2.064**	4.164**
Conc. Index	0.30	0.32	0.20	0.36
Observations	10,694	10,694	10,694	10,694

Notes: The dependent variable is the fraction of equipment types for which the household has received an incentive of the corresponding type, as indicated by the column headings. All models are ordinary least squares. 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. 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. The concentration index is a measure of distribution that is computed separately based on the underlying data (as described in Section 5); it is not estimated through the regression model.

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 receive 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 house-

Figure 3: Proportion of Households Receiving an Incentive by Income—By Type of Equipment.



(a) Refrigerator

(b) Dishwasher

(c) Clotheswasher

(d) Space Heater

(e) Central Air Conditioner

(f) Energy Eff. Light Bulbs

(g) Windows

(h) Insulation

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* Rat.	2.762**	6.423**	3.558**	3.065**	3.220**	1.863**	4.120**	3.615**
Conc. 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. The concentration index is a measure of distribution that is computed separately based on the underlying data (as described in Section 5); it is not estimated through the regression model.

holds due to primarily being allocated through tax credits (see Table 0), the two types of equipment that are most concentrated are dishwashers and clotheswashers. The $80*k*-household is over six times more likely to receive an incentive for a dishwasher than the $20*k*-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.[20] 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 the 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 0, 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.

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 earlier in this section.

The results described in this section and throughout the paper are based on linear probability models, which were chosen due to their ease of interpretation. Results are similar if a logistic

20. 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.

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

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1: Manuf. / Ret. Rebate	Frg.	Dishwsh.	Clthswsh.	Spc. Ht.	Cen. AC	Lightg.	Wndws.	Insul.
Prob. of Incent.	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* Rat.	3.447**	7.310**	3.536**	3.284**	3.042**	2.203**	3.034	1.415
Conc. Index	0.31	0.45	0.33	0.32	0.30	0.22	0.28	0.14
2: Utility Rebate	Frg.	Dishwsh.	Clthswsh.	Spc. Ht.	Cen. AC	Lightg.	Wndws.	Insul.
Prob. of Incent.	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* Rat.	2.027**	5.751	2.738**	1.871*	1.765	1.714**	5.223	2.443
Conc. Index	0.20	0.41	0.28	0.18	0.17	0.13	0.39	0.26
3: Tax Credit	Frg.	Dishwsh.	Clthswsh.	Spc. Ht.	Cen. AC	Lightg.	Wndws.	Insul.
Prob. of Incent.	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* Rat.	2.206	3.340	8.269	3.830**	4.672**		4.142**	4.695**
Conc. 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 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. The concentration index is a measure of distribution that is computed separately based on the underlying data (as described in Section 5); it is not estimated through the regression model.

regression is used instead. Table 10 reports results that are analogous to Table 4 except that the results are based on a logistic regression. Across scenarios, average marginal effects from the logistic regression are nearly identical to the regression coefficients from the linear probability models. The $80*k*-to-$20*k* incentive ratios differ a bit more but retain the same qualitative patterns: utility rebates tend to be least likely to go to the $80*k* household and tax credits the most likely; dishwashers and clotheswashers incentives are the most likely to go to the higher-income household across types of equipment.

6.2 Mechanisms

I next focus on investigating the mechanisms behind the distributional patterns described in Section 6.1. 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.[21] 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 most concentrated in Table 4, dishwashers and clotheswashers, also are substantially more likely to be owned by higher-income households.

Another channel for the 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 \$80*k*-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 likelihood of receiving an incentive for each type of 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 importance of homeownership for receiving an incentive can also be seen by examining the share of incentives that go to homeowners. I present this information in

21. See Figures 4, 5, and 6 for graphs related to Table 5.

Table 5: Investigating Mechanisms

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1: Equip. 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* Rat.	1.001	1.863**	1.285**	1.006**	1.333**	1.277**	1.002	1.009**
Conc. 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
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* Rat.	1.323**	1.487**	1.310**	1.122**	1.227**	1.040**	1.267**	1.479**
Conc. 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
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* Rat.	1.242**	1.164**	1.154**					
Conc. 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. The concentration index is a measure of distribution that is computed separately based on the underlying data (as described in Section 5); it is not estimated through the regression model.

Table 9. All incentives are more likely to go to homeowners. As one would expect, dishwashers and central air-conditioning nearly universally go to homeowners because, even when rental households have access to these types of equipment, the equipment is almost always owned by landlords. Tax credits also nearly universally go to homeowners because many tax credits require the filer to be a property owner in order to claim the credit.

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 house-

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)
1: Manuf. / Ret. Rebate	Frg.	Dishwsh.	Clthswsh.	Spc. Ht.	Cen. AC	Lightg.	Wndws.	Insul.
Prob. of Incent.	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* Rat.	2.456**	1.965	1.995**	2.243	1.702	1.455	2.444	0.889
Conc. Index	0.24	0.19	0.19	0.28	0.15	0.13	0.21	0.00
2: Utility Rebate	Frg.	Dishwsh.	Clthswsh.	Spc. Ht.	Cen. AC	Lightg.	Wndws.	Insul.
Prob. of Incent.	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* Rat.	1.495	1.616	1.380	1.163	1.024	1.269	3.470	1.576
Conc. Index	0.12	0.13	0.14	0.12	0.04	0.06	0.33	0.16
3: Tax Credit	Frg.	Dishwsh.	Clthswsh.	Spc. Ht.	Cen. AC	Lightg.	Wndws.	Insul.
Prob. of Incent.	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* Rat.	1.258	1.017	4.220	2.791**	2.424*		2.816**	2.952*
Conc. 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. The concentration index is a measure of distribution that is computed separately based on the underlying data (as described in Section 5); it is not estimated through the regression model.

holds 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 / retailer 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.

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. The concentration index is a measure of distribution that is computed separately based on the underlying data (as described in Section 5); it is not estimated through the regression model.

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 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 more likely to take advantage of incentives.

6.3 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. One of the reasons, for example, why the 2009 results may not be representative is that 2009 was part of a major economic recession.[22] The 2015 survey includes seven income categories (excluding the top-coded category) and I present a histogram of this variable in Figure 7. 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 forms. I graph mean rates of assistance across income for each type of assistance in Figure 8.

Regression 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 they were in 2009, with the \$80*k*-household 2.3 times as likely to receive incentives as the \$20k-household. Based on the \$80*k*-to-\$20*k* 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). Incentives for lighting 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. Ultimately, the extent to which the results from 2009 can be extended to future years is unknown and one of the limitations of the empirical setting, but the re-appearance of the same key patterns in the 2015 RECS provides support for their external validity.

6.4 The Distribution of Program Costs

As mentioned earlier, the analysis focuses primarily on how the receipt of incentives are distributed.[23] 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 unlikely to be enough to offset their disproportionate receipt of incentives. 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

22. Median household income was \$57,010 in 2009 and rose to \$61,372 by 2017. The Gini index of income inequality increased slightly over the same period, from .468 to .482, indicating growing income inequality (U.S. Census, 2019).

23. From a policy-making perspective, the distribution of incentives 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 uptake.

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

	Free/Sub. Lights (1)	Free/Sub. Audit (2)	Util. AReb. (3)	Free Recyc. A (4)	Tax Credit (5)	Other Ben./Asst. (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* Rat.	1.158	1.517*	2.361**	1.947**	4.253**	1.420*
Conc. 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. The concentration index is a measure of distribution that is computed separately based on the underlying data (as described in Section 5); it is not estimated through the regression model.

$80*k*-household is only 1.3 times greater than for the $20*k*-household. For context, recall that the $80*k*-household is 3.1 times more likely to receive 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.

7. 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 different types of equipment and different forms of subsidies. 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 utility 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. Utility rebates are no longer concentrated in higher-income households after controlling for these factors, but manufacturer / retailer rebates and tax credits remain concentrated.

The primary policy implication from the findings is that incentive programs will be more likely to go to lower-income households if incentives are provided through utility rebates and if they avoid targeting appliances that tend to be disproportionately owned by higher-income households. In this regard, the findings in the present paper may be helpful for choosing between policy options on distributional grounds. For example, policymakers that place a substantial weight on equitable distributional outcomes might prefer to avoid using tax credits for incentives. The results could also inform how incentive programs should be funded. For example, if incentives are expected to go to higher-income households, then ratepayer fees implemented to fund incentive programs could be designed to impose higher program-related charges in higher-income service areas.

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.[24] In this regard, criticism of energy efficiency incentives based on distributional effects may be softened by the fact that alternative policies may also create inequitable outcomes for lower-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.

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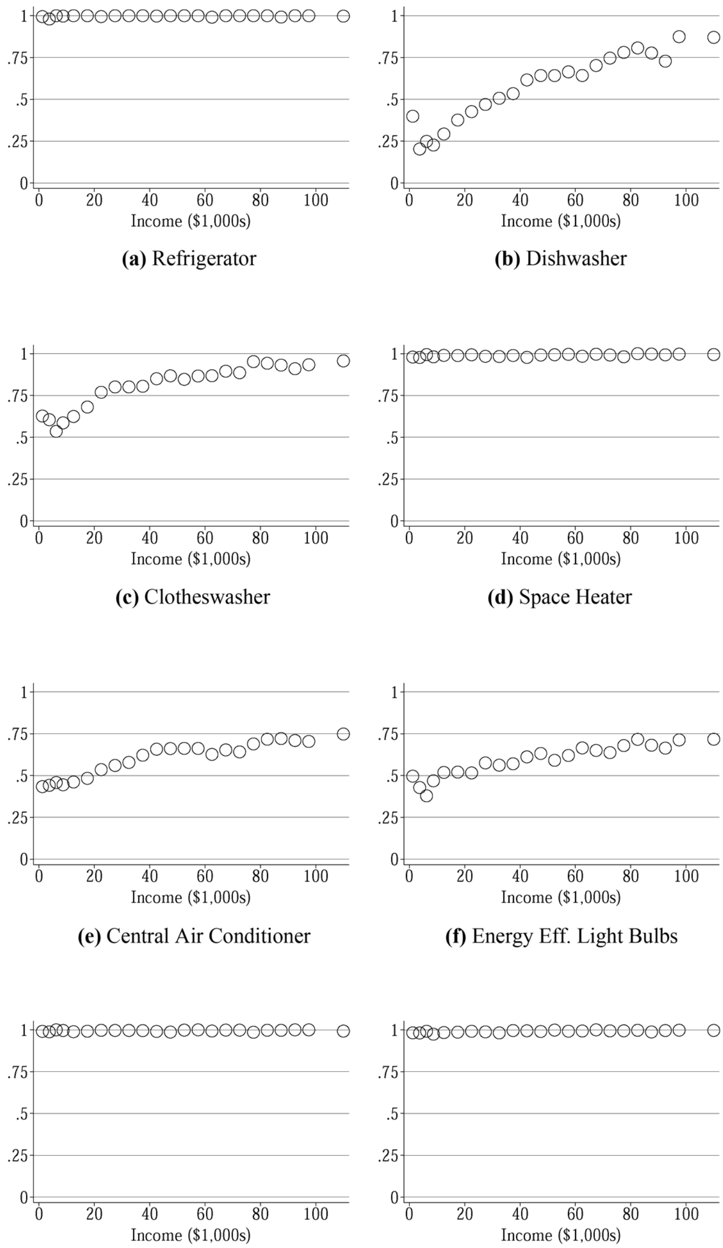
APPENDIX

Figure 4: Proportion of Households in Which the Equipment is Present in Residence by Income.



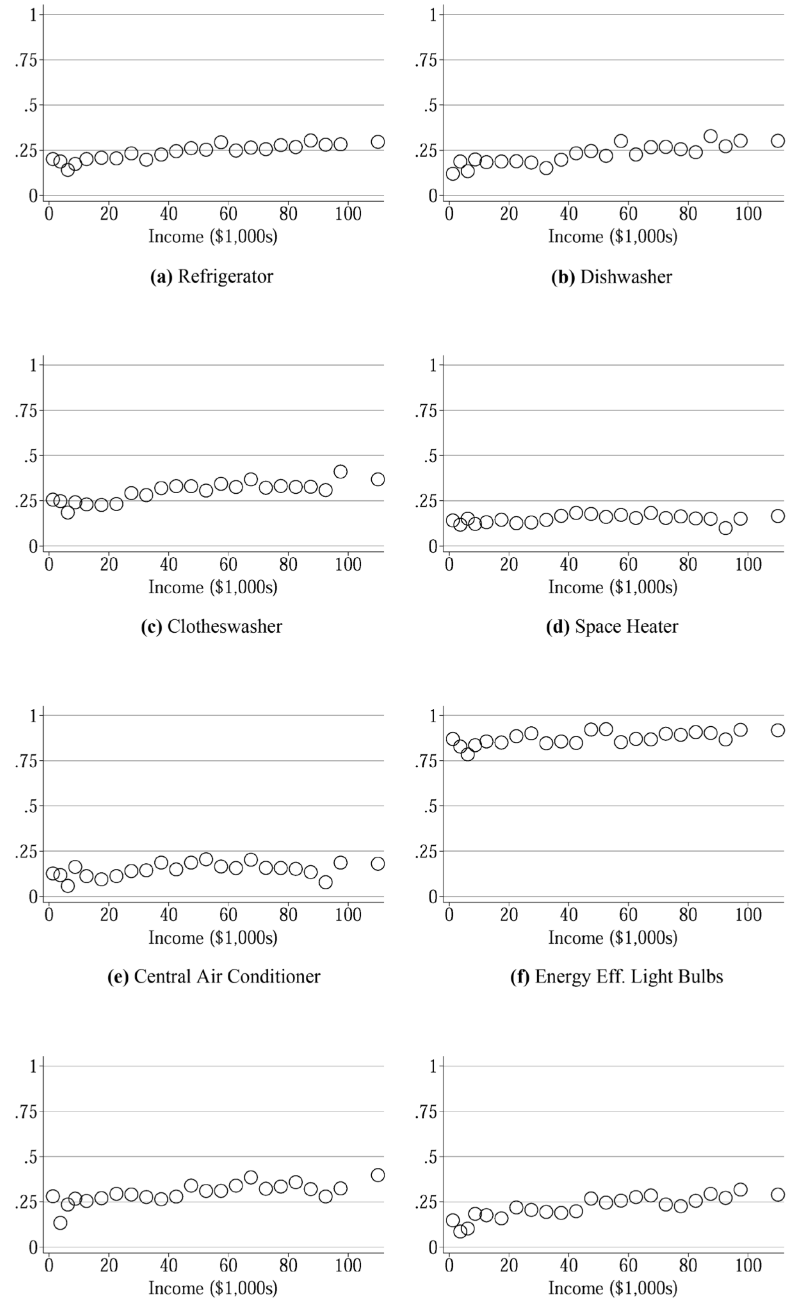
(a) Refrigerator **(b)** Dishwasher

(c) Clotheswasher **(d)** Space Heater

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

(g) Windows **(h)** Insulation

Figure 5: Proportion of Households Installing / Replacing Equipment After Moving In. 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) Clotheswasher

(d) Space Heater

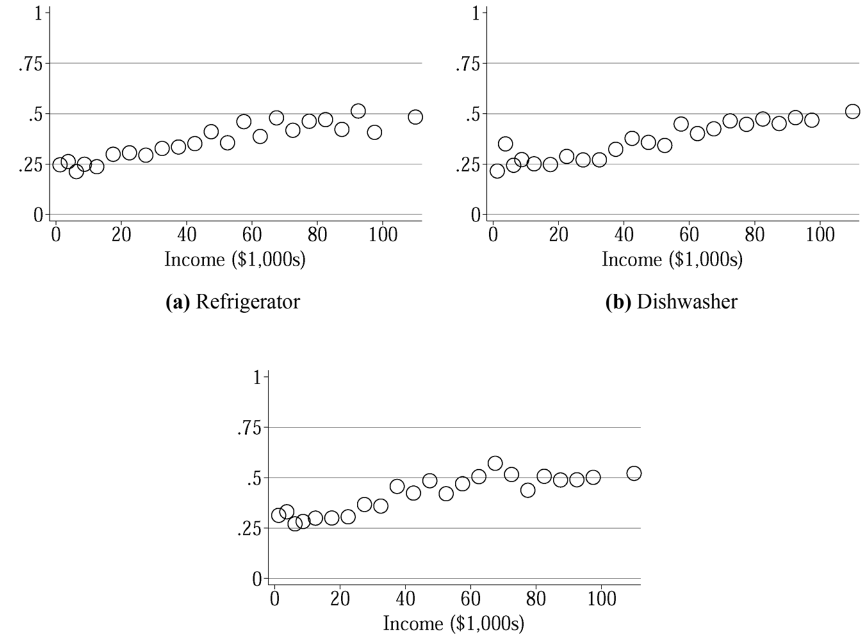
(e) Central Air Conditioner

(f) Energy Eff. Light Bulbs

(g) Windows

(h) Insulation

Figure 6: 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.



(a) Refrigerator

(b) Dishwasher

(c) Clotheswasher

Figure 7: Histogram of Income—2015 RECS.

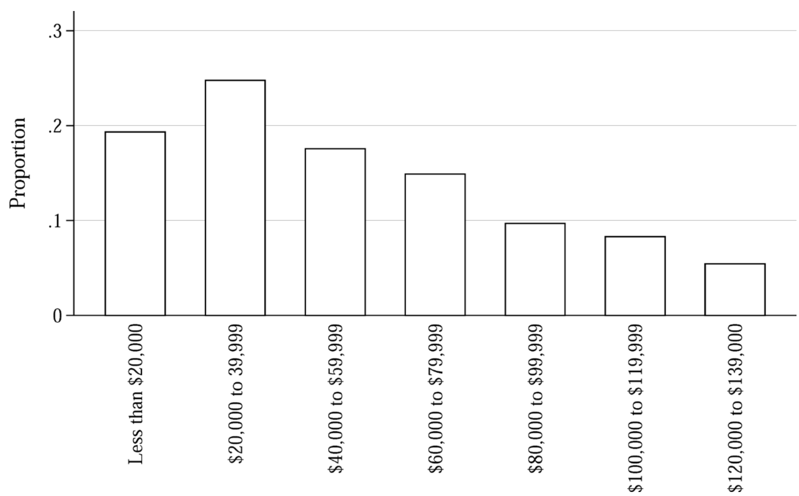
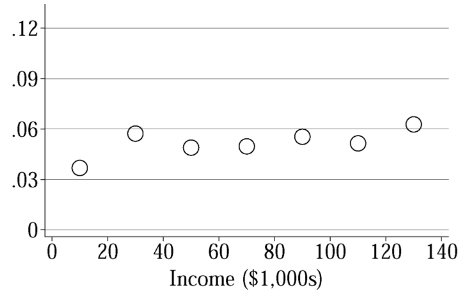
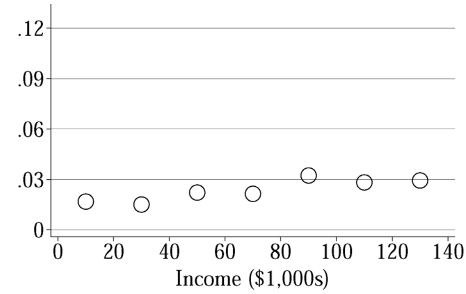


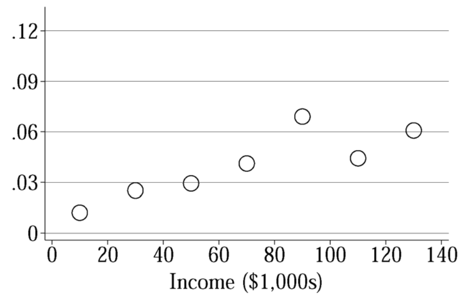
Figure 8: Proportion of Households Receiving An Incentive by Income—By 2015 RECS Category.



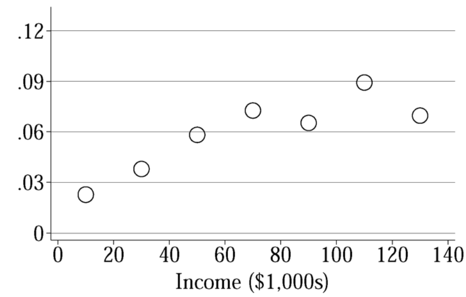
(a) Free or Sub. Lights



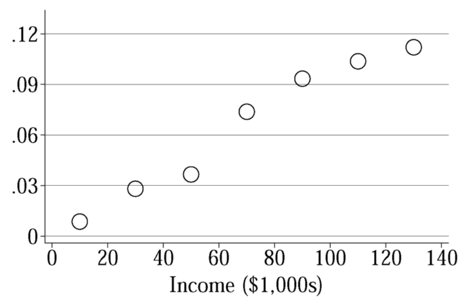
(b) Free or Sub. Audit



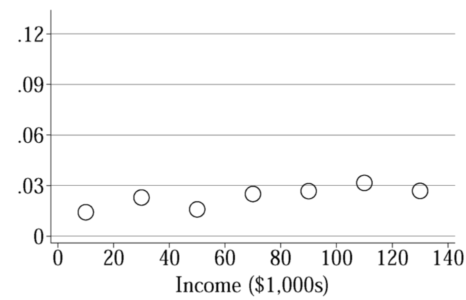
(c) Utility App. Reb.



(d) Free Recyc. App.



(e) Tax Credit



(f) Other Ben. or Asst.

Table 9: Probability of Being a Homeowner Conditional on Having Received an Incentive

	(1) Frg.	(2) Dishwsh.	(3) Clthswsh.	(4) Spc. Ht.	(5) Cen. AC	(6) Lghtg.	(7) Wndws.	(8) Insul.
Manuf./ Retailer Rebate	0.93	1.00	0.95	0.99	1.00	0.75	0.92	1.00
Utility Rebate	0.81	1.00	0.95	0.95	0.98	0.79	0.97	0.92
Tax Credit	1.00	1.00	1.00	0.99	0.99	.	0.99	1.00

Notes: The paper reports rates of home-ownership among survey respondents that received each type of incentive.

Table 10: Logistic Regression of Receipt of Incentive on Income by Type of Subsidy and Equipment—Average Marginal Effects and $80k-to-$20k Ratios

1: Manuf. / Ret. Rebate	Frg.	Dishwsh.	Clthswsh.	Spc. Ht.	Cen. AC	Lightg.	Wndws.	Insul.
Income ($10,000s)	0.002***	0.002***	0.002***	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)
$80*k*-to-$20*k* Rat.	2.987	4.754	3.045	2.877	2.715	2.092	2.707	1.403
2: Utility Rebate	Frg.	Dishwsh.	Clthswsh.	Spc. Ht.	Cen. AC	Lightg.	Wndws.	Insul.
Income ($10,000s)	0.001***	0.000**	0.001***	0.001**	0.000*	0.001***	0.001**	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$80*k*-to-$20*k* Rat.	1.947	4.152	2.502	1.815	1.722	1.678	3.926	2.280
3: Tax Credit	Frg.	Dishwsh.	Clthswsh.	Spc. Ht.	Cen. AC	Lightg.	Wndws.	Insul.
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)
$80*k*-to-$20*k* Rat.	2.093	2.909	5.017	3.224	3.677		3.413	3.684

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. Average marginal effects are reported in the income rows. All models are logistic 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. Robust standard errors are reported in parentheses. One, two, and three stars indicate 10%, 5%, and 1% significance, respectively. The concentration index is a measure of distribution that is computed separately based on the underlying data (as described in Section 5); it is not estimated through the regression model.