Limited Attention and the Residential Energy Efficiency Gap

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Inattention may be an important contributor to the energy efficiency gap. The energy operating costs associated with durables such as vehicles and major appliances can be difficult to observe and fully comprehend (Sallee forthcoming; Houde 2014; Allcott et al. 2014). As a result, a consumer may focus less on the energy costs, a "shrouded attribute" in Gabaix and Laibson (2006) terminology, than on other more salient characteristics, which can lead firms to exploit this inattention in their pricing and choice of product attributes (Ellison 2005; Brown, Hossain and Morgan 2010; Sallee forthcoming).

The inattention problem in residential buildings is particularly acute. Many different features will determine a home's energy use—the amount and type of insulation, numbers of windows and doors, types of lighting equipment, efficiency of heating and cooling equipment, and more. A typical homeowner is likely to fall somewhere along a continuum of attentiveness to these features: from completely inattentive to partially or fully attentive.

Attentive consumers may seek out information when considering equipment upgrades and building retrofits. One way they can do this is through a home energy audit. A home energy audit is a professional whole-house evaluation to determine if and where a house is losing energy and how to make the home more efficient. Audits also should include recommendations for optimal improvements, i.e., those that provide a stream of energy cost savings sufficient to offset the up-front investment. Very few households have energy audits, however. The U.S. Energy Information Administration's 2009 Residential Energy

Consumption Survey (RECS) finds that only about 3% of homeowners had had an audit in four years prior to the survey. In theory, a homeowner should have an audit if the value of the information in the form of improved decision making from the audit outweighs its cost (Stigler 1961; Hirshleifer and Riley 1979). But consumers who are inattentive to energy issues in the first place may not make decisions in this way. Can inattention partially explain the low uptake of home energy audits?

In this study, we address this question using responses to a survey of approximately 1,700 randomly selected homeowners, 550 of whom have had audits. We evaluate the relative importance of factors that affect the benefits and costs of an audit, as well as a measure of the intrinsic inattentiveness of homeowners to energy related matters. The benefits should be affected by characteristics of the house such as its size and age, as well as local climate and energy prices, while the costs include the audit cost net of subsidies and rebates, plus time and effort costs the homeowner incurs. Through a series of questions about energy bills, types and ages of heating, cooling and water heating systems, insulation, types of light bulbs in the home, and the frequency of servicing heating and cooling equipment, we are able to create an index of energy attentiveness for our survey respondents. This index and two additional behavioral factors, receipt of a home energy report and whether the homeowner knows friends, family or coworkers who have had audits, prove to be important determinants of the decision to have an audit.

I. Description of the Survey

The survey, described in detail in online supporting materials, is directed at randomly selected homeowners in 24 states. It first asked if the homeowner had had an energy audit in the past four years. We limited responses to the past four years to limit errors due to poor recall. All respondents were asked a series of questions related to characteristics of their house; for people who reported having an audit, we asked for answers that applied at

the time just prior to their audit. We also collected sociodemographic and other information about the household. Respondents who had had audits were directed to a series of questions about the audit and about their follow-up with retrofits and improvements to their home. The full survey is available from the authors upon request.

II. Explaining Audit Choice

While a rational consumer will invest in information—i.e., have an audit—if the payoff from the information warrants the cost, consumers will differ in the extent to which they are attentive to their home's energy use in the first place. Figure S1 in the supplemental materials shows the answers to six questions on the survey related to knowledge about (1) size of annual energy bills, (2) age of heating equipment, (3) age of water heater, (4) amount of attic insulation, and (5) number of CFL or LED light bulbs in the home, and (6) about whether heating and air conditioning (HVAC) equipment is serviced regularly. For each question we find a higher incidence of inattention among the homeowners who have not had audits, with the difference particularly pronounced for the insulation and servicing HVAC questions.

Behavioral Variables. We used the answers to these questions to create an attentiveness index. We add up the number of "don't know" answers to the first 5 questions and add 1 if the respondent does not service her HVAC system regularly. The sum of these 6 responses is then normalized to provide an index with values between 0 and 1, where 0 is fully attentive and 1 fully inattentive; the mean value of the index is 0.217. To capture exogenously provided information and peer effects, we include indicator variables for whether the homeowner had received a home energy report that compared her electricity consumption to that of other homes and whether the respondent knew friends, family or coworkers who had had an audit.

Variables Affecting Benefits and Costs. Holding attentiveness constant, a homeowner should be more likely to have an audit if the benefits outweigh the costs.

We thus include measures of house age and size and age of heating and cooling equipment, heating and cooling degree days constructed from local temperature data, and local electricity prices. We also include a dummy variable for whether the respondent intended to sell her house in the next two years as it may not be possible to fully recover the costs of retrofits in this case. We are unable to know the cost of an audit except for people who had audits but we include average per capita expenditures on energy efficiency programs within the state as a measure of the availability of potential subsidies and rebates and a dummy variable equal to one if the respondent reported that someone is regularly at home, her job allowed her to work from home, and/or she had flexible work hours, to capture the effect of time costs.

Controls. We include a set of basic socio-demographic characteristics of the respondent and an "environmental leaning" variable, which combines answers to some questions designed to elicit the respondent's environmental preferences.

Results. Our logit regression results are reported in table 1, which includes both estimated coefficients and average marginal effects.[1] Full discussion of the results is in the supplementary materials. Here we focus on the behavioral variables. The attentiveness index and exogenous measures of salience and peer effects (the home energy report and number of friends who have had audits) have significant positive effects on the likelihood of having an audit. Individually, both the audit-friends indicator variable and the attentiveness index have significant coefficients and signs that are consistent with our expectations. A Wald test confirms that the collection of attentiveness, salience and peer effects variables together has a significant impact on the probability of getting an energy audit ($F(3, 1638)=53.34$).

[insert Table 1 here]

[1] Recent studies of inattention have derived the logit by assuming the error on the uncertain component of energy costs has a Type I generalized extreme value distribution (Houde 2014; Matějka and McKay forthcoming).

The marginal effects suggest that going from fully attentive to fully inattentive, all else equal, lowers the probability of getting an audit by roughly 11%. As one point of comparison, this effect is slightly smaller than the effect of planning to sell one's house, which lowers the probability of an audit by 12%. Furthermore, the results suggest that to fully offset the effect of inattention one would need an increase in energy efficiency program expenditures of $11.20 per capita, roughly twice the sample average of $6.12, or a $55.74/MWh increase in the average price of electricity, to a level 48% higher than the sample average.

III. Discussion and Future Research

Energy audits can provide a useful information function, especially in the complex setting of a house where multiple features affect energy use and costs. HVAC installers, insulation specialists, and window providers may have incentives to provide some energy efficiency information about the products they sell but little incentive to guide optimal overall investment decisions. In fact, they could exploit consumers' lack of understanding and promote suboptimal investments—a high-efficiency furnace but unsealed air gaps, for example, or replacement windows but no attic insulation. Home energy audits may help correct this problem by providing whole-house information and advice.

Audit uptake is low, however, and our findings suggest that one important factor could be inattention. In the commercial building environment, we have found that mandatory energy disclosure programs adopted in 11 cities have had an attentiveness effect and lowered building energy use in cities that have the laws (Palmer and Walls 2015). Could such policies in the residential environment have a similar effect?

The survey approach allowed us to probe into multiple aspects of homeowner knowledge, behavior and choices and identify several aspects of homeowner behavior that reflect inattention. Future work can build on these findings to study, through randomized field experiments,

policy interventions that may "unshroud" some aspects of home energy use.

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TABLE 1— LOGIT REGRESSION RESULTS OF HOME ENERGY AUDIT CHOICE

	Coefficient Estimates (Std. Errors)	Average Marginal Effect (Std. Errors)
Respondent Characteristics		
Dummy=1 if retired	-0.401*	-0.0337*
	(0.235)	(0.0174)
Dummy=1 if married	-0.123	-0.011
	(0.222)	(0.0188)
Dummy=1 if black	0.760***	0.0767**
	(0.266)	(0.0306)
Dummy=1 if Hispanic	0.746**	0.0697*
	(0.32)	(0.0358)
Dummy=1 if other ethnicity	0.578	0.0566
	(0.365)	(0.0385)
Age of household head	0.0108	0.000858
	(0.00841)	(0.000681)
Ln(annual household income)	-0.334**	-0.0279**
	(0.144)	(0.0118)
Environmental leanings [a]	0.239***	0.0440**
	(0.0816)	(0.0202)
Variables affecting benefit/cost of audit		
Easily at home	0.27	0.0226
	(0.217)	(0.0162)
Age of house	0.00151	0.000128
	(0.0034)	(0.000277)
Number of rooms in house (excluding bathrooms)	0.0501	0.00439
	(0.049)	(0.00398)
HVAC system equal to or older than 6 years old	0.365**	0.0293**
	(0.177)	(0.0137)
Heating degree days	-2.02E-05	-1.34E-06
	(5.37E-05)	(4.32E-06)
Cooling degree days	2.65E-05	2.41E-06
	(4.24E-05)	(3.42E-06)
Average monthly electricity price (in $/MWh)	0.00525*	0.000436*
	(0.00315)	(0.000263)
2012 per capita state residential EE expenditure (in $)	0.0282*	0.00217*
	(0.0149)	(0.00122)
Dummy=1 if plan to sell house	-3.379***	-0.118***
	(0.555)	(0.00804)
Behavioral factors		
Dummy=1 if received home energy report	0.194	0.0132
	(0.194)	(0.0167)
Dummy=1 if know someone who had audit	2.230***	0.309***
	(0.193)	(0.0349)
Attentiveness index	-1.385***	-0.112***
	(0.476)	(0.0388)
Constant	-1.086	
	(1.582)	
N	1,641	1,641
F(20,1621)	11.8	

Note: Variable definitions provided in text.

[a] Environmental leanings variable has value of 1, 2, or 3; average marginal effect calculated at value of 2.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

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Supporting Information

The survey was administered by GfK Custom Research using the KnowledgePanel®, a probability-based online panel of about 50,000 adults who agree to participate in various surveys. The GfK panel is balanced on geography and various demographic characteristics and is thus made to be statistically representative of the U.S. adult population. We conducted a stratified sampling approach for our survey, first targeting homeowners and then oversampling homeowners who had had home energy audits to ensure that we had a minimum of 500 respondents with audits; this endogenous stratification approach is often used when frequency of an outcome is low (Cosslett 1981, 1993). We focused on the 24 states where our earlier research and other independent studies have shown that audits are more prevalent (Palmer et al. 2013). We collect information on a number of house attributes and household member characteristics. Because audits can take several hours to complete time costs of homeowners can be an important component of the cost of getting an audit, thus we collect data on whether or not a respondent can work from home, has flexible work hours and if there is someone at home most or all of the day. We use these responses to create an indicator variable of whether someone can be easily at home which takes on a value of one if the response to any of these questions is yes. We also ask a series of questions about environmental attitudes including whether the respondent believes that humans are contributing to global warming, how important environmental protection is to the respondent, and whether the respondent donated to an environmental organization in the past year and use the responses to this

collection of questions to construct an environmental leanings variable which takes on a value of between 0 and 3 depending on the number of positive responses. Basic demographic information as well as income and employment status are available from GfK. The survey is available from the authors upon request.

Our attentiveness index is calculated from the responses to six questions that reflect the homeowner's knowledge about her energy costs and equipment type and age and a question about whether she regularly (at least once a year) services her heating and cooling equipment. For each of these questions we provide a range of categories for the respondent to select from in order to make it easy to provide at least a qualitative response, thus the bar for a "do not know" answer is set pretty high and so is the bar for scoring high on inattentiveness. The percentage of homeowners who responded that they did not know on each of the equipment and energy bill questions and that they did not service their heating and cooling equipment is shown in Figure S1. The figure makes clear that homeowners who have not had audits are less attentive as they are more likely to report not knowing energy features of their home and less likely to service their equipment.

[insert Figure S1 here]

Table S1 shows summary statistics for the key variables that we use in the logit model.

[insert Table S1 here]

As described in the paper, the attentiveness index and other behavioral factors have a statistically significant effect on the choice to have an audit. Most of the other explanatory variables have the expected sign and many are statistically significant. The contributions of the different variables associated with higher expected benefits of getting an audit are somewhat mixed. As expected, having older heating and cooling equipment and facing a higher electricity price both have positive and significant

effects and the indicator for planning to sell one's house has a negative effect. However, house size, as measured by number of rooms, and age are not significant. The costs of getting an audit (and/or following up with the recommended retrofits) is expected to be lower in states with higher per capita expenditures on energy efficiency programs and this is consistent with the positive and significant coefficient on this variable. However the "easily at home" variable, our indicator for low transaction costs, is not significant.

Racial minorities and low income households are more likely to get an audit; while this last finding suggests that our survey could be picking up audits conducted as part of the federal low-income weatherization programs, we find that generally the households that have had audits have incomes that exceed the thresholds for these programs. The negative income coefficient is consistent with Gamtessa (2013), who argues that because energy costs are a lower share of income for high income households, those households are less likely to retrofit their homes.

We have not focused on audit follow-up in this paper, but our survey also included questions about what auditors' recommended and to what extent homeowners followed up on those recommendations. With respect to air sealing and insulation, two of the most frequently recommended actions (Palmer et al. 2013), we found that follow-up appears to be incomplete. Only 41 percent of households fully implemented all recommendations for air sealing and insulation. Further analysis of these findings is the subject of future work.

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TABLE S1— DESCRIPTIVE STATISTICS

	Households-Audits		Households-No Audits		All Households	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Respondent Characteristics						
Dummy=1 if retired	0.265	0.024	0.260	0.015	0.262	0.013
Dummy=1 if married	0.752	0.025	0.780	0.014	0.775	0.013
Dummy=1 if black	0.139	0.020	0.085	0.010	0.089	0.009
Dummy=1 if Hispanic	0.131	0.021	0.105	0.013	0.106	0.011
Dummy=1 if other ethnicity	0.083	0.018	0.059	0.010	0.062	0.009
Age of household head	55.071	0.887	53.381	0.532	53.618	0.481
Annual household income (in $)	87,093	2,920	88,796	1,691	88,682	1,525
Environmental leanings [a]	1.247	0.059	0.924	0.036	0.959	0.032
Easily at home [b]	0.804	0.022	0.784	0.015	0.785	0.013
Variables affecting benefit/cost from audit						
Age of house	40.480	1.547	37.326	0.913	37.715	0.821
Number of rooms in house (excluding bathrooms)	6.838	0.026	6.815	0.017	6.818	0.068
HVAC system equal to or older than 6 years old	0.682	0.026	0.603	0.017	0.614	0.016
Heating degree days [c]	4033.1	178.4	4142.1	107.5	4149.3	96.7
Cooling degree days [c]	7,697.9	263.5	7,309.9	149.1	7,343.8	134.4
Average monthly electricity price (in $/MWh) [d]	115.38	1.40	111.98	0.91	112.43	0.81
2012 Per Capita State Residential EE Expenditure (in $) [e]	7.47	0.40	5.94	0.17	6.13	0.15
Dummy=1 if plan to sell house	0.005	0.002	0.115	0.012	0.102	0.010
Behavioral factors						
Dummy=1 if received home energy report	0.312	0.026	0.212	0.015	0.225	0.013
Dummy=1 if know someone who had audit	0.434	0.027	0.070	0.009	0.112	0.009
Inattentiveness index [f]	0.161	0.010	0.225	0.008	0.217	0.007

[a] Environmental leanings is a categorical variable equal to 0, 1, 2, or 3 depending on answers to three questions about the degree to which humans are causing global warming, how important environmental protection is to the respondent, and whether the respondent donated to an environmental organization in the past year.

[b] Easily at Home is equal to 1 if respondent reported that her job allows her to work from home, she has flexible work hours, or someone is at home all, or most, of the day. See text for more detail.

[c] A heating/cooling degree day is the number of degrees that the mean temperature, taken over an 8-day period, is above/below 65 degrees. There are 635 degree day recordings for each zip code represented in the household survey over the period from 2000 to 2013. Temperature data accessed from the NASA Land Process Distributed Active Archive Center, see https://lpdaac.usgs.gov/products/modis_products_table.

[d] Electricity prices are constructed using the monthly data on revenues ($) and electricity sales (MWh) collected by the Energy Information Administration on form 826. Utility level data are matched to zip codes using utility service area boundary maps.

[e] 2012 U.S. electric and natural gas residential efficiency program expenditures by state from Consortium for Energy Efficiency Annual Industry Report, divided by state population; see http://library.cee1.org/sites/default/files/library/11385/CEE_AIR_Tables_April_04_2014.pdf.

[f] Attentiveness index constructed from 6 questions demonstrating attentiveness on issues related to home energy use. The index is equal to the fraction of the questions with "inattentive" answers. See text for more detail.

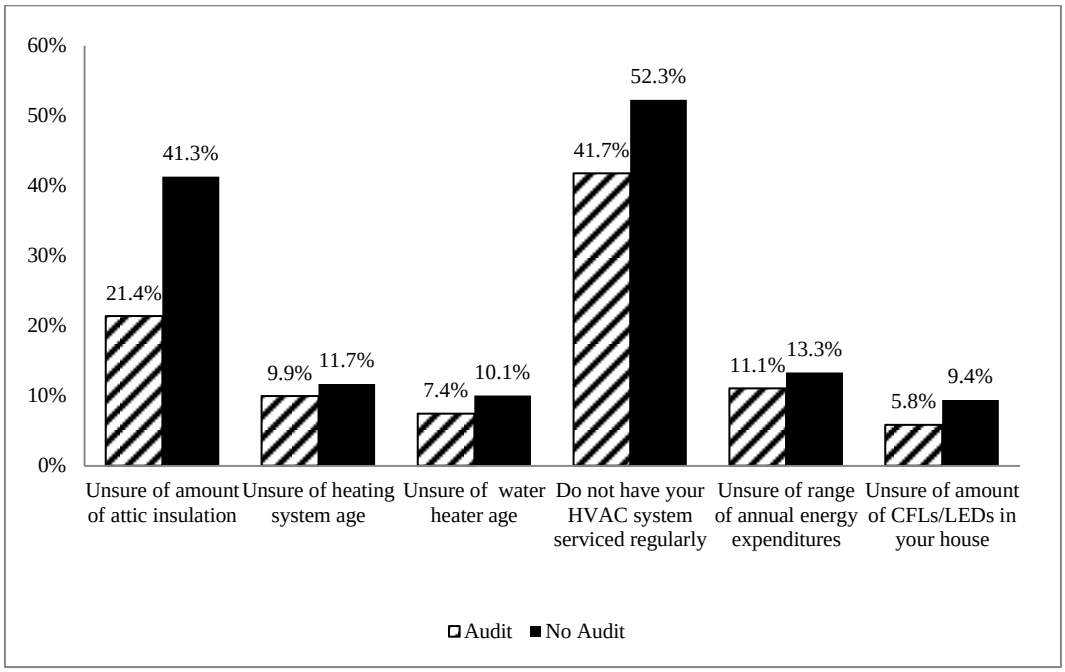

FIGURE S1. AUDIT UPTAKE AND INATTENTIVENESS

Note: Height of the bars represents the percentage of survey respondents.