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Putting Information into Action: What Explains Follow-up on Home Energy Audits?

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Abstract

Consumers often invest in information when faced with choices that have uncertain payoffs. Homeowners considering improvements or retrofits in order to lower their energy bills may decide to have a home energy audit, a professional assessment that identifies where a home is losing energy and recommends improvements that will lower energy use and costs. Follow-up on audit recommendations varies widely across households. We explore the reasons for these differences using data from a multistate survey of over 500 homeowners who have had energy audits. Our findings suggest that two sets of factors are important in explaining audit follow-up: factors related to the costs of retrofits and those related to the features and quality of the audits. Our findings have implications for policies to encourage the use of audits and suggest that the quality of the information and how it is delivered have important consequences for the role of audits in reducing energy consumption.

Key Words: energy efficiency, economics of information, energy retrofits

JEL Classification Numbers: L94, L95, Q40

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Introduction

Consumers often invest in information when faced with choices that have uncertain payoffs. They may hire stock brokers before investing in the stock market, get multiple medical opinions before opting for surgery or other procedures, and read reviews before going to restaurants. Homeowners considering improvements or retrofits in order to lower their energy bills may decide to have a home energy audit, a professional assessment that identifies where a home is losing energy and recommends improvements that will lower energy use and costs. Only about 4 percent of homeowners nationwide in the United States have had an energy audit, however (Palmer and Walls 2015). Moreover, among those homeowners who have had audits, the extent of follow-up on audit recommendations varies widely.

Why do some homeowners who pay for this information service, in both time and money, follow up on the information provided while others do not? We investigate this phenomenon using results from a 2014 survey of a representative sample of homeowners in 24 states. We look at the approximately 550 households that reported having had an audit and identify the factors that affect follow-up on the two most common recommendations from audits: air sealing and insulation. Building from a theoretical model of information acquisition, we identify factors that should explain consumer choices: individual homeowner attributes, house structural characteristics, local factors such as energy prices and climate, and the quality and features of the audit.

We find that two sets of factors are important in explaining audit follow-up: factors related to the costs of retrofits and those related to the features and quality of the audits. In terms of costs, households with lower time and transaction costs have a greater likelihood of follow-up, as do those that were aware of financial incentives for energy retrofits and improvements when they signed up for their audits. Households with major financial obligations (such as health care

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costs, college expenditures and the like) are less likely to follow up, particularly for insulation, which has a relatively high cost.

Energy audits can be quite heterogeneous. Despite the efforts of some trade associations to establish best practices and some state-subsidized or utility-run audit programs to standardize their procedures, the features included in an audit can vary substantially (Palmer et al. 2013). We find that this heterogeneity is important in explaining the extent of follow-up. In general, follow-up is more likely when an auditor uses a blower door test, which involves depressurizing the house and identifying sources of air leaks, and when he personally shows the locations in the house where improvements are needed. Not all audit features individually affect the likelihood of follow-up, but all the ones we are able to measure in our survey are statistically significant when taken as a whole.

Perhaps most important, we find that idiosyncratic and unobserved factors that affect a homeowner's satisfaction with the auditor are the strongest determinant of follow-up. In our survey, we asked homeowners whether they recommended their auditor to friends, neighbors, and colleagues. After accounting for the measured audit features that determine answers to this question, we find that the unexplained portion of the responses to this question is highly significant in explaining follow-up on both insulation and air sealing.

These findings have implications for policy. One commonly cited reason for the residential "energy efficiency gap," the apparent underinvestment in energy efficiency improvements that seem to more than pay for themselves with the energy cost savings they yield, is a lack of information (Gillingham and Palmer 2014; Gerarden et al. 2015). Homeowners faced with purchasing a heating or air-conditioning system, deciding whether to add insulation to attics or walls, calculating whether replacement windows are a worthwhile investment, and making a host of other decisions often lack the information necessary to make optimal choices. Our findings here suggest that the type of information provided and how it is provided are critical. Moreover, we find that when it comes to energy audits, it is not only the message delivered but possibly who is delivering it and how it is conveyed.

Audits are expensive. Palmer et al. (2013) found that the average price of an audit in 2011 was $349, and thus government subsidies for audits should be carefully considered in light of the wide variation in follow-up on their recommendations. Whether the value of the energy savings is worth the costs, of both the audit and the retrofits, is an open question. These findings, in combination with some other recent research on this topic (Fowlie et al. 2015a,b; LaRiviere et

al. 2014), suggest that it may be time for an evaluation of how to make residential energy audit and retrofit programs work better.

In the next section, we present a simple model of information acquisition when consumers are faced with choices that have uncertain payoffs and describe conditions under which acquired information may not be used. This is followed by a review of the literature. We then describe our survey and some additional data we gathered and provide summary statistics for the variables used in the model of audit follow-up. In the subsequent section, we present the results of our econometric model of audit follow-up on air sealing and insulation recommendations. The penultimate section provides some additional information from our survey about reasons for heterogeneous follow-up, and the final section presents some concluding remarks.

A Model of Information Acquisition

In a world with uncertainty, the benefit of information is the expected utility gain from shifting to better choices from among the set of terminal actions (Hirshleifer and Riley 1979). Working from this general precept, we assume that a homeowner's terminal action is retrofitting her home, but she has uncertainty about the payoff from the retrofits and the retrofit costs. We denote the benefit of the retrofit, which encompasses the energy savings and additional home comfort, by $X(\theta,\eta;\Omega)$, where θ is a vector of homeowner attributes (such as income, education, number of children, and "greenness" of preferences), η is a vector of house characteristics (such as size, age, number of rooms, and age and type of heating equipment), and Ω is a vector of exogenous factors, such as local climate and energy prices, that affect energy costs. The cost of a retrofit, $c(\eta)$, depends on the house characteristics.[1] In this simple setup, the energy retrofit is an all-or-nothing choice, but it would be straightforward to modify the expressions to include a vector of individual retrofit options.

If there is uncertainty in the benefits and costs of the retrofit, and preferences are risk-neutral, the homeowner will retrofit if $E(X(\theta,\eta;\Omega) - c(\eta))>0$—that is, if the expected net benefits are positive. The expected utility from the retrofit choice is then $max[E(X(\theta,\eta;\Omega) - c(\eta)), 0]$. If there is perfect information about the retrofit benefits and costs, then the homeowner will retrofit

[1] It could also depend on homeowner characteristics, θ, if time costs are important and are a function of income and other variables. We abstract from that possibility in the notation here.

if $X(\theta,\eta;\Omega) - c(\eta) > 0$. The expected utility in this case is $E[\max(X(\theta,\eta;\Omega) - c(\eta), 0)]$. Thus the value of information, *VI*, is the difference in utility with and without the information:

$$VI = E[\max(X(\theta,\eta;\Omega) - c(\eta), 0)] - \max[E(X(\theta,\eta;\Omega) - c(\eta)), 0] \; . \qquad (1)$$

It is straightforward to show that $VI \geq 0$, and thus the household will invest in information—that is, have a home energy audit—if $VI > K_A$, where K_A is the (nonnegative) cost of the audit, which could include the direct charge for the audit and any time and transaction costs involved.

In this simple framework, the audit provides full information about the net benefits of the retrofit. In real life, the information provided by the audit will not be sufficient to remove all uncertainty, but as long as it reduces it, *VI* will still be nonnegative, and the homeowner will have an audit if $VI > K_A$.

Audit follow-up is heterogeneous—that is, some homeowners act on the information provided and do the recommended retrofits and improvements, but others do not. The lack of full follow-up has been a puzzle to some observers: why would a homeowner go to the trouble and expense of having an audit and fail to follow the recommendations?

We see three possibilities. First, the costs of the recommended improvements, $c(\eta)$, may be higher than estimated by the auditor. Auditors do not typically do the retrofits themselves, and thus they may not have accurate information on costs. In addition, time and transaction costs, including the cost of finding a contractor to perform the retrofit work, are incurred by the homeowner but probably not considered by the auditor when making his recommendations. Second, the homeowner may not trust the recommendations from the audit, or the quality of the audit may be low. Home energy audits are not standardized, and auditors vary in their training and expertise. While the homeowner may intend ex ante to follow the auditor's advice, she may change her mind after the service is performed. Finally, procrastination may be a factor. Although a homeowner may plan to retrofit her house, she may simply not get around to doing it. If she exhibits naïveté about her future self-control problems (O'Donoghue and Rabin 1999), she may be overly optimistic about how soon she will complete retrofits. She has an audit because she believes the value of the information is greater than the audit cost, but then because she weights the retrofit costs more than the benefits, which are realized as a stream of energy savings over future time periods, she fails to do the retrofit.

We are able to explore several of these possibilities with our survey data and econometric model. For example, we know if retrofit costs were higher than the homeowner expected, and we included questions to capture transaction and time costs. The survey includes questions about a number of audit features and a measure of audit quality. We incorporate several measures of both θ, homeowner attributes, and η, house characteristics, as well as measures of local climate conditions and energy prices. Finally, while we are not able to incorporate a measure of procrastination in our model, we do provide some evidence of the extent of this phenomenon following our discussion of the econometric results.

Literature Review

Our study is part of a large literature on the role of information policies and disclosure programs to change consumer behavior (Dranove and Jin 2010). Studies that analyze the effects of information on decisions about energy efficiency include Allcott and Sweeney (2014) who use field experiments to look at the effect of information "nudges" on purchase of energy efficient hot water heaters, Allcott and Taubinsky (2013) who use a survey-based hypothetical experiment and a field experiment to analyze how information provision affects lightbulb purchases, Newell and Siikamäki (2014) who employ survey-based contingent choice experiments to assess the impacts of alternative information labels on purchase of hot water heaters, and Houde (2014) who also studies the effects of labels, using revealed preference data on purchases of refrigerators. All of these studies are focused on exogenously provided free information. In the case of home energy audits, homeowners make a choice to purchase information, then decide whether and how to act on that information.

The body of economic research on audits addresses three aspects of audit related behavior: (1) the decision to have an audit (Palmer and Walls 2015; La Riviere et al. 2014); (2) retrofit choices, either conditional on having had an audit (Gamtessa 2013; Considine and Sapci 2013)—that is, using a sample of households who had audits—or as a function of whether or not the homeowner had an audit (Ramseier 2013; Frondel and Vance 2013; LaRiviere et al. 2014)—that is, using a broader sample of households, some who had audits and some who didn't, and including an audit dummy variable as a regressor; and (3) effects of audits or retrofits on household energy use (Alberini and Towe 2015; LaRiviere et al. 2014; Considine and Sapci 2013). This study contributes to the literature on homeowner retrofit choices, with a specific focus on the two most common recommendations from audits: air sealing and insulation. We take the audit choice as given and analyze the follow-up decision, focusing our attention on how the characteristics of the audits affect behavior. To our knowledge this is the first study to

explore the question of follow-up using a multistate representative sample of US households that have had audits. It is also the first to include features and characteristics of a heterogeneous set of audits and auditors.

The extent to which audits affect homeowner investment in energy efficiency has been studied using survey data in different geographic settings with mixed findings. Using data from a mail survey of just under 1,000 homeowners in Switzerland and a two-stage least squares regression approach, Ramseier (2013) finds a positive effect of engaging an energy consultant on energy retrofits. In a study focused on the Netherlands, Murphy (2014) uses simple chi-squared tests in a comparison of means approach and finds no effect of audits on homeowner adoption of energy efficiency measures or on plans to make such investments. Frondel and Vance (2013) use data from Germany to study the effects of having an audit on four types of home retrofits: roof insulation, wall insulation, new windows, and new heating systems. They find that retrofit costs and expected energy savings are key determinants of renovation choices but that the effects of audits vary substantially across households and that some households respond negatively to the provision of information.

Considine and Sapci (2013) analyze follow-up among participants in a home energy audit program in Teton County, Wyoming. They find that homeowners are more likely to follow up when recommendations involve larger improvements in efficiency (measured by changes in R-value) and if they receive a cofunding offer that lowers retrofit costs. Gamtessa (2013), in a study of a Canadian home energy audit program, similarly finds that financial incentives offered to households, contingent on completion of the retrofits prescribed by the auditor, are an important factor behind household retrofit decisions, including both the decision to do retrofits at all and the number of retrofits. The study also finds that the cost of the retrofits and the estimated size of associated energy cost savings are important.

LaRiviere et al. (2014) carry out a field experiment in a medium-sized US metropolitan statistical area, analyzing three different types of social comparison messages on household electricity usage, audit uptake, and installation of energy-efficient durable goods. They find that social comparisons on electricity consumption tend to be associated with greater audit uptake but that these "nudged" households are less likely to install new energy-efficient durable goods than households that signed up for an audit on their own volition.

Another field experiment is the recent study by Fowlie et al. (2015a) of the federal Weatherization Assistance Program (WAP). The WAP provides a free audit and approximately $5,000 worth of home improvements, including typically some combination of insulation, air

sealing, and window and furnace replacement, to low-income households. The authors use a randomized encouragement design in which they provide extensive information about the benefits of the program, including in-person discussions and help filling out forms, to a random set of eligible households. Only 15 percent of treated households signed up for the program, and only 2 percent ended up following through with the free retrofits. These percentages are significantly higher than in the control group, where only 2 percent of eligible households signed up and less than 1 percent followed through with retrofits, but the authors view the numbers as surprisingly low given the effort and expense involved in encouragement and the fact that the households incurred no monetary costs to participate.[2]

One of the distinguishing features of our study is that we have information on measures of audit quality not included in most other studies. Themes explored in our study with respect to heterogeneity in the audit experience resemble a study by Ingle et al. (2012) that addresses the question of how well audits actually serve the homeowner. The study reports results based on a survey of homeowners who received a home energy audit through the Seattle City Light program. Although the study only reports summary statistics and does not include an econometric analysis, audits that included personal interaction with the auditors, blower door testing, and customized/specific upgrade recommendations rather than more standardized ones were rated higher by survey respondents. They also found that homeowners had a higher propensity to complete upgrades to equipment, appliances, or the envelope of the home if the auditor provided recommendations that were more customized to the home.

Description of Survey

The survey was administered in spring 2014 by GfK Custom Research using the KnowledgePanel, a probability-based online panel of approximately 50,000 adults who agree to participate in various surveys.[3] The GfK panel is balanced on geography and various

[2] The overarching purpose of the study was to compare actual measured energy savings with those predicted from standard engineering models. These findings are discussed in Fowlie et al. (2015b). The authors find that the measured energy savings are roughly 40 percent as large as what the engineering models predicted. In a smaller non-experimental study of a low income weatherization program at a Southern California utility, Graff Zivin and Novan (2015) also find that realized energy savings after the retrofits fall short of engineering model predictions, with ex post realized energy savings for homes with air condition of roughly 79 percent of those predicted by the engineering model used by the program.

[3] A partial list of academic papers published using the KnowledgePanel is available at http://www.knowledgenetworks.com/ganp/docs/KN-Bibliography.pdf.

demographic characteristics and thus made to be statistically representative of the US adult population. We conducted a stratified sampling approach for our survey, first targeting homeowners and then oversampling homeowners who had received 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). This is the case for home energy audits in the United States: only 3 percent of the homeowners surveyed in the US Department of Energy's 2009 Residential Energy Consumption Survey reported having had an audit in the past 4 years. Households that had received audits were included in our sample only if their audits took place in the past four years in order to reduce errors due to poor recall. We limited the survey to homeowners in the 24 states where our earlier research and other independent studies have shown that audits are more prevalent (Palmer et al. 2013).[4]

The final full sample included 1,771 homeowners, 546 of whom had received audits. We focus in this study on the audit subsample.[5] The survey included questions about homeowner characteristics and characteristics of the house, along with a wide-ranging list of questions about the features of the audit, the auditor recommendations, and the extent of follow-up on those recommendations. For people who reported having had an audit, we requested answers that applied at the time just prior to their audit. Each question was worded in such a way as to emphasize this, and in several places in the survey we reminded respondents to answer based on this earlier timing.

Respondent and House Characteristics

Basic demographic information, including household income, employment status, education, race, and gender, is provided in the KnowledgePanel. Our survey included additional questions about credit scores, environmental preferences, financial constraints facing the household, and the extent to which a household member was home during the day. Some key information on house attributes collected in the survey included the age of the house, the number of rooms, the main heating source, and whether the house had air-conditioning (central AC or separate room AC units).

[4] We administered several focus groups and pretests prior to the survey implementation. More information is available from the authors upon request.

[5] Palmer and Walls (2015) analyze the factors that affect a homeowner's choice to have an audit, finding that attentiveness to energy issues may play an important role.

Audit Features

Respondents who had received audits were directed to a series of questions about the features of the audit and the quality of the service provided by the auditor. To assess the comprehensiveness of the auditor's assessment, the survey asked respondents to indicate whether or not the auditor analyzed their past energy bills, conducted a blower door test to find air leaks, or provided infrared imaging to check heat loss. Blower door tests are considered standard practice for comprehensive, state-of-the-art home energy audits. In a 2011 survey of auditors, 91 percent of respondents reported conducting this test fairly often or always (Palmer et al. 2013). Infrared imaging is less common than the blower door test because the equipment is more costly. In the same survey of home energy auditors, 63 percent of respondents reported using infrared imaging fairly often or always (Palmer et al. 2013).

Our homeowner survey also asked whether the auditor "personally showed" the locations where improvements were needed and whether he provided photos. It asked whether the auditor provided cost estimates and/or energy savings estimates from the recommended improvements. The survey also asked about the price of the audit, providing categories of price ranges.

Audit characteristics are summarized for the entire sample of homeowners who had audits in Table 1. The survey suggests that the use of state-of-the-art tests such as the blower door test and the infrared test is less frequent in this sample than suggested by the earlier survey of home energy auditors. Only about half of the homeowners responded that the auditor analyzed their past bills, and roughly a quarter reported receiving pictures from the auditor of where improvements were needed. On the other hand, roughly three-quarters said that the auditor personally showed them where improvements where needed.

We also found that roughly half of the homeowners included in our survey reported that the audit was free. Some utilities and local governments provide free audits as one way to promote residential energy efficiency.[6] We asked these households whether they knew the audit was free when they signed up and how they found out about the audit. We also asked if they would have been willing to pay for it and, if so, how much. Of the 252 respondents to this question, only 26 percent said that they would have been willing to pay for the audit; the average

[6] The federal government's Weatherization Assistance Program (WAP), which subsidizes home energy improvements for low-income households, also includes free audits. Our survey households have incomes that are mostly too high to qualify for the WAP, so we believe that the free audits were more likely provided through utility and other programs.

price they were willing to pay was $69. The average price paid by households in the survey that reported a positive price for the audit was roughly $210.

Table 1. Summary Statistics for Audit Features

Variables	Mean (Std. Dev.)
Blower test	0.53
	(0.03)
Infrared test	0.43
	(0.03)
Analyze past bills	0.49
	(0.03)
Pictures	0.26
	(0.03)
Personally show	0.76
	(0.02)
Savings estimate	0.47
	(0.03)
Cost estimate	0.39
	(0.03)
Free audit	0.53
	(0.03)

Recommendations from the Audit and Extent of Follow-up

After performing the audit, a typical auditor will recommend specific improvements and retrofits to lower energy costs and improve the comfort of the home. The most common recommendation is sealing of air gaps (Palmer et al. 2013). This can include weather-stripping and caulking around windows and doors and sealing small holes and air gaps that may occur in the many nooks and crannies of a home. Air sealing is the low-hanging fruit of energy efficiency improvements, as it tends to be relatively low-cost. Another common recommendation is insulation, especially attic and crawlspace insulation. We thus chose to focus the survey questions on air sealing and insulation because of the frequency of these recommendations and in order to be very specific about the nature of follow-up. The survey asked households whether or not the auditor provided a recommendation for air sealing or attic/crawlspace insulation, and whether the auditor's recommendations seemed to be specific or not specific to the home. Of the 546 households in our survey that had a home energy audit, 72 percent received a recommendation for air sealing, 61 percent a recommendation for insulation, and 51 percent a recommendation for both. Thus our sample of households that had audits seem to have received recommendations that are roughly consistent with what auditors themselves reported in the 2011 survey—that is, high rates of air sealing recommendations and slightly lower rates, but still above 50 percent, for insulation (Palmer et al. 2013).

The survey asked about the extent of follow-up on the air sealing and insulation recommendations by categorizing responses into follow-up on all, some, or none of the recommendations.[7] Seventy-nine percent of the homeowners who received air sealing recommendations followed up on some or all of those recommendations, with about half doing all and half doing some. Sixty-four percent of homeowners followed up on some or all of the recommendations for insulation—40 percent on all of the recommendations and 24 percent on only some.

The survey also asked homeowners whether the costs of the recommended improvements and retrofits were higher than they expected, about the same as they expected, lower than they expected, or if they had no idea beforehand what the retrofits would cost. Seventeen percent of homeowners who received an air sealing recommendation and 26 percent of those who received an insulation recommendation reported that the costs were higher than expected.

Other Information

The survey also asked whether or not a respondent was aware of any discounts, incentives, or rebates for insulation or air sealing work. Approximately 42 percent of respondents reported knowing about incentives for air sealing, and 63 percent for insulation.

To assess the homeowners' satisfaction with the audit and the auditor, we included two additional questions: (1) whether the household had recommended the auditor it used to friends, neighbors, or colleagues; and (2) on a scale from 1 to 10, what was the overall quality of the information the audit provided? The first question was intended to capture characteristics of the auditor or quality of the audit separately from the standard checklist of audit characteristics. By asking if the household had recommended the auditor, the question focused on a specific action rather than a subjective assessment. The 1 to 10 rating, on the other hand, was more subjective. Forty-five percent of respondents recommended their auditor to others. The average 1 to 10 rating across all respondents was 7.

[7] We also asked a general question about the extent of follow-up, asking respondents whether they followed up on all, more than half, about half, less than half, or none of the recommendations from the audit, without specifically mentioning air sealing and insulation or other improvements. Sixty five percent of respondents reported following up on about half or more of the recommendations. However, we focus our analysis here on the two specific recommendations of air sealing and insulation.

Descriptive Statistics

Table 2 shows the mean and standard deviation for key respondent and house characteristics, along with additional data from other sources that we merged with our survey data. These additional data include local weather and energy prices, both of which affect home energy costs and thus have a potential effect on the benefits of following up on auditor recommendations for home energy improvements. Annual average residential natural gas prices by state were obtained from the US Energy Information Administration (EIA), averaged over the period from 2000 to 2012, and put in inflation-adjusted 2012 dollars.[8] Electricity prices were constructed using the monthly data on revenues and electricity sales collected by the EIA on Form 826. Utility-level data were matched to zip codes of the survey respondents using utility service area boundary maps. We average prices over the 2000–2012 period and put in inflation-adjusted 2012 dollars. We construct cooling degree days (CDD) and heating degree days (HDD) using zip code level, eight-day average temperature data from the NASA Land Processes Distributed Active Archive Center.[9]

In Table 2, the descriptive statistics are shown separately for households that received an air sealing recommendation and those that received an insulation recommendation. The table shows some differences between respondents who followed up and those who did not but little difference across air sealing and insulation. Homeowners who followed up are more likely to be unmarried, black, Hispanic, and more easily at home during the work week (which is constructed from a series of questions). They are also less likely to report having major financial obligations but have lower average incomes. Homeowners who did not follow up on recommendations tend to have older homes, on average; this is true for air sealing and insulation follow-up. Those who followed up on air sealing are more likely to have houses with natural gas or electric heat, indicating that the less common options such as oil, wood, and other fuel sources have lower follow-up rates. Very little difference in heating equipment shows up for insulation follow-up, however. Finally, follow-up on both air sealing and insulation is more common if the house has air-conditioning.

[8] See http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_nus_a.htm.

[9] See https://lpdaac.usgs.gov/products/modis_products_table.

Table 2. Descriptive Statistics: Respondent and House Characteristics, Local Energy Prices, and Climate

	Air sealing		Insulation	
	Yes Mean (S.D.)	**No** Mean (S.D.)	**Yes** Mean (S.D.)	**No** Mean (S.D.)
Respondent characteristics				
Dummy = 1 if married	0.75	0.80	0.75	0.79
	(0.04)	(0.06)	(0.04)	(0.05)
Dummy = 1 if black	0.13	0.03	0.13	0.04
	(0.03)	(0.02)	(0.04)	(0.02)
Dummy = 1 if Hispanic	0.18	0.11	0.16	0.12
	(0.03)	(0.05)	(0.04)	(0.04)
Dummy = 1 if other ethnicity	0.08	0.12	0.08	0.09
	(0.03)	(0.06)	(0.03)	(0.04)
Age of household head	54.51	51.88	50.97	56.48
	(1.21)	(2.80)	(1.50)	(1.95)
Annual household income (in $)	82,405	110,150	86,732	99,577
	(3,190)	(10,605)	(4,536)	(8,282)
Easily at home[a]	.80	.72	.81	.71
	(.03)	(.07)	(.04)	(.06)
Major financial obligation[b]	0.55	0.65	0.52	0.68
	(0.04)	(0.07)	(0.05)	(0.06)
House characteristics				
Age of house	40.99	46.92	44.63	47.53
	(2.08)	(3.81)	(3.02)	(3.31)
Number of rooms in house (excluding bathrooms)	6.66	6.73	6.92	7.06
	(0.17)	(0.42)	(0.24)	(0.24)
Dummy = 1 if house has natural gas heat	0.54	0.48	0.56	0.60
	(0.04)	(0.08)	(0.05)	(0.06)
Dummy = 1 if house has electric heat	0.31	0.24	0.24	0.24
	(0.04)	(0.06)	(0.04)	(0.05)
Dummy = 1 if house has air-conditioning	0.90	0.79	0.87	0.83
	(0.02)	(0.08)	(0.03)	(0.06)
Local characteristics				
Heating degree days (2000–2012)[c]	4,003.18	4,231.02	4,572.74	4,409.98
	(250.15)	(479.48)	(343.95)	(374.64)
Cooling degree days (2000–2012)[c]	8,044.70	7,138.79	7,297.13	7,357.07
	(401.29)	(710.52)	(570.21)	(522.02)
Real average annual natural gas price (in $/Mcf)	13.90	14.31	13.93	13.69
(2012$)	(0.23)	(0.48)	(0.25)	(0.37)
Real average monthly electricity price (in $/MWh)	120.96	128.60	123.58	126.04
(2012$)	(1.99)	(4.64)	(2.70)	(3.47)

[a] **Easily at home:** Dummy = 1 if respondent's job allows her to work from home, she has flexible work hours, or someone is at home all, or most, of the day during the week.

[b] **Major financial obligation:** Dummy = 1 if the household has "major ongoing financial obligations" related to college expenses or a college savings plan, child care costs, elder care costs, student loan repayment, car loan, home equity loan, or health care/medical bills.

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

Note: Means and standard deviations (S.D.) constructed using sampling weights provided in the survey; weights account for our stratified sampling approach (used to obtain a sufficiently large number of households that had audits) and ensure representativeness of sample with population in our 24 states.

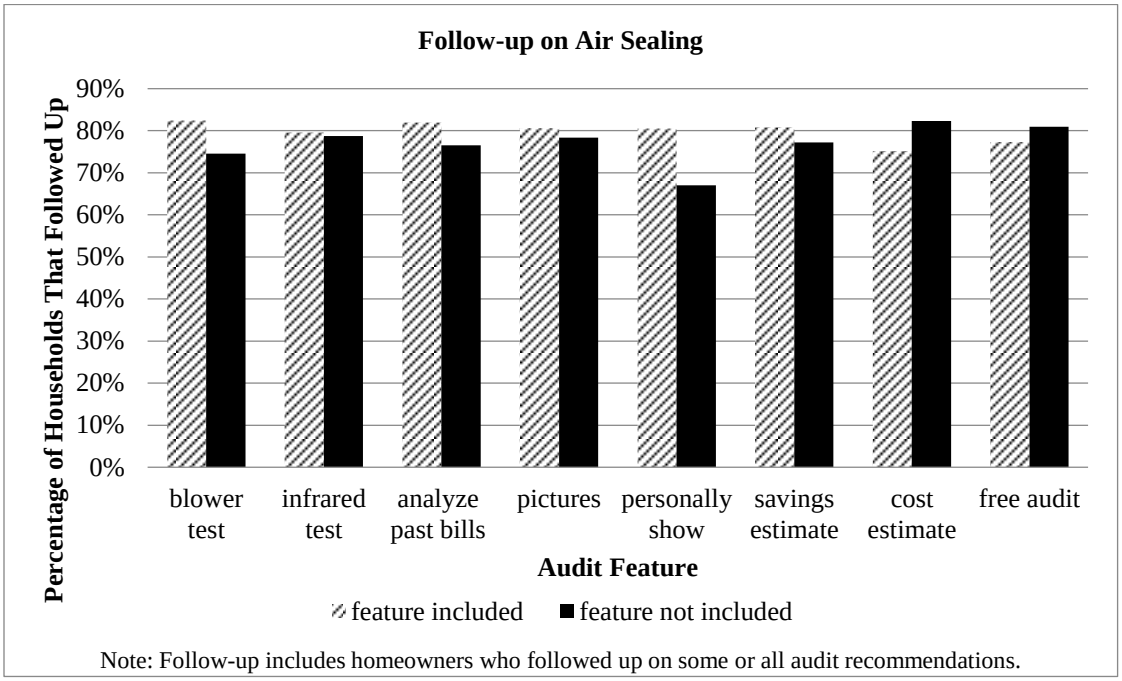
What Factors Explain Energy Audit Follow-up?

Examining Audit Characteristics and Quality

Because audits are heterogeneous with different types of tests and information gathered and presented, it is useful to understand how follow-up varies with different audit characteristics. Gathering information on these audit characteristics was an important feature of our survey and is thus a focus of our empirical work. Figures 1 and 2 provide bar graphs that show the percentage of the survey respondents who followed up on air sealing and insulation recommendations, respectively, by whether or not the audit included particular attributes.

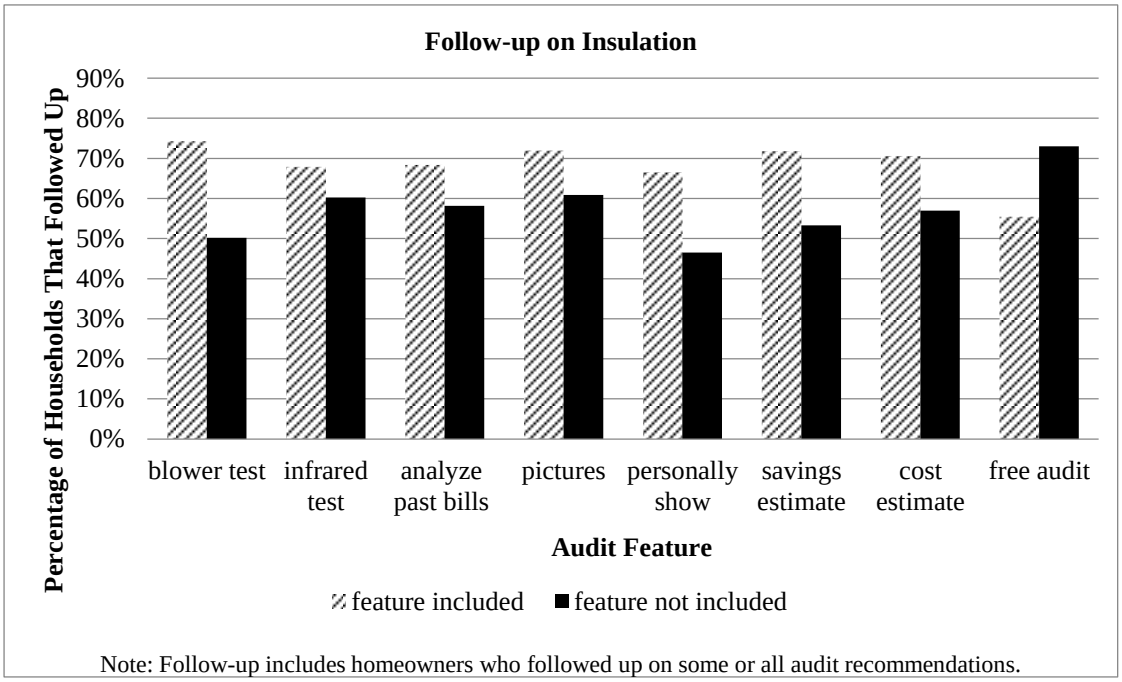
Some differences are evident across the two figures. First, follow-up rates are higher on the generally less expensive improvements, air sealing, than they are for insulation. Second, for air sealing, most of the individual audit characteristics do not appear to have had a big effect on homeowner follow-up, with the exceptions being the auditor personally showing the homeowner where retrofits were needed and the blower door test, both of which are associated with a greater rate of air sealing follow-up. Third, virtually all of the features appear to have led to higher follow-up rates for insulation, and in some cases—namely, using the blower door test, personally showing the locations for improvements, and providing an estimate of energy savings—the effect appears large. Homeowners who had a blower door test (and received an insulation recommendation) are over 20 percentage points more likely to follow up on that recommendation than homeowners whose audit did not include a blower door test. Last, free audits are associated with lower follow-up rates, especially in the case of insulation, where homeowners who had a free audit are nearly 20 percentage points less likely to follow up than households that paid for the audit.

Figure 1. Percentage of Households that Followed Up on Air Sealing Recommendations by Whether or Not Audit Included Specific Features



Note: Follow-up includes homeowners who followed up on some or all audit recommendations.

Figure 2. Percentage of Households that Followed Up on Insulation Recommendations by Whether or Not Audit Included Specific Features



Note: Follow-up includes homeowners who followed up on some or all audit recommendations.

The measured audit characteristics provide some information about audit quality, but even audits that include all of the features shown in Figures 1 and 2 can vary in quality. As with any service personnel, an auditor may be good at his job—well trained, highly capable, and an effective communicator—or he may be bad at it. The extent of follow-up on recommendations could be a function of these idiosyncratic factors, and our survey question that asked whether respondents had recommended their auditors to friends, neighbors, or colleagues is one way of capturing them. Figure 3 shows the percentage of survey respondents who followed up on air sealing and insulation by whether or not they recommended their auditor to others. The figure shows a much higher follow-up rate for both air sealing and insulation if the auditor was recommended: 92 percent of homeowners who recommended their auditors to others followed up on air sealing, and 77 percent who recommended their auditors followed up on insulation; the corresponding percentages for those who did not recommend their auditors were 71 percent (air sealing) and 56 percent (insulation).

Figure 3. Percentage of Households That Followed Up on Air Sealing and Insulation Recommendations by Whether or Not They Recommended Their Auditor to Others

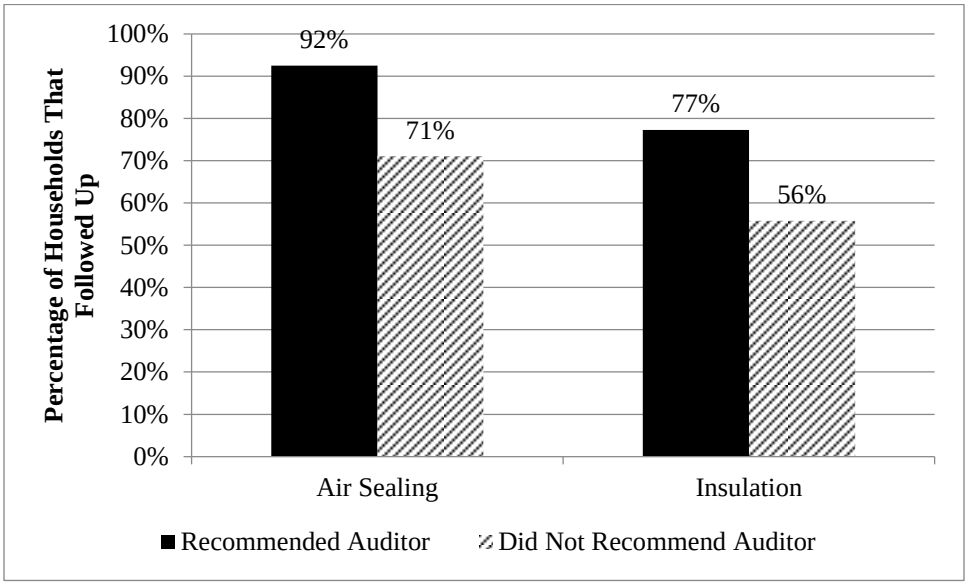


Figure 3 suggests that recommending one's auditor to others could be an important signal of auditor quality and thus a key factor in explaining audit follow-up. Before using it in our air sealing and insulation follow-up regressions, however, we remove the component that is explained by the measured audit characteristics. We do this by estimating a probit regression in which whether or not the homeowners recommended their auditors is a function of all the auditor characteristics shown in Figures 1 and 2; we then use the residuals from this regression as an

independent measure of auditor quality in our econometric model of follow-up. The results of the recommend auditor regression are reported in Table 3.

Table 3. Probit Regression Results of Homeowner Recommending Auditor to Others

Audit features	Coef. (Std. error)	Avg. marg. effect (Std. error)
Blower test	0.127 (0.175)	0.0410 (0.0565)
Infrared test	0.242 (0.174)	0.0785 (0.0559)
Analyze past bills	0.0352 (0.161)	0.0114 (0.0521)
Pictures	0.118 (0.191)	0.0382 (0.0617)
Personally show	0.835*** (0.213)	0.270*** (0.0685)
Savings estimate	–0.0568 (0.174)	–0.0184 (0.0562)
Cost estimate	0.326* (0.180)	0.105* (0.0573)
Free audit	0.0635 (0.161)	0.0206 (0.0522)
Constant	–1.528*** (0.213)	
N	522	
F(8, 514)	4.99	

The F-statistic for the regression suggests that collectively, the different audit characteristics contribute significantly to determining whether or not homeowners recommend their auditors. However, the only individual audit characteristic that has a strongly statistically significant effect is the "personally show" variable. If an auditor showed the homeowner where to make improvements, the homeowner is 27 percent more likely to recommend the auditor to a

friend or neighbor. We use the residuals from this regression to create a variable that represents the unobserved aspects of auditor quality as perceived by the homeowner, and we include this variable as an additional independent variable, along with specific audit features, in our regression analysis of the determinants of propensity to retrofit.

Econometric Results: Explaining Audit Follow-up

The results of our probit regression analysis of air sealing and insulation follow-up decisions are reported in Table 4. Audits that included a blower door test show significantly higher rates of follow-up on both air sealing and insulation. Audits in which the auditor personally showed where improvements were needed are also associated with higher follow-up rates, but the effect is statistically significant only for air sealing. The differential effects of this variable make sense, as air gaps can be located in many different places around a house, whereas our insulation questions focused on attics and crawlspaces. Most of the other coefficients are not statistically significant, with the exception of receiving a cost estimate from the auditor, which we find has a marginally significant negative effect on air sealing. Homeowners who received free audits were less likely to follow up, and the effect is statistically significant for insulation. This finding is consistent with LaRiviere et al. (2014). Although only a few individual audit characteristics are statistically significant, Wald tests for the significance of the collection of audit characteristics suggest that they are significant as a group in explaining both air sealing and insulation follow-up.[10]

Our measure of auditor quality independent of the specific audit features does have an important and highly significant effect on follow-up for both air sealing and insulation. In both cases, homeowners who recommended their auditors to others were 17 percent more likely to follow up, and the measured effect is highly significant. Indeed audit quality had a bigger and more significant effect on follow-up than other variables associated with the benefits of home weatherization, such as the age of the house, energy costs, and weather, none of which are statistically significant.

Costs of retrofits, both financial and time costs, appear to play a role in determining likelihood of follow-up. Homeowners were more likely to follow up when they were aware of subsidies or incentives for air sealing and less likely to follow up on insulation when the retrofit

[10] For the air sealing regression, the p-value for the Wald test is .0392, and for the insulation regression, the p-value is .0018.

costs were higher than they expected. Also, households where someone was easily at home during the day, which is a measure of time costs associated with arranging for home improvements, were more likely to install insulation. Ability to pay also plays a role, as households that reported having major financial obligations were less likely to install insulation, the more costly of the two types of energy improvements we consider. However, income has a negative coefficient in both follow-up regressions, though the coefficient is significant only in the case of air sealing. We hypothesize several potential explanations for this effect. First, because energy costs are a smaller share of the budget for households with higher incomes, they may be less motivated to reduce those costs by retrofitting. Second and related, they may have higher time costs or be more likely to procrastinate in doing the improvements. Third, they may already have made some improvements to their homes, and the marginal benefit from the recommended improvements may be small.

In general, we find very little effect of factors typically associated with the size of the benefits of weatherization retrofits on the propensity to make those investments. We include heating and cooling degree days over a 13-year time frame as a measure of average weather and find no effect of more extreme temperatures, hot or cold, on retrofits. We also look at the effects of energy prices in combination with particular energy uses in the home to ensure relevance of that cost. So, for example, we interact the average natural gas price over the 13-year period with the presence of natural gas heat in the home, and for electricity, we include the interaction between electricity price and the presence of electric heat or air-conditioning. In neither case is this energy cost variable significant. We also include number of rooms in the house as a measure of household size and age of house to capture the fact that newer houses may be more energy-efficient due to changes in building codes over time. We find that household size has no effect and that age of house has a negative effect—that is, homeowners who live in older homes were actually less likely to add air sealing or insulate their homes in response to recommendations from an auditor.

Table 4. Probit Regression Results: Homeowner Follow-up on Auditors' Recommendations

	Air sealing		Insulation	
	Coef. (Std. error)	Avg. marg. effect (Std. error)	Coef. (Std. error)	Avg. marg. effect (Std. error)
Audit features[a]				
Blower test	0.533**	0.110**	0.788***	0.218***
	(0.224)	(0.0448)	(0.242)	(0.0626)
Infrared test	–0.283	–0.0583	–0.316	–0.0876
	(0.223)	(0.0465)	(0.239)	(0.0664)
Analyze past bills	–0.0260	–0.00536	–0.0702	–0.0194
	(0.205)	(0.0423)	(0.227)	(0.0627)
Pictures	0.0524	0.0108	–0.0668	–0.0185
	(0.247)	(0.0508)	(0.286)	(0.0794)
Personally show	0.735**	0.151**	0.416	0.115
	(0.336)	(0.0697)	(0.349)	(0.0966)
Savings estimate	0.104	0.0214	0.312	0.0863
	(0.230)	(0.0473)	(0.243)	(0.0658)
Cost estimate	–0.496*	–0.102*	0.275	0.0762
	(0.291)	(0.0577)	(0.236)	(0.0644)
Free audit	–0.310	–0.0638	–0.480**	–0.133**
	(0.224)	(0.0447)	(0.237)	(0.0657)
Auditor quality[b]	0.836***	0.172***	0.622***	0.172***
	(0.227)	(0.0463)	(0.237)	(0.0634)
Other variables related to audits and retrofits				
Aware of incentives for air sealing (insulation)[c]	0.413*	0.0852*	0.155	0.0428
	(0.241)	(0.0478)	(0.250)	(0.0697)
Retrofit costs higher than expected[d]	–0.0894	–0.0184	–0.494*	–0.137*
	(0.295)	(0.0611)	(0.281)	(0.0769)
Selected household characteristics				
Ln(annual household income)	–0.458**	–0.0945***	–0.261	–0.0722
	(0.178)	(0.0355)	(0.174)	(0.0465)
Easily at home[e]	0.255	0.0525	0.553**	0.153**
	(0.254)	(0.0514)	(0.243)	(0.0648)
Major financial obligation[e]	–0.223	–0.0460	–0.765***	–0.212***
	(0.218)	(0.0449)	(0.207)	(0.0544)
House characteristics				
Age	–0.00786**	–0.00162**	–0.00854**	–0.00237**
	(0.00398)	(0.000771)	(0.00401)	(0.00108)
Number of rooms	0.0810	0.0167	0.0577	0.0160
	(0.0590)	(0.0116)	(0.0457)	(0.0127)
Local characteristics				
Heating degree days[e]	7.30e-05	1.50e-05	–7.79e-05	–2.16e-05
	(7.37e-05)	(1.50e-05)	(6.95e-05)	(1.88e-05)
Cooling degree days[e]	8.63e-05	1.78e-05	–6.71e-05	–1.86e-05
	(6.10e-05)	(1.22e-05)	(5.27e-05)	(1.43e-05)
(Natural gas price)*(dummy for natural gas heat)[e]	0.0179	0.00369	–0.00385	–0.00107
	(0.0162)	(0.00332)	(0.0163)	(0.00452)
(Electricity price)*(dummy for electric heat or AC)[e]	0.000635	0.000131	–0.00115	–0.000319
	(0.00224)	(0.000461)	(0.00218)	(0.000604)

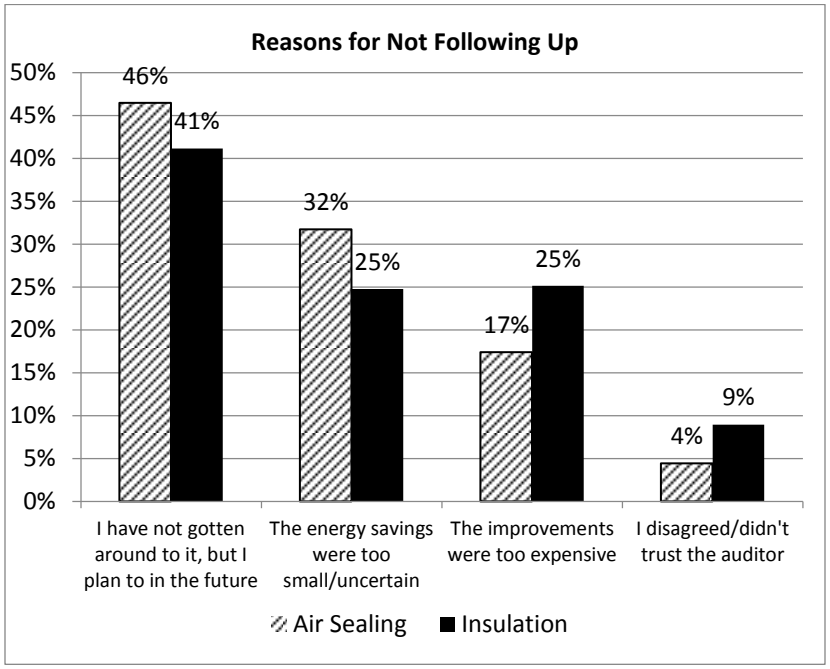
Household demographic characteristics[f]	yes	yes	yes	yes
Constant	3.672		4.740**	
	(2.261)		(2.404)	
N	301		249	
F(25, 276); F(25, 224)	2.00		2.66	

[a] All audit features are dummy variables equal to 1 if the audit included the feature.
[b] Auditor quality is equal to the residual from the estimated probit regression of whether or not a household recommended its auditor based on the features of the audit; see Table 3.
[c] Dummy variable equal to 1 if the household was aware of incentives for air sealing (in the air sealing follow-up regression) or insulation (in the insulation follow-up regression).
[d] Dummy variable equal to 1 if the costs of recommended improvements and retrofits were higher than the household expected.
[e] See footnotes to Table 2 for variable definitions.
[f] Household demographic characteristics include dummy variables equal to 1 if the respondent is married, black, or Hispanic, and the age of head of household.
*** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level.

More about Homeowners Who Did Not Follow Up

For households that did not do any air sealing or insulation, we presented possible explanations in the survey and asked them to select the top two reasons why they chose not to follow through on the auditor's advice. Responses are displayed in Figure 4. For respondents who did not do any air sealing, the top explanation selected, at 46 percent, is that they had not gotten around to it, but that they plan to in the future. This is also the most commonly selected reason for not following up on recommendations for insulation, though the percentage is slightly lower, at 41 percent. Small or uncertain energy savings was the second most popular reason why households did not follow up on recommendations, with 32 percent of respondents selecting this for air sealing and 25 percent for insulation. A higher percentage of households reported that the improvements were too expensive in the case of insulation (25 percent) than air sealing (17 percent). This makes sense, as insulation tends to be more expensive than air sealing. Lack of trust in or disagreement with the auditor's recommendations did not play a big role in the respondents' explanations for lack of follow-up.

Figure 4. Percentage of Responses Regarding Reasons for Lack of Audit Follow-up by Type of Recommendation Received



Conclusions

Consumers often make the choice to acquire information to reduce the uncertainty associated with large expenditures or investments. Home energy audits are a tool that homeowners interested in making investments to reduce their energy bills can use to learn more about the factors affecting the current energy performance of their homes and, more important, recommendations for cost-effective improvements that could save energy. Few homeowners avail themselves of this service, however, and among those who do, follow-up on the recommended home improvements is often incomplete. This raises the question of why homeowners bear the costs of getting audits, both in time and inconvenience as well as financial costs, and then fail to follow up on the auditors' recommendations. Using data from a large multistate survey, we have explored the reasons for differences in homeowner follow-up on audit recommendations related to insulation and air sealing.

Our findings suggest that audit follow-up is influenced substantially by factors that affect the cost of the investments and the quality of the audit. In particular, lower time and transaction costs are associated with a greater likelihood of follow-up, and awareness of financial incentives for the retrofits and improvements, such as rebates and discounts, also increases propensity to

follow up. On the other hand, learning that the cost of a retrofit is higher than expected has a negative effect on propensity to follow up.

Our survey also reveals that energy audits can be quite heterogeneous. Despite the efforts of some trade associations to establish best practices and some state-subsidized or utility-run audit programs to standardize procedures in their programs, the features included in an audit can vary substantially. We find that this heterogeneity is important in explaining the extent of follow-up. In general, follow-up is more likely when an auditor uses a blower door test and personally shows the location in the house where improvements are needed. Not all audit features individually affect the likelihood of follow-up, but all the ones measured in our survey are statistically significant when taken as a whole. Perhaps most important, we find that idiosyncratic and unobserved factors that affect a homeowner's satisfaction with the auditor are the strongest determinant of follow-up.

Conducting a multistate survey gave us an opportunity to collect information on audit features and homeowners' assessments of the quality of their audits across multiple states and thus provided an important picture of the range of different audit experiences that is possible only with broad-based surveys. Experimental research that involves randomization in audit treatments and in particular methods of engaging with the homeowner could be an important next step in identifying how changes in audit quality and homeowner experiences affect home retrofits and ultimately energy use. Recent experimental studies (Fowlie et al. 2015a, 2015b; La Riviere et al. 2014) suggest that policies to encourage audits and subsidize weatherization may not be delivering the anticipated energy savings. In combination with this prior work, our study suggests that it may be time to find ways to make these policies more effective and more cost-effective.

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