Effects of Mandatory Energy Efficiency Disclosure in Housing Markets

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Abstract

Mandatory disclosure policies are increasingly prevalent despite sparse evidence that they improve market outcomes. We study the effects of requiring home sellers to provide buyers with certified audits of residential energy efficiency. Using similar nearby homes as a comparison group, we find this requirement increases price capitalization of energy efficiency and encourages energy-saving residential investments. We present additional evidence characterizing the market failure as symmetrically incomplete information, which is ameliorated by government intervention. More generally, we formalize and provide empirical support for seller ignorance as a motivation for disclosure policies in markets with bilaterally incomplete information about quality.

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1 Introduction

Government-mandated information disclosure is increasingly used as a policy intended to improve the ability of consumers to make optimal decisions in the face of imperfect information about product quality. Policymakers view disclosure requirements as a lower-cost and less-intrusive means of improving market efficiency compared to alternative forms of regulation. As a result, such requirements are a significant policy component in many economic sectors including health care, education, and finance, among others (Hastings and Weinstein, 2008; Bollinger et al., 2011; Seira et al., 2017).[1] In theory, mandatory disclosure should improve the quality of goods and services by correcting for information-related market failures. In practice, the literature finds minimal evidence supporting the efficacy of disclosure programs at improving market outcomes (see Winston, 2008; Loewenstein et al., 2014; Ho et al., 2019). Reconciling the theoretical guidance with the empirical evidence necessitates an improved characterization of *which* information frictions are effectively corrected by disclosure mandates, so that policies can be better-targeted to address market failures.

This paper focuses on one setting where mandated disclosure may play a crucial role: investment in energy efficiency in housing markets. Prominent analyses such as McKinsey & Company (2009) point to substantial unexploited investment opportunities that would pay for themselves through energy savings within a short period, encouraging global climate mitigation plans to depend on energy efficiency to deliver more than forty percent of targeted emissions reductions (International Energy Agency, 2015). Towards this end, numerous jurisdictions have enacted mandatory residential energy efficiency audit and disclosure requirements in recent years, including many European countries, at least ten states in the U.S., and dozens of municipalities.[2]

The success of these programs in combating climate change ultimately depends on their ability to exploit cost-effective opportunities to improve energy efficiency, which in turn depends on the underlying market failure. If the "Energy Efficiency Gap" in residential investments is primarily attributable to behavioral or information-driven market frictions, then

[1]Several United States policies with mandatory disclosure requirements include the (1) Patient Protection and Affordable Care Act, (2) No Children Left Behind initiative, (3) Credit Card Accountability Responsibility and Disclosure Act, (4) Dodd-Frank Wall Street Reform, and (5) Consumer Protection Act.

[2]For example, the Oregonian (January, 5, 2018) states that Portland's policy "...is intended to give buyers a better idea of maintenance costs in the long run." Programs in Massachusetts and Austin, Texas are also motivated by a desire to increase residential energy efficiency investments. The Boston Globe (April 23, 2018) wrote that Massachusetts' program "could spur consumers to replace their windows or seal their doors, for example, reducing energy consumption." And, Austin Energy's website states that, "ECAD promotes energy efficiency by identifying potential energy savings in homes, businesses and multifamily properties."

mandatory audit and disclosure policies are poised to yield substantial benefits (Gillingham et al., 2009; Allcott and Greenstone, 2012; Gerarden et al., 2017). In contrast, if the perceived under-investment is simply because realized savings from energy efficiency programs often fall short of engineering projections, then disclosure policies will be largely ineffective at improving quality (c.f. Davis et al., 2014; Levinson, 2016; Allcott and Greenstone, 2017; Fowlie et al., 2018; Davis et al., 2019).

Our study examines the Energy Conservation Audit and Disclosure (ECAD) ordinance in Austin, Texas. As with similar disclosure policies, this law stipulates that home sellers must provide a standardized report of a certified technical audit of their properties' energy efficiency to prospective buyers. Our empirical setting and administrative data enable us to make two unique contributions. First, we identify a market failure that contributes to under-provision of information and under-investment in energy efficiency, such that an audit and disclosure program may be welfare-enhancing. We show that it appears to be a symmetric lack of information, i.e. ignorance about product quality on the part of both buyers *and* sellers, that is a barrier to voluntary disclosure of residential energy efficiency in housing transactions. Second, our study is one of the first to our knowledge to find credibly-identified evidence of product quality improvements resulting from *any* disclosure policy.

We identify the effects of this disclosure program by comparing homes sold in Austin to similar homes located just outside of the city limits but sold on the same real estate market and serviced by the same energy utility. We provide supporting evidence for this counterfactual; these homes are similar in their relevant attributes and we demonstrate that the jurisdictions exhibit parallel pre-policy trends for our outcomes of interest. For years spanning the policy's implementation and for areas both inside of and adjacent to Austin city limits, we use property-level data on housing transaction prices and characteristics, monthly electricity billing data, energy efficiency program participation, and technical information contained in the ECAD audit reports.

First, we estimate the effects of the ECAD disclosure program on the capitalization of energy efficiency into home prices and on homeowners' decisions to invest in energy efficiency. We use a panel fixed effects model including property fixed effects and a rich set of controls for local housing market shocks that might be correlated both with homes' energy efficiency and with the regression outcomes. We show that the policy significantly increases the capitalization of energy efficiency into housing transaction prices. This suggests that home purchasers are not obtaining full information about homes' respective energy efficiency from other sources in the absence of a disclosure policy. Next, we show that the policy successfully encourages investments in energy efficiency technologies by homeowners. Of note, we find that the policy increases investments made by both sellers and by home buyers.

We then explore the economic mechanism(s) underlying the effects we estimate for the disclosure policy. One interesting feature of our setting is that while the ECAD program is officially mandatory for all encompassed property sales, in practice few resources are dedicated to enforcement and compliance is incomplete (about 60 percent of targeted homes comply).[3] Therefore, we can leverage property owners' decisions of whether to comply with the program to explore pre-existing market failures that ECAD helps to correct. Voluntary disclosure theory would predict an "unraveling" effect from the highest quality sellers to the lowest (Grossman, 1981; Milgrom, 1981).[4] However, contrary to the theoretical prediction that the highest-quality sellers should be those most likely to disclose, we show that ECAD disclosure propensity varies little across the energy efficiency distribution of homes sold inside of Austin post-policy. That is, we find little evidence of an unraveling effect in this market, despite significant financial stakes associated with quality disclosure via policy compliance.

We examine several plausible explanations for the weak relationship between home sellers' relative energy efficiency and their likelihood of disclosure. First, we note that this pattern is not driven simply by seller ignorance about ECAD requirements. All sales in our sample are brokered through realtors, who are well-informed of the policy and whose financial incentives complement those of their home-selling clients. Moreover, the relationship is also not attributable to some realtors consistently complying while others consistently do not; instead, we find that the disclosure propensity across realtors follows a bell-shaped distribution. We additionally show that compliance is not attributable to buyers asking for the audit information, which could drive the flat relationship if the requests come from prospective home buyers uniformly-distributed across energy efficiency space. The timing of disclosure is generally within a few days of the real estate listing agreement – before a property is marketed – and is uncorrelated with the sale closing date.

This leaves two plausible explanations for the weak relationship between homes' relative quality and sellers' propensities to disclose: sellers might be ignorant about their own prop-

[3]In this sense, the ECAD program can be thought of as a disclosure encouragement policy: the government standardization of audits lowers the cost of disclosure and the threat of a fine for non-compliance increases the net benefits to sellers of disclosing.

[4]Because buyers may infer that undisclosed product quality implies poor quality, strategic sellers with the highest-quality products will always volunteer their private information so long as their disclosure costs are sufficiently low. This in turn creates an incentive for sellers with the next best quality products to disclose, and so on, until the benefits of disclosure for the next seller are equal to the costs, and all but the lowest-quality product sellers will voluntarily disclose quality information to the market.

erties' *relative* energy efficiency, and/or there might be substantial variation across sellers in effective compliance costs (including psychic and other nonmonetary disclosure costs). To distinguish between these candidate mechanisms, we construct a behavioral model of the seller's policy compliance decision. We then connect the model to our empirical findings using a computational simulation, in which we evaluate the decision to perform an ECAD audit given our capitalization estimates and a range of simulated distributions of effective disclosure costs. This exercise reveals that the flat empirical relationship between benefit from disclosure and likelihood of disclosure can be rationalized with the model only if there is either extremely large heterogeneity in disclosure costs or, much more plausibly, if a significant share of homeowners are uninformed about the (relative) energy efficiency of their homes. Thus, homeowners' ignorance about their own homes' respective quality appears to be a significant factor for why market-improving information disclosure does not occur in the absence of public policy.

Our study has several important policy implications and contributes to multiple strands of the literature. First, we provide some of the only empirical evidence of quality-improving effects of a mandatory disclosure policy. Second, we demonstrate evidence consistent with a specific market failure of symmetrically incomplete information – i.e. uninformed buyers *and* uninformed sellers – which likely explains why government intervention improves market outcomes in our context. In doing so, our study is also the first to our knowledge to test two of the "often strong assumptions" for the disclosure unraveling prediction: that sellers have complete information about their own product quality and that the distribution of available quality is public information (Dranove and Jin, 2010). In addition to real estate, as we study, there are likely other peer-to-peer markets where these strong assumptions do not hold and a disclosure mandate would improve market quality.

Our findings additionally speak to the Energy Efficiency Gap. Most prior work on the topic focuses on explanations of uninformed consumers or on optimistic engineering estimates of energy savings (Brounen and Kok, 2011; Busse et al., 2013; Allcott and Wozny, 2014; Myers, 2015; Sallee et al., 2016; Allcott and Greenstone, 2017; Fowlie et al., 2018; Grigolon et al., 2018; Allcott and Knittel, 2019; Myers, 2019). A smaller branch of this literature considers the role of nonmonetary costs, such as the hassle burden associated with investing in energy-saving technologies and building materials, and the implications for self-selection into program participation (Fowlie et al., 2015; Allcott and Greenstone, 2017). Prior research on the supply side explores whether the energy savings from more efficient technologies are fully capitalized into property values (Aydin et al., 2017; Frondel et al., 2017; Walls et al., 2017; Cassidy, 2018; Myers, 2019). To our knowledge, ours is the first study to consider that sellers' ignorance of their own properties' quality might also be a significant barrier to improving the energy efficiency of durable goods such as homes. Furthermore, because homeowners elsewhere may be as uninformed about residential energy efficiency as those in Austin, our study supports that mandatory disclosure programs are likely to lead to improvements in other markets as well.

2 Empirical setting

In order to estimate the effect of energy efficiency information disclosure on home prices and cost-saving investments, we leverage a natural policy experiment in the housing market provided by the City of Austin, Texas through the city's Energy Conservation Audit and Disclosure (ECAD) ordinance. Austin's ECAD ordinance came into effect on June 1, 2009. The policy mandates that qualifying residential properties obtain an official energy efficiency audit and that home sellers disclose this information to prospective buyers as part of the regular seller's disclosure notice. A home is subject to the disclosure requirement if all of the following conditions apply: (1) the home is within Austin city limits, (2) the home is aged ten years or older, (3) the home's electricity is serviced by Austin Energy (which services essentially all Austin homes), and (4) the home is sold. While audit reports must be disclosed for all qualifying home sales, an audit report itself remains valid for ten years following the date of the audit.[5] Originally, the energy audit must be provided to potential buyers before the point of sale. An amendment effective as of May 2011 pushed the disclosure timing more specifically to at least 3 days before the close of the option period, during which the prospective buyer may legally cancel their contract to purchase the home penalty-free.

These energy efficiency audits must be conducted by certified professional technicians who have received special training from Austin Energy and are approved contractors for the program.[6] A typical audit takes about an hour and costs the home seller around $100-$300 in direct cost. After completing the audit, the engineering professional provides a standardized report to both the seller and to Austin Energy, who publicly publishes each report.

An example ECAD audit report is included in Appendix A. The first page of the form

[5]Sellers are also exempted from obtaining a new audit report if the property has undergone major energy efficiency improvements through Austin Energy's Home Performance with ENERGY STAR (HPWES) program within the last 10 years, a mechanism that appears to be used minimally for compliance.

[6]These engineering professionals are certified either by the Residential Energy Services Network (RESNET) or the Building Performance Institute (BPI). For summary details of the ECAD process, c.f. https://austinenergy.com/ae/energy-efficiency/ecad-ordinance/energy-professionals/energy-professionals.

summarizes any cost-saving actions recommended in each of four categories: (1) windows and shading, (2) attic insulation, (3) air infiltration and duct sealing, and (4) heating and cooling system efficiency (HVAC). The remaining four pages of the form provide detailed information on specific measurements performed, such as the condition and estimated R-value of the attic insulation, the percentage of air leakage from the duct system, and the age, efficiency, and overall condition of the heating and cooling system, etc. Importantly, the ECAD Energy Professional is required to send the audit results to Austin Energy within 30 days following the inspection. Therefore, it is not possible for a home seller to obtain an audit and subsequently withhold that information from realtors and potential buyers.

As per the ECAD ordinance, Austin Energy maintains a record of the audits that are performed. However, it is not in its mission nor budget to track or enforce compliance. In a strictly statutory sense, noncompliance with the mandate can result in pecuniary penalties ranging from $500-$2000. However, because housing transactions are not directly monitored for compliance, penalties for noncompliance have almost never been incurred: to date, there has been only a single instance of an ECAD noncompliance penalty action being filed with Austin Municipal Courts.[7] As shown below, around 40 percent of homes in our sample are sold without complying with the program.

Austin Energy's service territory extends beyond the boundaries of Austin city limits. Therefore, while only homes inside of Austin are required to comply with ECAD, all of the homes within the territory receive the same utility promotional materials for its rebate and pricing programs. For the purposes of our analysis, we treat the establishment of the ECAD ordinance as an exogenous disclosure encouragement. The cost of disclosure is reduced for all households in the service territory by standardizing the audit format and even more so for Austin City homeowners by introducing the threat of a fine for non-compliance. We leverage the resulting change in the relative propensity to disclose between homes inside and homes just outside of Austin city limits to estimate the effects of the information on capitalization of and investment in energy efficiency. Further, imperfect compliance with the program provides us an opportunity to examine sellers' disclosure decisions in order to shed light on the economic mechanisms preventing voluntary disclosure unraveling in the absence of government intervention.

[7]Personal communication with Tim Kisner, ECAD project manager, Austin Energy.

3 Data

We combine data from several administrative sources for our analysis. First, to determine the physical location and characteristics of all single-family residences within the territory serviced by Austin Energy, we purchased the tax appraisal records and GIS shapefiles for all parcels in Travis and Williamson counties. From these appraisal records, we extracted the geographic location, construction year, square footage, and other details about each home. We use the shapefiles to assign each premise to either inside or outside of Austin city limits.

Next, we obtained residential property sales transaction details through the Austin Board of Realtors' (ABOR) Multiple Listing Service database (MLS). In most states, housing transactions are collected by county clerk offices and are public record; however, Texas is among a handful of non-disclosure states that do not provide the financing and sales price details for property transactions when a deed is transferred from one party to another. The data available through the MLS roughly correspond to all transactions conducted through a licensed realtor, which represents around 89 percent of sales.[8] We pulled the universe of transaction information for single-family homes sold in Travis and Williamson counties during 1997-2014. For our analysis, we use MLS data on the timing and closing price of each property sale.

Austin Energy provided us with property-level data on the universe of ECAD energy efficiency audit reports, participation in any utility-sponsored energy efficiency program, and monthly electricity billing records for all single-family residences during 2006-2014.[9] The ECAD audit reports include the date of the audit and the property address, along with the audit findings. For energy efficiency program participation, we focus on the utility's four largest residential programs: the Appliance Efficiency Program, Home Performance with ENERGY STAR Program (HPWES), Power Partner Thermostat Program, and Weatherization Assistance Program. We use information on the timing of participation and the total dollar amounts of rebates paid to property owners through these four programs. With few

[8]c.f. https://www.zillow.com/sellers-guide/for-sale-by-owner-vs-real-estate-agent/.

[9]The Appliance Efficiency Program provides customers with rebates for installing energy efficient equipment; about 95 percent of program participation is for air conditioning and heat pumps, with a small fraction of rebates awarded for pool pumps and water heaters. Home Performance with Energy Star focuses on improving the overall efficiency of a home, offering rebates for the following upgrades done through a participating contractor: new air conditioner or heat pump, HVAC tune up and efficiency improvement, attic insulation overhaul, duct and envelope sealing, covers for attic pull down stairs, solar shading for windows, and smart thermostats. The Power Partner Thermostat Program provides subsidies for purchasing smart thermostats from an approved list. The Weatherization Assistance Program helps low-to-moderate income customers to improve their homes' weatherization via new attic insulation, sealing duct work, weather stripping on doors, and similar upgrades. Combined, the AEP and HPWES programs account for more than 97 percent of energy efficiency program rebates.

exceptions, eligible utility customers may participate in each program at most only once per account. And, finally, the monthly billing data include the kWh of electricity consumed at the address between the start and end date for each bill.

3.1 Defining the energy efficiency proxy measure

Our empirical study focuses on the energy efficiency of homes sold. Ideally, we would directly observe an engineering measurement quantifying the efficiency for each home, but such data do not exist for the homes in our sample. For properties that obtained an ECAD audit, we do observe some engineering measures of energy efficiency, but many of the audit components are qualitative (non-quantitative), and the report does not provide any summary metric of the overall efficiency for the property (see Appendix A for a sample report). Moreover, ECAD audit measurements are only available for properties that obtained an audit – i.e. homes that were sold post-2009, particularly so within the city limits of Austin – whereas our identification strategies require a comprehensive measure of every in-sample property's energy efficiency.

Leveraging pre-policy energy consumption data and characteristics of the homes, we form an ordinal proxy measure of energy efficiency as follows. First, we use linear interpolation to recenter the monthly energy billing data for each property to correspond to calendar months rather than billing cycles.[10] Using these recentered values and dividing by each property's square footage, we determine the average monthly electricity consumption per square foot for each property during the full available pre-policy period spanning from January 2006 through May 2009. Finally, we rank these kWh/SqFt values within-vintage (but pooling jurisdictions) and scale the ordinal set to range from zero to one.

This proxy measure of energy efficiency has several advantages. In addition to being available for all in-sample homes, it serves as a single value that concisely summarizes the relative expected energy use at each property. Furthermore, because we define the measure within-vintage and accounting for home size, our proxy should primarily capture the less obvious components of energy efficiency that would comprise the information shock provided by an ECAD audit. That is, a home buyer can readily anticipate that a "newer" home is likely more energy efficient than an "older" home, but predicting differences in energy efficiency between two homes of the same vintage will be much more subtle. Finally, as our proxy

[10]For example, for a household that consumed 900 kWh during the billing cycle of May 16 through June 15 and 1000 kWh during the billing cycle of June 16 through July 15, we assign a consumption value of 950 kWh during June.

is ordinal rather than cardinal, it should be less sensitive to statistical outliers in energy consumption.

In Appendix A, we provide empirical support for our energy efficiency proxy. Using the sample of ECAD audited properties, Appendix Table A1 shows that various qualitative and quantitative measurements from the engineering inspections are significantly correlated with our proxy term. For instance, a ten percent improvement in our proxy is associated with: a one percentage point (two percent of the mean) increase in the probability that the home has double-pane or low-emissivity windows; a 0.22 degrees Fahrenheit square feet hours per Btu (one percent of the mean) increase in the R-value thermal resistance of the attic insulation; and a 0.16 percentage point (0.84 percent of the mean) reduction in air duct leakage. Thus, especially when considering that these correlations are not independent, while our ordinal proxy does not perfectly characterize residential energy efficiency, it seems very well-suited to serve as a tractable measure.

3.2 Sample compilation and summary statistics

We combine the data from our various sources using the unique tax appraisal id (parcel number) for each property.[11] In compiling our sample for analysis, we make several restrictions. Most substantially, we restrict our sample to properties that were constructed no later than 1998, as the ECAD policy enacted in 2009 applies only to homes aged ten years or older. In addition, we drop less than half of one percent of properties for which we are unable to determine the jurisdictional geography and/or energy efficiency. Our final sample consists of 131,028 single-family homes served by Austin Energy that were at least 10 years old at the start of the ECAD program, i.e. constructed in 1998 or earlier. Of these properties, 83.5 percent are within the Austin city limits, as depicted in a map in Appendix Figure A1. We observe 65,454 (50 percent) of these homes sold on the MLS at some point during 1997-2014, generating a total of 105,978 sales transactions.

Table 1 presents summary statistics for selected attributes of the homes in our empirical sample. The "full sample" in Column (1) includes all homes in the sample, regardless of whether or not the home was ever sold during our sample period. Columns (2) and (3) include, respectively, only the subset of these homes that are inside or outside the Austin city limits and were sold at least once during 1997-2014. Overall, homes in the sample are

[11] Technically, we rely on two identifier fields: the tax appraisal real "property id" and the "geographic id" or parcel number. For single-family homes, both values are unique to each particular parcel of land. The Austin Energy data are tracked by property id whereas the MLS data are tracked via the geographic id. We use the Travis and Williamson county tax appraisal roll files, which contain both identifiers, as a cross-walk.

sold on average 0.8 times each, and 0.22 times post-policy. The average vintage is 1973 and average size is 1839 square feet. By construction, the average energy efficiency quantile is 0.5, with corresponding average monthly electricity use of 1178 kWh (0.67 kWh per square foot). For homes that were sold at least once between 1997-2014, average sale prices are $228 thousand inside Austin and $315 thousand outside the city limits. "Pre-sale EE rebates ($)," which include the total dollar value of rebates paid to the property's owners by Austin Energy within two years prior to the property sale for participation in energy efficiency programs, average $29.6 and $27.6, respectively inside and outside of Austin; note, however, that 96 percent of these values are zero dollars.

Comparing Columns (2) to (3), the most stark differences are that homes sold just outside of the city limits are systematically newer and larger; correspondingly, they also tend to use more energy and command higher sales prices. Of interest, there is not much difference across jurisdictions in the energy use per square foot, which could arguably be more closely-related to a difference in the composition of occupants. And, there is not substantial difference in the homes' energy efficiency by jurisdiction. In most of the regression estimations to follow, we control for vintage-by-year or jurisdiction-by-year fixed effects – and often also for property fixed effects – in order to account for systematic differences across jurisdictions in the composition of properties. Overall, the descriptive statistics in Table 1, combined with the empirical identification exercises to follow, provide compelling support for the identification strategy outlined above in Section 2.

4 Empirical strategy and results

4.1 Capitalization effects of disclosure

Our first empirical question is whether ECAD increases the capitalization of homes' energy efficiency into sale prices. Because we use a proxy for homes' relative energy efficiency (discussed in Section 3.1), we do not view our estimates as fully capturing the capitalization of energy efficiency; rather, we examine whether our proxy – and by extension homes' true energy efficiency – becomes *more* capitalized into sale prices as a result of ECAD. To estimate the effects of the ECAD policy, we use a difference-in-differences identification strategy comparing outcomes of homes sold inside Austin versus outside of the city limits, before versus after the ECAD ordinance took effect only for homes within the Austin city limits. If our hypothesis is correct, then we should see the price spread between less- and more-efficient homes increase by more inside Austin than for the counterfactual.[12]

Appendix Figure A1 shows a map of the greater Austin area of our empirical sample, with our treatment and control group homes indicated by color in Panel (b). Not only are the counterfactual homes nearby to the treated homes, the properties are all sold on the same regional Realtor Multiple Listing Service and they are serviced by the same electric utility (Austin Energy). Further, the probability of selling a home in either jurisdiction is remarkably similar during the sample period. In Appendix Figure A2 we display the fraction of homes in each jurisdiction (i.e. inside or outside of Austin city limits) sold in each year in our sample. Importantly, there is no visible discontinuous change in the probability a home is sold inside of Austin relative to nearby outside of Austin areas, either just before or just after the change in policy regimes. This pattern, which is further supported by regression analyses in Appendix Table A2, indicates that homeowners do not appear to adjust the timing of sale or decision to sell in anticipation of or as a result of the introduction of the energy efficiency disclosure requirement.

To illustrate our "first stage" for compliance with the the policy, Figure 1 displays the fraction of sales in each jurisdiction with an ECAD audit for each year in our sample. Once the program begins in 2009 (depicted by the vertical line), roughly 60 percent of sales inside of Austin and 15 percent of sales outside of Austin obtain ECAD audits. The presence of audits for homes sold in the Outside Austin area could be due to treatment spillovers or curiosity on the part of homeowners.[13] However, the figure displays a substantial spread in energy efficiency disclosure across jurisdictions post-2009, a pattern that is further supported by regression analyses in Appendix Table A3.

Given this support for our identification strategy, our capitalization estimation asks whether the correlation between the energy efficiency proxy and the housing price is stronger when energy efficiency information is disclosed than when it is not. Figure 2 provides a graphical representation of the energy efficiency capitalization for each jurisdiction over time. We plot the year-specific correlation by jurisdiction between the homes' sale prices and the homes' energy efficiency proxy, controlling for property fixed effects as well as jurisdiction-by-year fixed effects. The omitted base year is 1997. Importantly, the residual correlation

[12]Conceivably, one might use a regression discontinuity design at the ten-year-old home age treatment cutoff. The first draw-back to using such an approach is relevance: homes constructed close to ten years prior to the policy, i.e. in the late 1990s and early 2000s, do not have nearly as much heterogeneity in energy efficiency as is present in older homes. More importantly, there is inadequate statistical power to conduct meaningful RDD tests around the 10-year-old cutoff.

[13]As these homes were all sold by professional realtors, who were well-informed of the specifics of the ECAD mandate, it is quite unlikely that seller confusion is responsible for audits outside of Austin.

between home price and energy efficiency appears to be on parallel trends in the two jurisdictions prior to the introduction of the ECAD program. However, following the policy change in 2009, the two lines discontinuously separate and show a relatively much more positive correlation between energy efficiency and sale price for homes inside of Austin compared to those outside of Austin. This visual evidence suggests that homes that are more energy efficient receive larger price premiums post policy inside of Austin compared to counterfactual.

In order to more formally estimate the energy efficiency capitalization effects of disclosure, our preferred specification is as follows:

$$\begin{aligned} ln(P_{ivjt}) = \;& \beta_1 EEProxy_i \times Post_t \; + \\ & \beta_2 EEProxy_i \times Austin_j \times Post_t + \mu_i + \tau_{vt} + \zeta_{jt} + \varepsilon_{ivjt} \end{aligned} \tag{1}$$

Our outcome variable is the log of the sales price for house i of vintage (year-built) v in jurisdiction j in month t. The energy efficiency proxy is denoted by $EEProxy_i$ and takes on a continuous value between zero and one, where one indicates the highest efficiency. The jurisdiction is indicated by $Austin_j$ and takes on a value of one for homes within Austin city limits (and zero otherwise), and $Post_t$ is an indicator for the months after the introduction of ECAD (post June 2009). House fixed effects are denoted by μ_i, τ_{vt} indicate vintage-by-month fixed effects, ζ_{jt} indicate jurisdiction-by-month fixed effects, and ε_{ivjt} is an idiosyncratic error term.

The house fixed effects control for the time-invariant qualities of a house that affect its price. Since the composition of the ages of the homes are different inside versus outside of Austin, we include vintage-by-month fixed effects to control for any differences in sales prices between the jurisdictions that are driven by differential trends in preferences for particular vintages of homes. Likewise, we include jurisdiction-by-month fixed effects to account for differential trends in preferences for homes inside or outside of the city that are not related to energy efficiency. Given these fixed effects, the identification of the coefficients in our model comes from comparing the slope of the energy efficiency proxy with respect to house price for same-age homes sold in the same month, controlling for any differential price trends in one jurisdiction relative to the other and for each homes' time invariant qualities. Our coefficient of interest is β_2, which is an estimate of the difference-in-differences of that price-efficiency slope for homes sold inside Austin versus outside of the city limits, before versus after the ECAD ordinance took effect.

Table 2 more formally evaluates this capitalization of energy efficiency, displaying regression estimates for how the natural log of properties' sale prices relates to interactions between energy efficiency, jurisdiction, and time period. The specification for Column (1) includes the full sample of sales, with jurisdiction and vintage-by-monthly fixed effects. For Column (2), we estimate a model that includes property fixed effects rather than jurisdiction fixed effects, which limits the sample to include only homes sold more than once between 1997 and 2014. The advantage of this sub-sampling is that property fixed effects account for substantially more potential heterogeneity across homes, controlling for any property-specific factors which might be correlated with both their energy efficiency and sale prices. In Column (3), we include property fixed effects and jurisdiction-by-monthly fixed effects rather than vintage-by-monthly fixed effects. Finally, Column (4) displays the results from our preferred and most saturated specification including property fixed effects and both vintage-by-monthly and jurisdiction-by-monthly fixed effects.

The first row in the table displays the estimates for the coefficient on the interaction between the energy efficiency proxy and the post-policy period (post-June 2009). This quantifies any change post- versus pre-policy for the residual correlation between energy efficiency and sale prices for homes *overall*. For the full sample of sales, the point estimate is positive and significant at the 10 percent level. However, once we include property fixed effects to control for any changes in the composition of homes' time invariant qualities (Columns (2-4)), the effect is no longer statistically nor economically distinguishable from zero.

The second row in the table displays estimates for our coefficient of interest: the triple interaction between the energy efficiency proxy, an indicator for being inside Austin city limits, and an indicator for post policy. Across specifications, the point estimates are positive and significant. This indicates that comparatively more efficient homes receive a deferentially higher price premium as a result of the ECAD policy applicable inside of Austin but not outside of Austin. The point estimate in Column (2) of .096 log-points is only half the magnitude of that in Column (1) of .186, suggesting that asymmetric changes in the composition of homes sold over time may be driving some of the relative differences in housing prices between the two jurisdictions over time. However, once we control for house fixed effects, as done in Figure 2, the pre-trends for the two jurisdictions are parallel and the point estimates then remain qualitatively and quantitatively consistent across specifications in Columns (2-4). These findings here are consistent with Cassidy (2018) who also studies the ECAD program using a different identification strategy. That work also finds evidence of capitalization; moreover the capitalization is larger for difficult-to-observe features of homes, suggesting that information is the mechanism at play.

To provide some perspective for the quantitative magnitudes of the results shown in Table 2, consider the point estimate of 0.08 log-points in our preferred specification in Column (4). At the average inside Austin home sale price of $228,000 (Table 1), this treatment effect corresponds to about a $19,000 price difference in reduced-form between the lowest and highest quality home, or $190 for each percentage point improvement in our ordinal energy efficiency proxy. If we are willing to fully attribute the price difference only to the audits themselves and rescale by the 45 percentage point relative difference in audit disclosure, then the average treatment effect of disclosure is about $422 per percentage point increase in energy efficiency. We view this as a strong exclusion restriction, however, considering that the policy might also have more generally influenced the attention that home buyers pay to energy efficiency. More generally, we remain agnostic on the specific causal mechanisms by which ECAD influences the price capitalization of energy efficiency, which are likely a combination of increased salience and reduced computational costs of evaluating these features of homes, in addition to the added information provided to the market.

In the underlying data for the summary statistics in Table 1, each percentage point improvement in homes' energy efficiency is associated with about an 11.26 kWh reduction in average monthly electricity use. Using the reduced-form capitalization estimate, at Austin Energy's average post-2009 electricity tariff of $0.10/kWh, a back-of-the-envelope calculation indicates an expected pay-back period of about 14 years.[14] For a homeowner operating with a 30-year outlook, this corresponds to about a six percent annual discount rate. For reference, 30-year mortgages had fixed rates of around four to five percent during this time period. Thus, our back-of-the-envelope calculation supports that the capitalization estimates in Table 2 are quite reasonable in quantitative magnitude.

4.2 Effects on investment in energy efficiency

We next explore how the ECAD disclosure program impacts home sellers' and buyers' investments in energy efficiency technologies and building materials. More specifically, we estimate how the ordinance affects the total dollar value of program rebates paid to property owners by Austin Energy for participation in any of the four energy efficiency rebate programs offered by the utility. Note that each dollar of rebates corresponds to substantially more out-of-pocket total dollars of energy efficiency capital investment on the part of the

[14] That is, home buyers on average are willing to spend $190 more in purchase price in order to save an expected $1.126 each month, which balances after 14.06 years. We assume no change in tariffs for this back-of-the-envelope calculation. The findings of Ito (2014) support using the average tariff rate.

homeowner.[15]

We start by using our difference-in-differences framework to assess how the disclosure policy affects total program rebate dollars paid to (soon to be) home sellers. This evaluation tests whether the availability of credible energy efficiency disclosure provided through the ECAD ordinance induces sellers to invest in higher product quality prior to listing their home for sale. As our outcome variable, we use the total dollar value of rebates paid per property for any program participation within the two years prior to sale. Post-2009 overall, ninety-four percent of these values are zero within our sample.[16]

Figure 3 plots the annual inside Austin coefficients from regressing these rebate dollars on vintage-by-year fixed effects and annual jurisdiction indicators. The series starts with 2006 as these are the first home sales for which we observe program participation. The 2009 policy change year serves as the omitted base-year. Of importance to the identification strategy, the overall trends appear very similar across jurisdictions prior to the ECAD policy. Following 2009, there is a visible jump up in the investment dollars inside Austin compared to counterfactual, which persists throughout the rest of the time series in Figure 3.[17] As indicated by the confidence intervals for each plotted coefficient, each of these year-specific estimates is noisy. Table 3 shows a more formal evaluation.

In Column (1) of Table 3, we estimate the post-pre difference between the coefficients shown in Figure 3. The econometric specification regresses the total two-years pre-sale dollar value of rebates paid to each seller (inclusive of zeros) on an interaction for the sale occurring inside Austin and post-June 2009, controlling for jurisdiction and vintage-by-monthly fixed effects. The difference-in-differences coefficient of interest is an economically and statistically significant $13.15 average effect of the policy on total energy efficiency investment rebate dollars. As the post-policy mean for this outcome variable is $42.39, this reduced-form treatment effect is a 31 percent increase in average energy investment rebates paid to home sellers. In the second column, we focus more specifically on rebate dollars paid to the seller for participation in HPWES, the efficiency program that is explicitly highlighted on the first page of the ECAD report (see Appendix A) and therefore the types of investments that

[15]The four programs are discussed in Section 3. Austin Energy's rebate payment schedule is here: https://savings.austinenergy.com/rebates/residential/offerings/home-improvements/hpwes-rebate.

[16]Primarily for this reason, we focus on the average value of rebates, inclusive of zeros, rather than the share of sellers that participate. From a more practical standpoint, our approach is also able to leverage both extensive and intensive margins of program participation, which improves statistical precision.

[17]Although the policy change occurred in mid-2009, it is reasonable to expect a short lag before seeing effects on this outcome, as homeowners are unlikely to undergo additional major renovations in their current homes immediately following the policy change.

are most closely tied to ECAD report values. Here, we find an effect on HPWES-specific investment by home sellers that is larger in both point estimate ($16.47) and relative to subgroup mean (61 percent). This evidence of investment by home sellers indicates that at least *some* sellers are aware both of their homes' respective energy efficiency and that this quality is more likely to be capitalized into home prices when it may be credibly disclosed.

In the final two columns of Table 3, we evaluate the effects of the ECAD ordinance on energy efficiency program rebates paid for participation in the two-years post-sale, i.e. paid to home *buyers*. Column (3) shows the estimates for all program rebates. Although the point estimate is positive, it is statistically insignificant; moreover, it is smaller in both magnitude and proportionately compared to that for total pre-sale rebate dollars. In Column (4), however, which focuses only on rebates paid to home buyers for HPWES participation, we find a large and statistically significant effect of $21.25 (31 percent of the mean). Together, these latter two findings indicate that: (1) the ECAD ordinance induced investment in energy efficiency improvements highlighted on the ECAD audit report, and (2) these investments might in part be substitutions away from other program participation (e.g. appliance replacement).[18]

5 Market failures and value of mandatory disclosure

5.1 Relationship between energy efficiency and disclosure

Our finding that audits increase the internalization of energy efficiency into house prices creates a broader puzzle about the role of a government disclosure policy. Under some circumstances, policymakers need not mandate disclosure in order for quality information to be incorporated into market outcomes. For example, if sellers know quality but buyers do not, and if disclosure is sufficiently low cost, then sellers with the highest quality products have an incentive to *voluntarily* disclose quality to induce buyers to purchase from them. Given this incentive, the sellers with the next highest quality product also have incentives to disclose for similar reasons. This dynamic leads to an "unraveling" where all but the lowest quality seller discloses, which eliminates incomplete information in the market. Even given some disclosure costs, such incentives to voluntarily disclosure still predict a sharp

[18] Given this evidence of increased investments, it is tempting to explore how the ordinance affects energy consumption. Two data limitations preclude such an exercise. First, the margin of investment is relatively small, so the analysis is under-powered statistically. Second, we cannot observe *which* households are buying which homes, and the policy might have facilitated increased sorting of households across homes.

relationship between quality and the decision to disclose (Grossman, 1981; Milgrom, 1981).

However, these dynamics of voluntary disclosure are inconsistent with two robust empirical features that we observe in our setting. First, the voluntary disclosure dynamics imply that making audits mandatory should not increase price internalization. More precisely, given that an audit infrastructure was in place both inside and outside of Austin, there should not exist a greater annual relative energy efficiency capitalization in Austin versus outside of Austin after 2009. However our results in Section 4 indicate otherwise.

Second, the voluntary disclosure dynamics would imply a sharp relationship between the energy efficiency of homes and the disclosure decision. However, we find only a very weak relationship. Figure 4 plots the share of in-sample homes sold inside Austin post-June 2009 that complied with the ECAD policy by obtaining and disclosing an energy efficiency audit, across the homes' energy efficiency quantiles. Each point depicts a local average compliance rate for the respective energy efficiency decile. The line shows the linear fit to the underlying microdata. Strikingly, the slope between energy efficiency and disclosure propensity is fairly flat. The first decile does have the lowest average disclosure rate at 55.4 percent; however, the most efficient decile's average disclosure rate is only 3.5 percentage points higher at 58.9 percent. More broadly, sellers of properties with below-median energy efficiency obtain an audit in 59 percent of sales, while above-median efficiency homes are audited in 62.4 percent of sales.

In this section, we construct an alternative model of disclosure that predicts these two empirical regularities. We offer evidence supporting that the mechanism by which mandatory disclosure increases capitalization is that both buyers *and sellers* have incomplete information about quality. Specifically, some sellers do not know the energy efficiency of their own homes, and a mandatory disclosure policy encourages that information to be revealed and incorporated into market prices. This bilateral incomplete information stands in stark contrast to much of the literature on the role of disclosure, which assumes that sellers know product quality (Dranove and Jin, 2010). This mechanism suggests a rethinking about the normative implications of mandating disclosure in some market settings, as we discuss below.

Our model below shows that when some sellers are uninformed about the relative energy efficiency of their homes, the relationship between energy efficiency and disclosure can by weak. We note that there are several other *a priori* possible explanations for a flat relationship, but none appear to be plausible in this setting. The first is that our proxy for homes' energy efficiency is a poor or relatively meaningless one. It is difficult to argue that this is the case. For one, as shown and discussed in Section 3 and Appendix A, we validate that our proxy is highly correlated with actual audit measures of residential energy efficiency. In addition, our empirical results above demonstrate that this measure is significantly capitalized among treated homes post-policy relative to counterfactual.

A second possibility is that buyers are driving the compliance decision by asking sellers to provide the information as part of the closing process. If the requests come from home buyers who are uniformly distributed across efficiency space, it could drive the weak relationship we observe between compliance and energy efficiency. However, the timing of the audit is generally within a few days of the real estate listing agreement – before the property is marketed – and is uncorrelated with the closing date (see Appendix Figures A3 and A4). A related potential explanation is that the decision to disclose is driven by realtors. If some realtors consistently ask their clients to perform ECAD audits, while others consistently do not, this could result in the weak relationship between compliance and energy efficiency that we observe. In contrast, we find that the propensity to disclose across realtors instead follows a bell-shaped distribution as shown in Appendix Figure A5.

Another hypothetical explanation, in principle, is that many seller's are simply uninformed about the requirements of the ECAD program. However, this explanation has minimal support given that these are all properties sold via realtors, who are well informed about ECAD.[19] If sellers were well-informed about the efficiency quality of their properties, realtors would have a strong financial incentive to encourage their client sellers of more efficient homes to disclose. Therefore, if we take seriously that the compliance decision is most likely driven by the seller in consultation with a realtor who knows about the program, there are two plausible explanations for the empirical pattern of disclosure, which we model and evaluate just below: (1) sellers are not aware of the energy efficiency of their homes and (2) there is substantial heterogeneity in costs (including time, effort and psychological) of disclosure.

5.2 Model of ECAD compliance decision

We present a simple model of the seller's decision to comply with a mandatory disclosure policy. This model shows that when both the buyers and *some sellers* are uninformed about (relative) product quality, that compliance with a mandatory disclosure policy will be incomplete and only weakly related to quality.

Consider a single house that is being sold from a seller to a buyer. Beliefs about the

[19] The Austin Board of Realtors regularly puts on events in coordination with Austin Energy to disseminate information about ECAD to local realtors, and our own discussions corroborate that they are well-informed.

energy efficiency of the house do not affect whether the house is sold, but do affect the negotiated transaction price. The house's true energy efficiency – which we refer to as quality – is characterized by $q \in [0, 1]$, with a larger q corresponding to a higher level of energy efficiency.

In this incomplete information setting, denote seller beliefs about quality as q^s and buyer beliefs as q^b. First, consider the seller's beliefs. Let the seller be informed about the true quality with probability Φ, and we take this probability to be exogenous to the model. For example, the seller may be unaware of the number of inches of insulation in the attic or unaware of the relative energy efficiency of the home relative to other homes. An informed seller knows the true product quality ($q^s = q$) whereas an uninformed seller has beliefs about quality given by $q^s = \hat{q^s}$, which we specify below.[20]

Next, consider buyer beliefs. The buyer is uninformed about the true quality q unless the seller chooses to conduct an audit. If an audit is conducted, the results of the audit are automatically reported to the buyer (i.e. the seller cannot observe the audit results and keep that information private). We assume that the audit is unbiased and reports the true quality q.[21] Therefore, if no audit is conducted then the buyer's beliefs are given by $q^b = \hat{q^b}$, but if an audit occurs then buyer knows the true quality and $q^b = q$.

Beliefs about quality determine the buyer's and seller's respective beliefs about the dollar value of the home as given by $b(q^b)$ and $b(q^s)$. Nash Bargaining determines how beliefs about the pecuniary benefits of quality map to the price premium for the energy efficiency characteristics of the house. Therefore, the home's energy efficiency affects the negotiated transaction price of the house by the amount: $\frac{1}{2}[b(q^s) + b(q^b)]$.

The audit/disclosure decision is made by the seller. Let the net pecuniary costs of getting an audit versus not getting an audit be given by c. In other words, c is the dollar costs of paying for the audit process net of the expected penalty for not obtaining an audit prior to sale. (Voluntary disclosure corresponds to an expected penalty of zero). In our setting, the expected penalty appears to be very small given the degree of enforcement.

The benefits to the seller of undertaking an audit are driven by how much the disclosure changes the beliefs of the buyer. An informed seller will choose to disclose quality if $b(q) - c \geq \frac{1}{2}[b(q) + b(\hat{q^b})]$. That is, the seller chooses to disclose if and only if the expected benefit from disclosure is greater than the net of the direct disclosure cost and the expected Nash

[20]For simplicity, we assume here that uninformed agents' beliefs are loaded at a single mass point, but one could also allow for non-degenerate distributions.

[21]See Dranove and Jin (2010) for a discussion of the literature investigating whether third-party certifiers necessarily have an incentive to report unbiased results.

Bargaining opportunity cost. An uninformed seller faces a similar tradeoff but evaluates expected benefits on (perhaps incorrect) beliefs of the quality of the house. An uninformed seller discloses if $b(\hat{q^s}) - c \geq \frac{1}{2}[b(\hat{q^s}) + b(\hat{q^b})]$, where $\hat{q^s}$ may not necessarily be true quality q.

Given this model, we illustrate how full unraveling can break down. Figure 5 presents several scenarios. In the illustration, we set the domain of $b(\cdot) \in [0, \bar{b}]$. For ease of exposition, these scenarios all assume that the buyer's belief in the absence of disclosure $\hat{q^b} = 0$. This assumption is equivalent to the seller operating as if the buyer's belief about an undisclosed product quality is that it is of the lowest possible quality, consistent with assumptions in classic models of voluntarily disclosing of asymmetric information (Dranove and Jin, 2010). Note that this assumption is not Bayesian in the sense that our model will predict something different – some high quality and some low quality homes will fail to get an audit. However, in this incomplete information environment, it is not clear that buyers follow a "fully strategic" model of belief formation.

Similarly, for exposition we assume in this illustration that an uninformed seller believes her house to be of median quality, i.e. $b(\hat{q}) = \bar{b}/2$. Of course, uninformed sellers and buyers might hold alternate beliefs, such as that unknown quality is positively correlated with true quality. The key insight of the model is to illustrate that incomplete information by both the buyer *and seller* yields a weak relationship between disclosure and quality.

In the first scenario, we illustrate that full unraveling can breakdown when disclosure is costly to the seller. In this benchmark scenario, all sellers are informed about the quality of their homes ($\Phi = 1$). Suppose that the seller faces a deterministic disclosure cost $c = \bar{b}/4$. Deterministically, the seller will disclose product quality if and only if $b(q) \geq \bar{b}/2$. This scenario is shown by the solid line in Figure 5. This signals to the market only that the energy efficiency value of an unaudited house lies in the range $b(q) \in [0, \bar{b}/2)$, but provides no more detailed information about product quality. In this scenario, the sellers of all houses of sufficiently high quality disclose quality to the buyer.

In the second scenario, all sellers are informed but there is heterogeneity in the cost of disclosure. Cost heterogeneity could reflect the fact that the time, effort, and psychological costs of disclosing and the perception of expected penalties of non-compliance may vary across sellers. In this illustration, the disclosure cost is drawn from a normal distribution around $\bar{b}/4$: $c \sim N(\bar{b}/4, \bar{b}/8)$. The relationship between quality and equilibrium disclosure is shown by the long-dashed line. The probability of disclosure is visibly smoother with respect to the seller's product quality q. Even the highest quality houses do not always have quality disclosed to the buyer, but higher quality homes are much more likely to have quality disclosed. In particular, a seller with benefit of less than $\bar{b}/2$ will still disclose quality if the cost draw is sufficiently small, and vice versa. Note that the relationship between disclosure probability and disclosure benefit is relatively steep when the seller is informed with certainty, despite our imposition here of sizable variation in disclosure cost.

Next we allow for the major innovation of this exercise – sellers can be uninformed about the quality of their own homes. We continue to model disclosure costs as heterogeneous as in the scenario above, but we reduce the probability Φ that the seller is informed. In the short-dashed line, the probability the seller is informed $\Phi = 0.50$ and independent of the true quality q. And in the dotted line, the probability is $\Phi = 0.10$. In general, when the seller is uninformed, the relationship between true quality and disclosure is substantially flattened.

Collectively, the theoretical scenarios illustrated in Figure 5 show two insights. The first is that, given either a dispersion in disclosure costs and/or the possibility for seller ignorance about product quality, the classic theoretical unraveling result breaks down. The second insight is that for unraveling to be minimal requires either that there be a large dispersion in disclosure costs or that there be a substantial likelihood that the seller is uninformed (or both).

5.3 Computational simulation

Next we conduct a simulation exercise that connects our reduced-form empirical findings to the theoretical model presented in Section 5.2. Our computational exercise simulates draws of audit costs for each post-policy inside Austin home seller and uses these simulated cost values – along with data on homes' true energy efficiency and sellers' actual disclosure decisions – to determine the maximum plausible share of home sellers that could be informed under various cost distributions without violating the specification of the model.

Our starting point for the simulation is the solution to the seller's disclosure problem in the model in Section 5.2. Recall, an informed seller will choose to disclose quality if $b(q) - c \geq \frac{1}{2}[b(q) + b(\hat{q}^b)]$ while an uninformed seller discloses if $b(\hat{q}^s) - c \geq \frac{1}{2}[b(\hat{q}^s) + b(\hat{q}^b)]$, where $\hat{q}^s$ may not necessarily be the true quality q. Let $i \in \{0, 1\}$ denote whether the seller is informed, with $i \sim \text{Bernoulli}(\Phi)$ and Φ taken as exogenous to the model. Then, the seller's decision to disclose $d \in \{0, 1\}$ can be summarized as a function of the seller's information status:

$$d = \begin{cases} 1 & \text{if} \quad i \cdot b(q) + (1 - i) \cdot b(\hat{q}^s) \geq 2c + b(\hat{q}^b) \\ 0 & \text{if} \quad i \cdot b(q) + (1 - i) \cdot b(\hat{q}^s) < 2c + b(\hat{q}^b) \end{cases} \tag{2}$$

That is, the seller chooses to disclose quality if and only if the seller's (expected) benefit from disclosure is greater than the seller's combined disclosure cost and expected Nash bargaining opportunity cost. When making the disclosure decision, the seller may or may not be informed, $i \in \{0, 1\}$, about the value of the home's quality. We observe disclosure decisions d in the data, we can use the reduced-form results shown above to provide a sale price benefit $b(q)$ for each property, and we can simulate values for $2c + b(\hat{q^b})$, which we hereafter refer to as effective disclosure cost. However, we do not observe whether or not a seller is informed, nor do we observe sellers' beliefs about their homes' quality, $\hat{q}^s$. By rearranging the above solution, we can define:

$$i \equiv \begin{cases} 0 & \text{if} \quad d = 0 \quad \text{and} \quad b(q) \geq 2c + b(\hat{q^b}) \\ 0 & \text{if} \quad d = 1 \quad \text{and} \quad b(q) < 2c + b(\hat{q^b}) \\ 1 & \text{if} \quad d = 1 \quad \text{and} \quad b(q) \geq 2c + b(\hat{q^b}) \\ 1 & \text{if} \quad d = 0 \quad \text{and} \quad b(q) < 2c + b(\hat{q^b}) \end{cases} \tag{3}$$

The first two scenarios in Equation (3) are mechanically true per the model, whereas the latter two only indicate that the seller is *plausibly* informed. Note that with this framing, we do not need to assume nor simulate any values for uninformed sellers' beliefs $b(\hat{q}^s)$. We simulate values of the effective disclosure cost $2c + b(\hat{q^b})$ and conduct the computational simulation exercise as follows.

First, we linearly re-scale the gross price benefits to range $b(q) \in [0, 1]$ by using the energy efficiency proxy term directly as the gross benefit value. The advantage to this re-scaling is that it preserves the quantitative implications of the model without being sensitive to the specific values estimated for price capitalization above (i.e. it doesn't matter whether we use the reduced-form intent-to-treat or the ATE to quantify price benefit). Next, we assume that effective disclosure costs are normally distributed and determine the requisite average cost that would generate the empirically-observed (61 percent) share of sellers who disclose quality, using the model and assuming that all sellers are informed. This value is 0.44. That is, in the scenario that all sellers are informed about their homes' relative energy efficiency and with price capitalization re-scaled to be in $[0, 1]$, the only sellers to disclose will be those who would realize re-scaled gross price benefit of greater than 0.44.[22] We hold average effective disclosure cost fixed across all simulations and vary the standard deviation of simulated effective disclosure costs, such that $2c + b(\hat{q^b}) \sim N(0.44, \sigma)$. Within each

[22]Note that the reason for the average effective disclosure cost value of 0.44, rather than 0.39, is that the distribution of energy efficiency for these sold homes slightly deviates from the overall sample distribution.

simulation loop, we specify a value of σ and simulate a cost vector. Rather than randomly assigning cost values to sales, we sort the cost vector such that the maximum plausible share of sellers could be informed per Equation (3).[23]

Thus, for specified values of σ and observed vectors of values of $d \in \{0,1\}$ and $b(q) \in [0,1]$, the steps of each simulation loop are:

1. Draw a vector of gross effective disclosure cost values from $2c + b(\hat{q^b}) \sim N(0.44, \sigma)$.
2. Sort the cost vector such that the maximum possible share of sellers could plausibly be informed without violating the rationality of the model per Equation (3).
3. Store the aggregate value for this maximum possible fraction of informed sellers.

Simulation results are shown in Figure 6 and Table 4 for values of σ ranging from 0.0 to 0.3 in increments of 0.01. To reduce the influence of simulation variation, we repeat steps 1-3 for 1000 repetitions of each specified value for σ. The figure plots the median values from the repetitions for each σ in the solid line in the graph; the first and ninety-ninth percentile values for each simulated standard deviation value are shown in the dashed grey lines. Table 4 shows the first, median, and ninety-ninth percentile values for the share of plausibly-informed sellers from 1000 repetitions at selected σ values.

In the first row of Table 4, effective disclosure costs are set to be constant (at 0.44) across sellers. With no heterogeneity in audit costs, Equation (3) can be rationalized only with at most 54.18 percent of sellers being informed about their homes' relative energy efficiency. As the simulated spread in effective disclosure costs increases (moving down the first column of Table 4 or across the horizontal axis of Figure 6), the corresponding share of plausibly-informed sellers also increases. This is consistent with the illustration in Figure 5 of the theoretical model described in Section 5.2.

More quantitatively, the simulation shows that for all sellers to be plausibly-informed requires a standard deviation in simulated effective disclosure costs of at least 0.27, i.e. $2c + b(\hat{q^b}) \sim N(0.44, 0.27)$. At face value, this spread in costs might not seem very large economically. As noted in Section 2, the direct out-of-pocket cost of an ECAD audit is around \$100-\$300. However, because of the re-scaling in the simulation, the direct ECAD report cost is not the average value of $2c+b(\hat{q^b})$. For exposition, let average $b(\hat{q^b}) = 0$, average $c = \$200$,

[23] More precisely, we sort the vector of cost draws such that the largest cost value is assigned to the seller with the largest gross benefit among the subset of sellers who did not disclose. We assign the second largest cost value to the seller with the second largest gross benefit among sellers who did not disclose, and so on. After all nondisclosing sellers have been assigned a cost value, we assign the next largest available cost value to the seller with the largest gross benefit who *did* disclose, repeating the above process.

and use the ATE estimated in Section 4 to quantify $b(q) = 42200q$ for energy efficiency $q \in [0, 1]$. Recognizing that this benefit measure is a relative one, we can recenter (but do not re-scale) the distribution such that average gross effective disclosure costs $2c = \$400$ and $b(q) = \$42200q - \$18168$. This implies that $2c + b(\hat{q^b}) \sim N(\$400, \$11394)$.

In principle, one could argue that a very large spread in disclosure costs is possible if there are substantial nonmonetary costs involved with the disclosure process. For instance, there might be privacy considerations or hassle costs that are not captured in a technician's \$200 fee. This explanation is challenging to support for ECAD audits. These homes are all sold by a realtor and sales involve open houses, visits by buyers, other seller and buyer inspections, and often contractor work (e.g. touch-up painting). The short visit by an energy efficiency technician is unlikely to induce such sizable nonmonetary costs as would be required to support such a large spread in disclosure costs as $N(\$400, \$11394)$ – or even $N(\$400, \$2110)$, which corresponds to $\sigma = 0.05$ in the simulation.

Instead, it is much more plausible that the simulation exercise indicates that a significant share of homeowners are uninformed about the energy efficiency of their homes, at least in a relative sense. As highlighted in the theoretical scenarios in Figure 5, if few sellers are informed, then a large spread in disclosure costs is not required to support a relatively flat disclosure slope, as seen in our empirical Figure 4.

5.4 Discussion

These findings suggest a new dimension to the voluntary disclosure literature. In contrast to the stark theoretical prediction of complete voluntary disclosure through unraveling, the empirical literature finds that "there are many markets in which voluntary disclosure is incomplete" such that "unraveling often does not occur in practice" (Dranove and Jin, 2010). Explanations for this lack of unraveling have largely focused on the size of the disclosure costs (e.g. Jovanovic, 1982; Lewis, 2011), the role of consumers (e.g. Milgrom and Roberts, 1986; Fishman and Hagerty, 2003; Li and Shi, 2017), and the influence of competition (e.g. Board, 2009; Guo and Zhao, 2009). We provide suggestive evidence for another explanation for a lack of unraveling in information disclosure markets: sellers might also not be fully informed about their own products' relative quality.

For quality disclosure models, Dranove and Jin's (2010) review article notes (p. 943) that two of the "often strong assumptions" for the unraveling prediction are that sellers have complete information about their own product quality and that the distribution of available quality is public information. Ours is the first study to our knowledge, however, to provide empirical support for this plausible explanation for a lack of unraveling of quality disclosure in markets with private information. Market failures driven by sellers' ignorance about the relative quality of their own goods or services most closely applies to disclosure in markets that are peer-to-peer, including sales of previously-owned assets such as residential real estate (as we study) and used automobiles, but also digital marketplaces such as eBay and airbnb (e.g. Lewis, 2011; Klein et al., 2016; Ma et al., 2017). However, a growing literature shows that even firms and other organizations often appear to be ignorant of many of their own qualities (e.g. Brehm and Hamilton, 1996; Anderson and Newell, 2004; Bloom et al., 2013). Thus, the general insight from our findings that mandating standardized testing and disclosure can increase economic welfare would apply to other circumstances with symmetrically incomplete information about quality, even for goods and services provided by large organizations such as manufacturing plants, hospitals, and schools, to note but a few example settings from the literature on disclosure (Bui and Mayer, 2003; Dranove et al., 2003; Andrabi et al., 2017).

6 Conclusions

In this paper, we analyze the Energy Conservation Audit and Disclosure program in Austin, Texas. We show that encouraging home sellers to provide potential buyers with certified energy audits increases price capitalization of energy efficiency and leads to quality-improving residential investments in energy-saving technologies. This is one of the few empirical settings wherein a government disclosure program is shown to have socially beneficial effects, particularly for product quality in the targeted market.

To understand why government intervention is effective in this context, we examine sellers' decisions to comply with ECAD. Despite substantially larger expected price premiums from disclosure for more efficient homes, we find that properties' relative energy efficiency only weakly predicts whether or not sellers choose to disclose this information. We rule out that this weak relationship is attributable to buyers or realtors dictating compliance by asking sellers to provide audits, rather than by home sellers making the decision.

Then, we examine two other plausible explanations for the flat relationship between homes' relative energy efficiency and sellers' propensities to disclose: either sellers are ignorant about their own homes' relative quality or there is substantial variation in effective ECAD compliance costs. Using a computational simulation, we find that, given our estimated capitalization effects, this flat relationship can be rationalized only by either extremely large heterogeneity in disclosure costs or, much more plausibly, by a significant share of homeowners being ignorant about the relative energy efficiency of their own homes.

Our findings have important policy implications. First, our work suggests that homeowners' ignorance about their own energy efficiency is a market failure that disclosure policies can help to ameliorate. Our capitalization findings indicate that home purchasers do understand and care about residential energy efficiency information when it is made available. Thus, mandatory disclosure may improve residential sorting and, as we find, increase overall quality by creating stronger incentives to invest in energy efficiency. Our findings also support that homeowners' ignorance about energy efficiency may be a contributor to the Energy Efficiency Gap in residential housing. Therefore, encouraging homeowners to get energy audits can increase participation in energy efficiency incentive programs.

More broadly, our study indicates that in markets with symmetrically incomplete information, mandating standardized testing and disclosure has potential to increase economic welfare by harnessing the positive externalities associated with information provision. Our framework is most directly analogous to peer-to-peer markets, such as residential real estate, used automobiles or digital marketplaces such as eBay. However, in light of evidence that even large firms are often ignorant of their own qualities, the general insights from our study should apply even in markets supplied by incorporated organizations.

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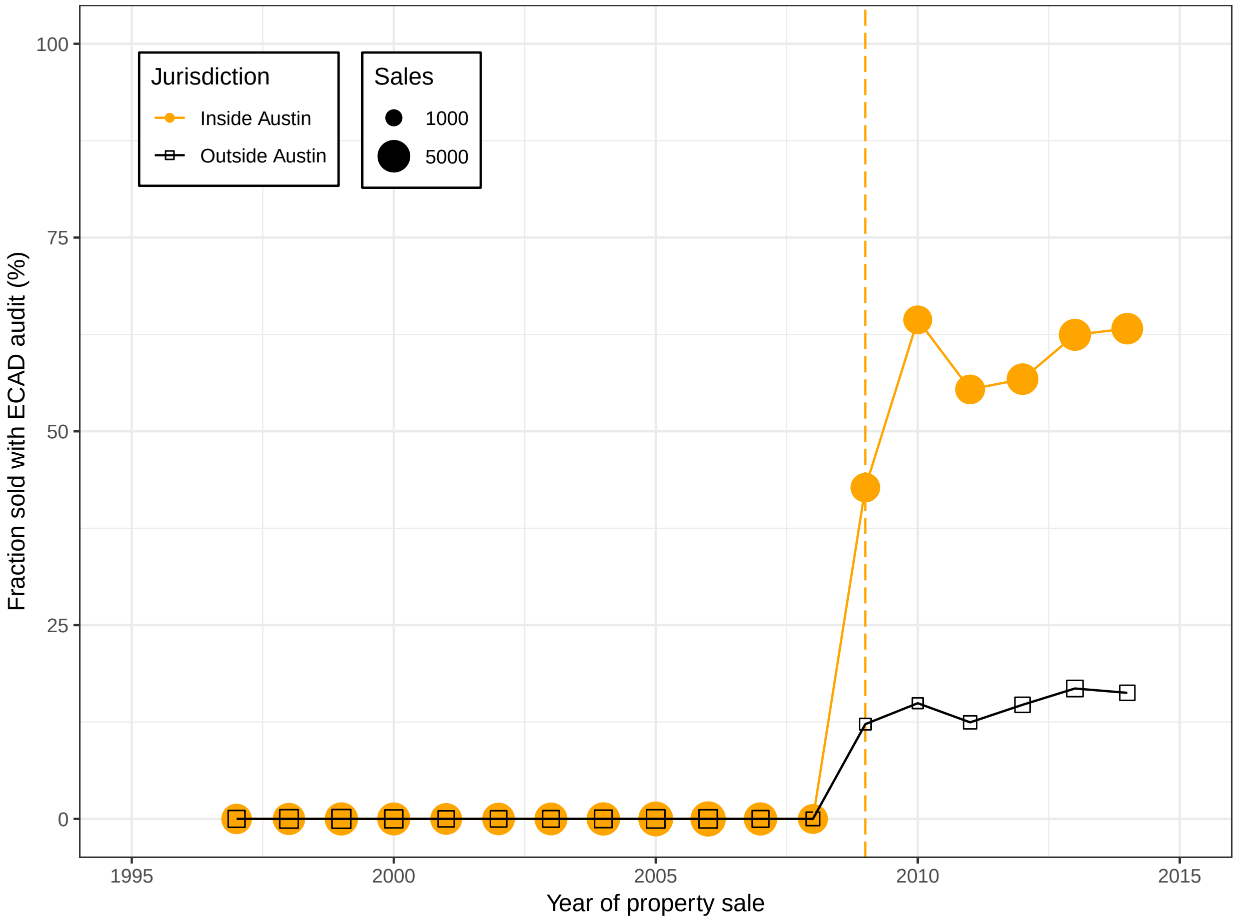
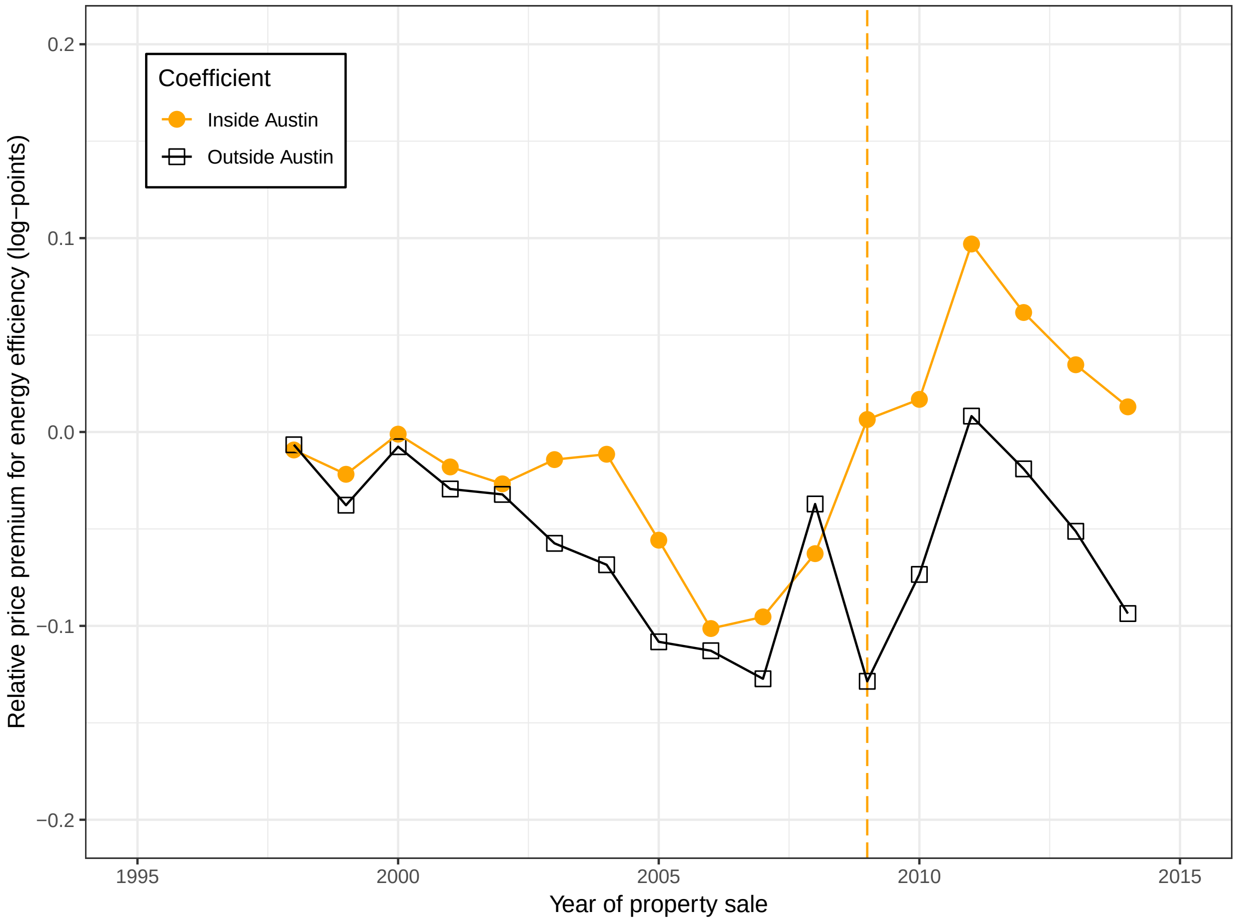
Figures and tables

Figure 1: Fraction of in-sample home sales each year that had conducted ECAD audit



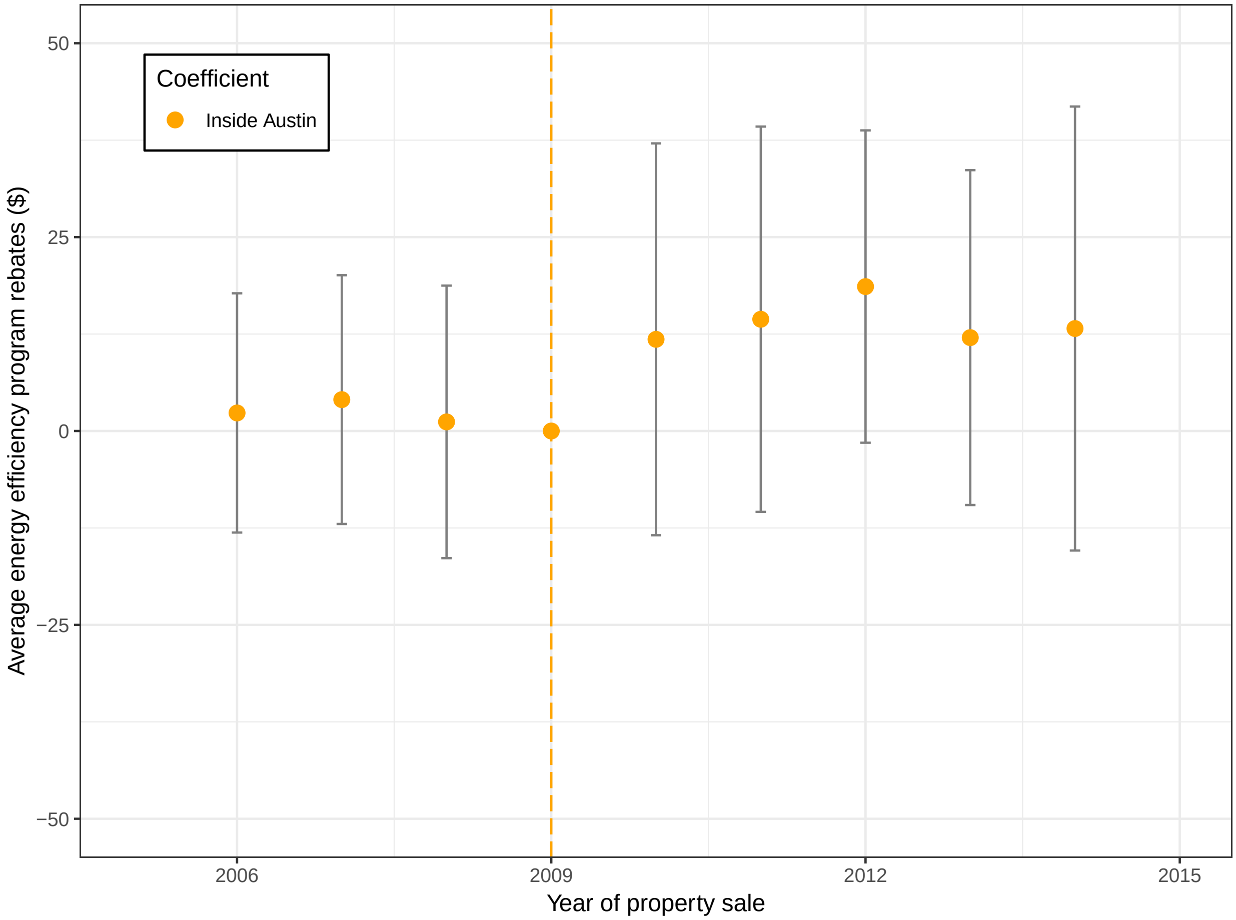
Notes: Figure 1 plots the annual fraction of in-sample home sales by jurisdiction – inside Austin versus outside of the Austin city limits – that had conducted an ECAD energy efficiency audit prior to the closing date of the sale. The dashed vertical line at 2009 indicates when the ECAD audit and disclosure policy went into effect for homes sold inside Austin only. The sample includes sales of single family residential properties constructed no later than 1998, for which all inside Austin sales were officially bound by the ECAD policy starting in June 2009.

Figure 2: Estimated annual relative energy efficiency capitalization by jurisdiction



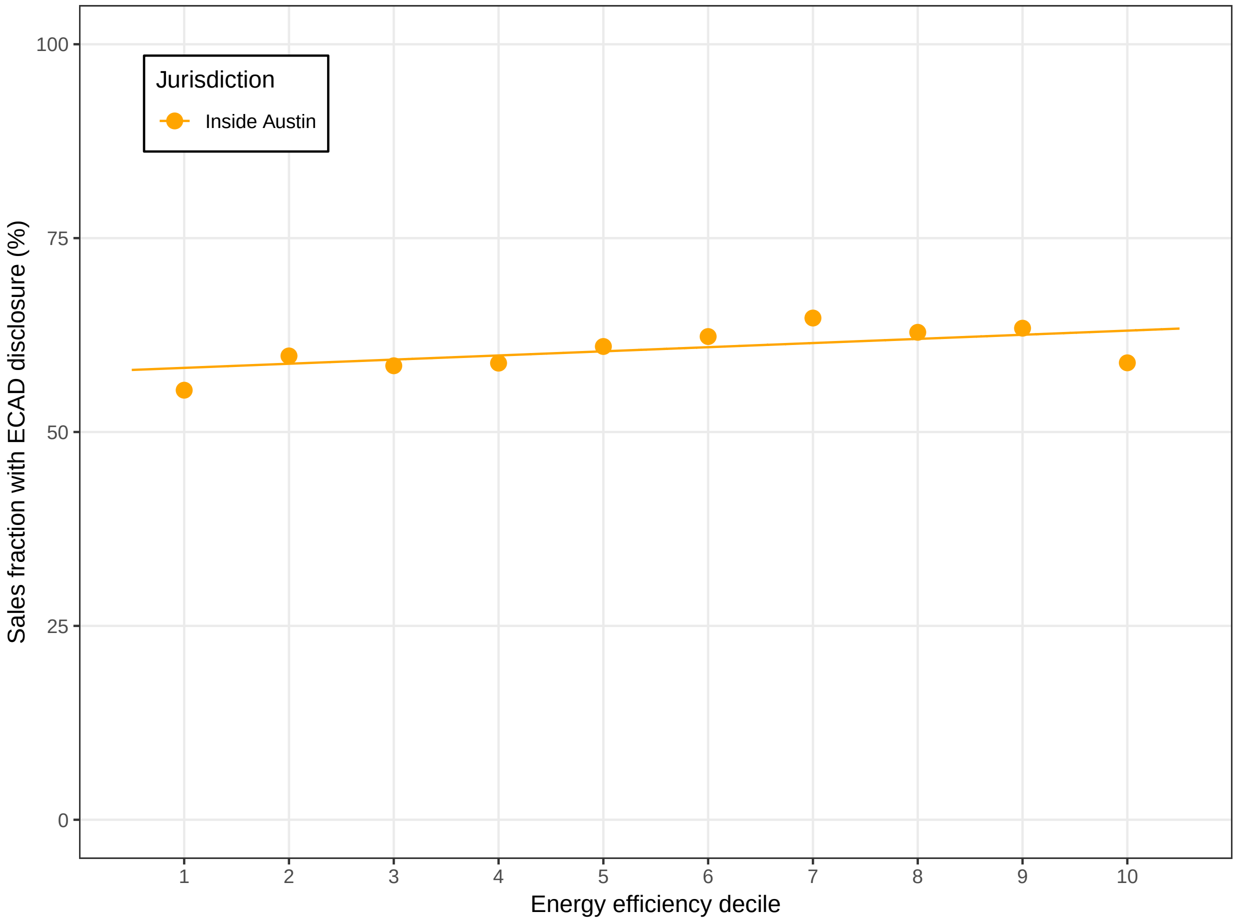
Notes: Figure 2 plots coefficients by jurisdiction – inside Austin versus outside of the Austin city limits – from regressing the natural log of homes' sale prices on the homes' energy efficiency, a term that ranges continuously from zero to one and indicates each home's fixed energy efficiency quantile. The underlying regression includes property fixed effects as well as jurisdiction-by-year fixed effects. The omitted base-year is 1997. The ECAD audit disclosure program for all sales inside Austin took effect in June 2009.

Figure 3: Inside Austin coefficients by year for pre-sale energy efficiency rebate dollars



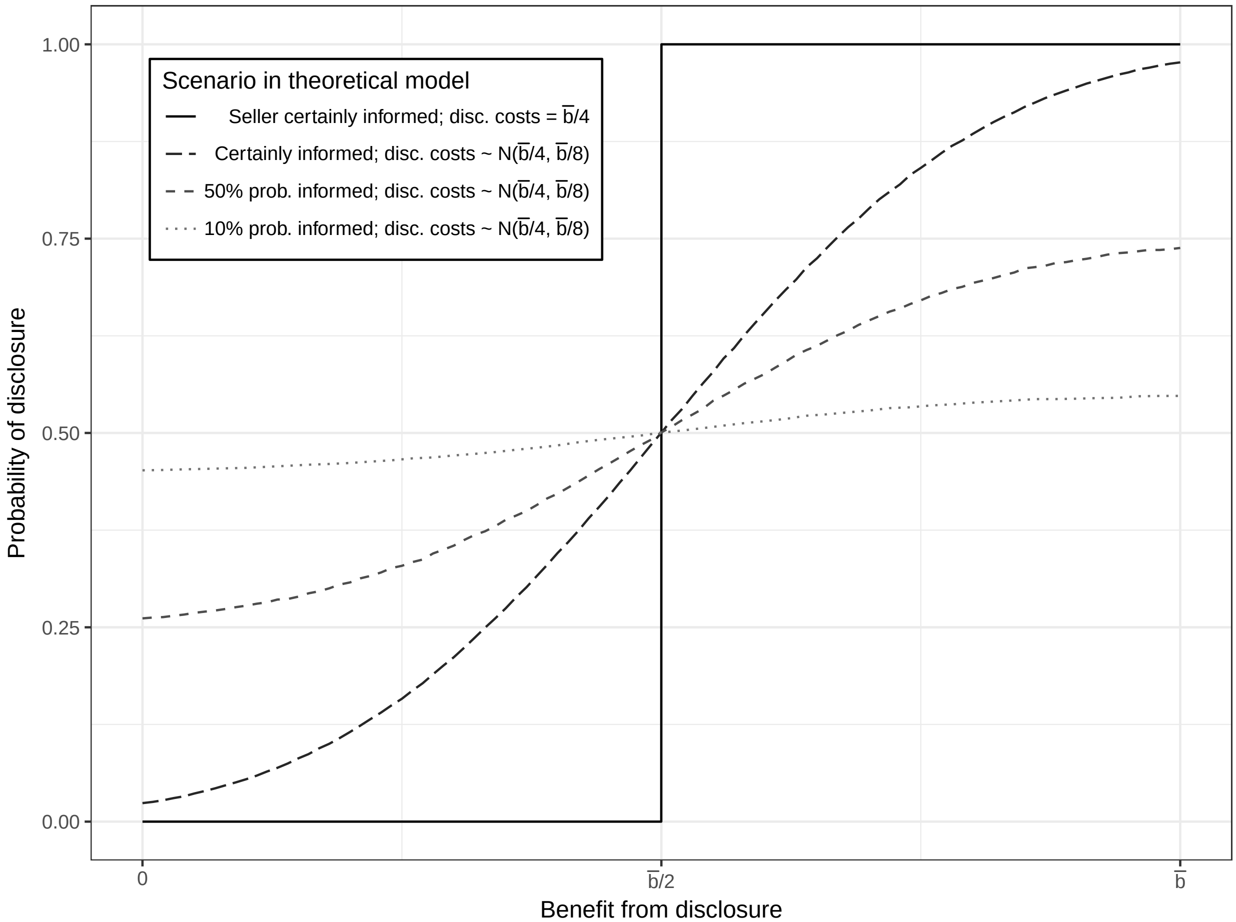
Notes: Figure 3 plots the annual inside Austin coefficients from regressing pre-sale energy efficiency rebate dollars on vintage-by-year fixed effects and annual jurisdiction indicators. The 2009 policy change year is the omitted base-year. The outcome variable is the total dollar value of rebates paid to the property's owners by Austin Energy within two years prior to the property sale for participation in any of the four energy efficiency rebate programs offered by the utility; 96 percent of these values are zero dollars.

Figure 4: ECAD audit disclosure propensity by energy efficiency of home sold



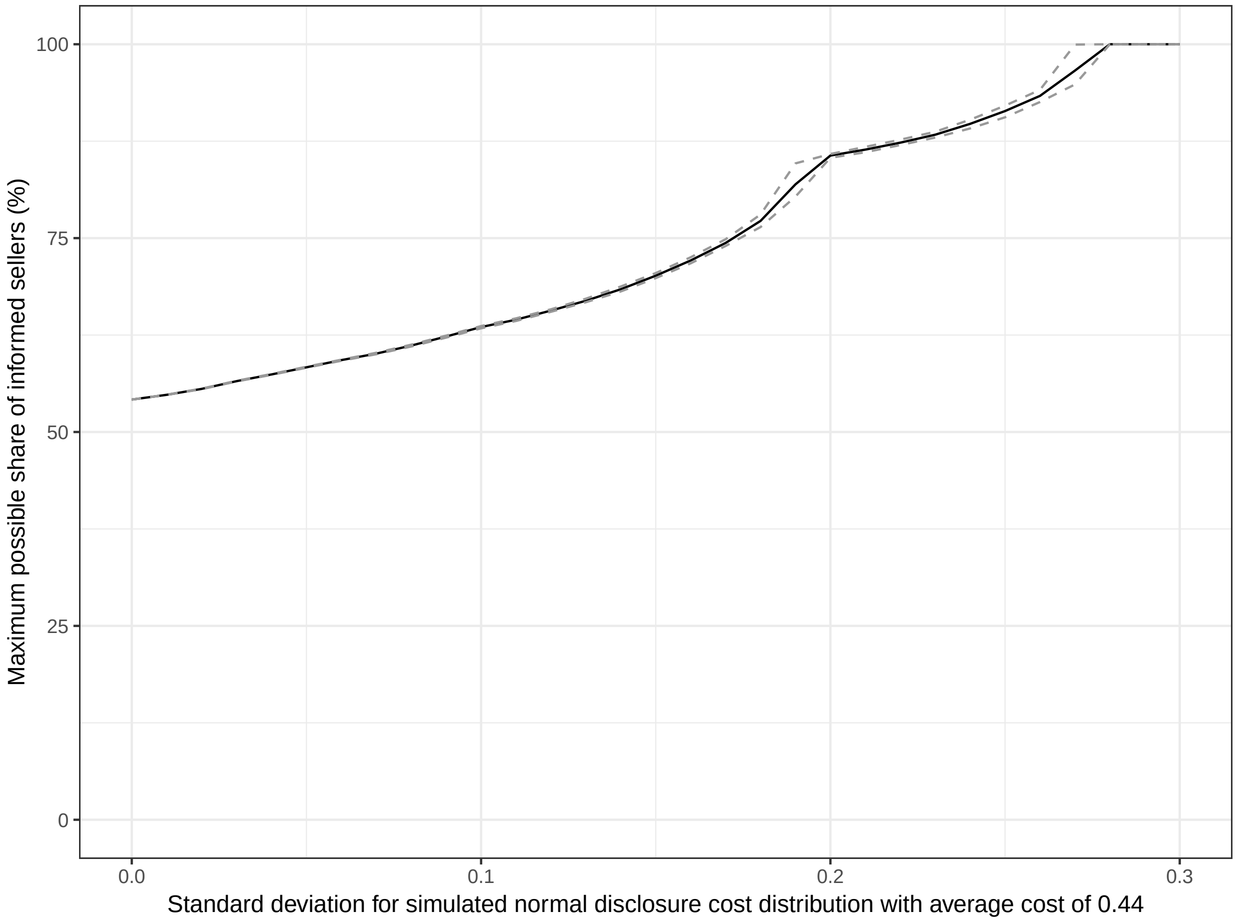
Notes: Figure 4 plots the share of in-sample homes sold inside Austin post-June 2009 that complied with the ECAD policy by obtaining and disclosing an energy efficiency audit, across the homes' energy efficiency quantiles. Each point depicts a local average compliance rate for the respective energy efficiency decile. The line shows the linear fit to the underlying microdata.

Figure 5: Illustration of various scenarios in theoretical model



Notes: Figure 5 depicts four scenarios in illustration of the theoretical model described in Section 5.2. The solid line illustrates the classic unraveling scenario, in which an informed seller will certainly disclose the quality of the product if and only if the expected benefit from disclosure is greater than the constant disclosure cost (inclusive of opportunity cost). The long-dashed line extends this scenario so that the seller's audit cost may vary, which visibly flattens the relationship between the magnitude of disclosure benefit and propensity for disclosure. The short-dashed line allows that the seller might be uniformed, with 50 percent probability, of the expected magnitude of the benefit from disclosure. Finally, the dotted line shows the case in which the seller is informed with only 10 percent probability.

Figure 6: Simulation results for plausible share of informed sellers by audit cost spread



Notes: Figure 6 plots results from simulations of the model for the maximum share of plausibly-informed sellers at various given spreads in audit compliance costs. To generalize our simulation results, rather than pinning them to specific quantitative values for estimated capitalization, we linearly re-scale the gross disclosure benefits to range from zero to one by using the energy efficiency proxy directly to characterize disclosure benefit. We set the mean disclosure cost fixed at a value such that the empirically-observed aggregate 60.86 percent of sellers would obtain an audit in the scenario that all sellers are informed and audit costs are constant across sellers. This average cost value is 0.44. We simulate values in increments of 0.01 between 0.0 and 0.3 for the standard deviation around this average cost, running 1000 repetitions of each standard deviation value. The median values from these repetitions are shown in the solid line in the graph; the 1st and 99th percentile values for each simulated standard deviation value are shown in the dashed grey lines. Within each simulation loop, we sort benefits and costs such that maximum possible share of sellers could plausibly be informed.

Table 1: Summary statistics and covariate comparisons of homes

	Full sample	Properties sold	
		Inside Austin	Outside Austin
Attribute	(1)	(2)	(3)
Within Austin city limits	0.835	1.000	0.000
# Times sold: 1997-2014	0.809	1.606	1.681
	(1.001)	(0.827)	(0.856)
# Times sold: post-June 2009	0.222	0.447	0.433
	(0.469)	(0.586)	(0.573)
Year built (vintage)	1973	1972	1987
	(17.52)	(17.33)	(9.45)
Square feet	1839	1780	2421
	(931.1)	(759.7)	(1143.4)
Energy efficiency	0.500	0.534	0.448
	(0.289)	(0.275)	(0.286)
Monthly electricity use (kWh)	1178	1085	1650
(2006-2014 only)	(710.0)	(580.1)	(1023.2)
Monthly kWh/SqFt	0.673	0.636	0.693
(2006-2014 only)	(0.293)	(0.249)	(0.270)
Sale price ($)		228,003	315,452
		(185,280)	(311,946)
Pre-sale EE rebates ($)		29.64	27.64
(2006-2014 only)		(187.8)	(176.2)
Properties	131,028	53,752	11,702

Notes: Table 1 presents means and standard deviations (in parentheses) for selected attributes of single family residential properties in the greater Austin area during 1997-2014. The "full sample" in Column (1) includes all homes constructed no later than 1998, regardless of whether or not the home was ever sold during our sample period. Columns (2) and (3) include, respectively, only the subset of these homes that are inside (outside) the city limits and were sold at least once during 1997-2014. The "Energy efficiency" term is a value ranging continuously from zero to one that indicates each home's fixed energy efficiency quantile. "Pre-sale EE rebates ($)" include the total dollar value of rebates paid to the property's owners by Austin Energy within two years prior to the property sale for participation in the utility's four energy efficiency programs. 96 percent of these values are zero dollars.

Table 2: Estimated price capitalization of energy efficiency due to ECAD policy

	Dependent variable: Natural log of sale price			
	(1)	(2)	(3)	(4)
Energy efficiency	0.046^{*}	-0.008	0.006	0.004
X I{Post June-2009}	(0.025)	(0.014)	(0.019)	(0.020)
Energy efficiency				
X I{Inside Austin}	0.186^{***}	0.096^{***}	0.073^{***}	0.080^{***}
X I{Post June-2009}	(0.023)	(0.012)	(0.022)	(0.024)
Sales sample	All	Repeat	Repeat	Repeat
Spatial fixed effects	Jurisdiction	Property	Property	Property
Time fixed effects	Vint-monthly	Vint-monthly	Juris-monthly	V-M and J-M
Number of homes	65,454	28,628	28,628	28,628
Observations	105,978	69,152	69,152	69,152

*p<0.1; **p<0.05; ***p<0.01 Each column presents estimates for the capitalization of energy efficiency into home sale prices. The "Energy efficiency" term is a value ranging continuously from zero to one that indicates each home's fixed energy efficiency quantile. The ECAD audit disclosure program for all sales inside Austin took effect in June 2009. Figure 2 shows annual coefficients for energy efficiency capitalization for each jurisdiction. Standard errors in parentheses are clustered by property.

Table 3: Energy efficiency program rebates: Difference in differences estimates

	Dependent variable: Total energy efficiency rebate dollars			
	Within 2-years pre-sale		Within 2-years post-sale	
	All programs	HPWES	All programs	HPWES
	(1)	(2)	(3)	(4)
I{Inside Austin}	13.149***	16.470***	11.144	21.246***
X I{Post June-2009}	(4.395)	(3.881)	(7.601)	(6.894)
Post June-2009 mean	42.39	26.82	94.49	68.39
Spatial fixed effects	Jurisdiction	Jurisdiction	Jurisdiction	Jurisdiction
Time fixed effects	Vint-monthly	Vint-monthly	Vint-monthly	Vint-monthly
Number of homes	65,454	65,454	65,454	65,454
Observations	105,978	105,978	105,978	105,978

*p<0.1; **p<0.05; ***p<0.01 Each column presents a difference in differences estimate for the total energy efficiency program rebate dollars paid to the property owner for participation in the indicated energy efficiency program(s) during the indicated time period. Columns (1) and (2) evaluate rebates paid for improvements made within the two year prior to the sale. Columns (3) and (4) evaluate rebates paid for improvements made within the two year following the sale. Figure 3 shows the coefficients by year corresponding to Column (1). Standard errors in parentheses are clustered by property.

Table 4: Maximum plausible share of informed sellers by simulated audit cost spread

Simulated audit costs	Share of plausibly informed sellers (%)		
Standard deviation	1st percentile	median	99th percentile
0	54.18	54.18	54.18
0.050	58.28	58.34	58.42
0.100	63.37	63.53	63.66
0.150	69.84	70.16	70.49
0.200	85.36	85.65	85.85
0.250	90.58	91.39	92.08
0.270	94.81	96.60	99.95
0.300	100.00	100.00	100.00

Table 4 presents results from simulations of the model for the maximum share of plausibly-informed sellers at various given spreads in audit compliance costs. To generalize our simulation results, rather than pinning them to specific quantitative values for estimated capitalization, we linearly re-scale the gross disclosure benefits to range from zero to one by using the energy efficiency proxy directly to characterize disclosure benefit. We set the mean disclosure cost fixed at a value such that the empirically-observed aggregate 60.86 percent of sellers would obtain an audit in the scenario that all sellers are informed and audit costs are constant across sellers. This average cost value is 0.44. We simulate values in increments of 0.01 between 0.0 and 0.3 for the standard deviation around this average cost, running 1000 repetitions of each standard deviation value. The table shows the median values from these repetitions, along with the 1st and 99th percentile values for each simulated standard deviation value. Within each simulation loop, we sort benefits and costs such that maximum possible share of sellers could plausibly be informed. The 1st, median, and 99th percentile values from these repetitions are shown more generally across a broader set of simulated values in Figure 6.

A Appendix tables and figures

Table A1: Correlations between our energy efficiency proxy and ECAD audit measurements

	Dependent variable: Various components of ECAD audit reports				
	Double-pane windows (1)	Programmable thermostat (2)	Electric heating (3)	Attic R-value (4)	Duct leak percentage (5)
EE proxy	0.100***	0.068***	−0.144***	2.197***	−1.631***
	(0.016)	(0.016)	(0.009)	(0.289)	(0.413)
Mean	0.504	0.454	0.082	21.83	19.38
Std. Dev.	0.500	0.498	0.274	9.028	11.64
Observations	13,318	13,146	13,139	12,698	10,444

*p<0.1; **p<0.05; ***p<0.01 Each column presents linear estimates from regressing a measure from the actual ECAD audit report (in column titles) on our proxy for homes' energy efficiency. The sample used here is all homes from our analysis sample that conducted an ECAD energy efficiency audit. The "EE proxy" term is a value that ranges continuously from zero to one that indicates each home's fixed energy efficiency quantile, defined based on the pre-policy within-vintage electricity use per square foot for the home. "Double-pane windows" is a binary indicator for whether the home has double-pane and/or low-emissivity windows. "Programmable thermostat" is a binary indicator for whether the home has a programmable thermostat. "Electric heating" is a binary indicator for whether the home has electric heating (versus gas). "Attic R-value" is the measured R-value of insulation in the home's attic. "Duct leak percentage" is the measured percent air flow leakage from the home's air ducts. The differing number of observations across columns is due to heterogeneity in the completeness of official ECAD audit reports. For properties that conducted more than one audit, we use the first audit report for each property.

Table A2: Sales Probability: Difference in differences identification tests

	Dependent variable: Indicator for whether the home is sold within the year				
	Full sample			Homes with energy efficiency	
				Below-median	Above-median
	(1)	(2)	(3)	(4)	(5)
I{Inside Austin}	−0.0090***	−0.0040***	0.0020***	0.0002	0.0022**
	(0.0005)	(0.0009)	(0.0006)	(0.0007)	(0.0009)
I{Inside Austin} X I{Post 2009}	0.0062***	0.0013	−0.0007	0.0009	−0.0016
	(0.0007)	(0.0011)	(0.0008)	(0.0010)	(0.0012)
Years included	1997-2014	2006-2014	1997-2014	1997-2014	1997-2014
Time fixed effects	Year	Year	Vintage-year	Vintage-year	Vintage-year
Sample mean	0.044	0.041	0.044	0.042	0.047
Number of homes	131,028	131,028	131,028	65,579	65,449
Observations	2,355,413	1,179,252	2,355,413	1,178,864	1,176,549

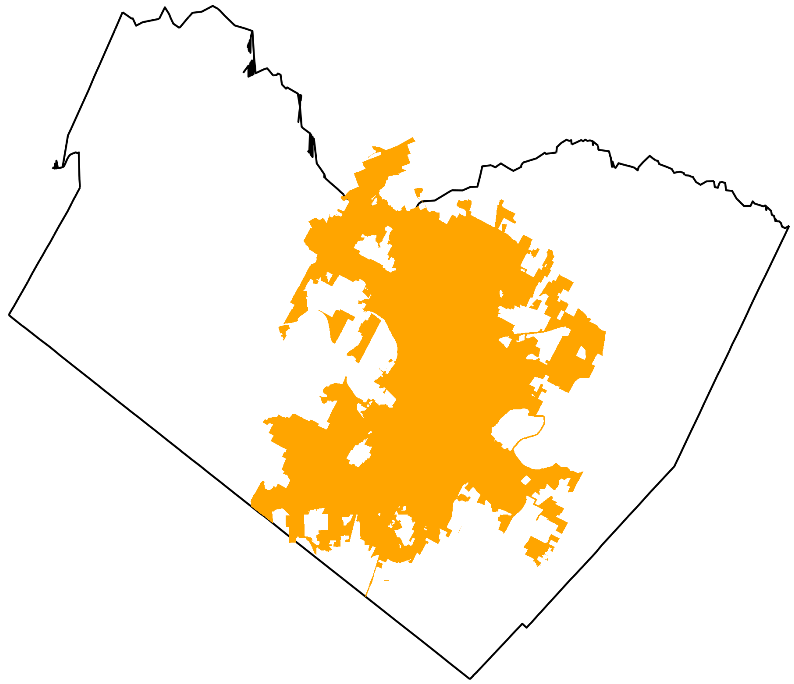
*p<0.1; **p<0.05; ***p<0.01 All columns present difference in differences estimates testing whether the probability that a home is sold varies asymmetrically between Inside Austin and Outside Austin pre- versus post-2009, when the ECAD audit and disclosure policy went into effect. The annual fraction of in-sample homes sold by jurisdiction is shown in Figure A2. Standard errors in parentheses are clustered by property.

Table A3: ECAD audit disclosure: Difference in differences estimates

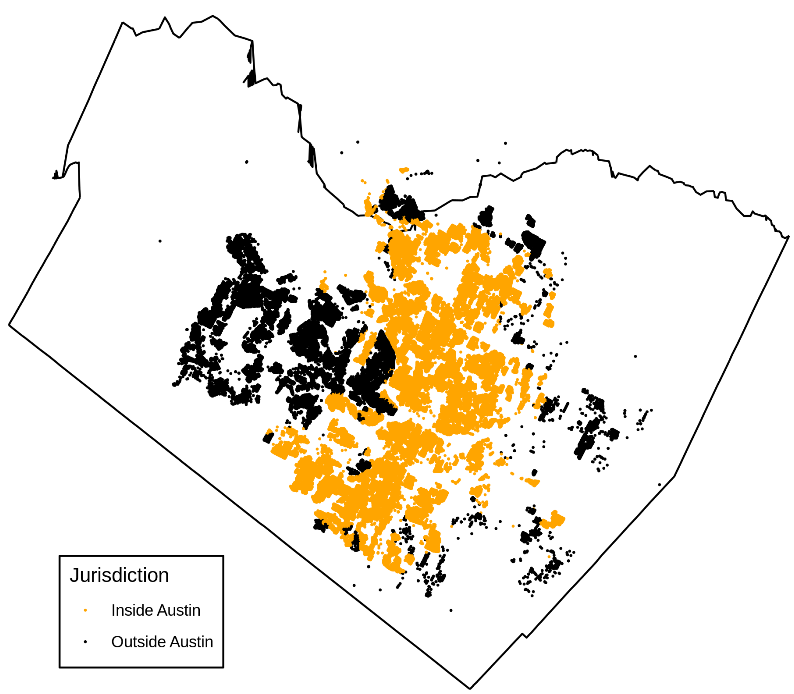
	Dependent variable: Indicator for ECAD audit			
	(1)	(2)	(3)	(4)
I{Inside Austin}	0.453***	0.459***	0.453***	0.450***
X I{Post June-2009}	(0.006)	(0.008)	(0.011)	(0.015)
Sales sample	All	All	Repeat	Repeat
Spatial fixed effects	Jurisdiction	Jurisdiction	Property	Property
Time fixed effects	Monthly	Vint-monthly	Monthly	Vint-monthly
Number of homes	65,454	65,454	28,628	28,628
Observations	105,978	105,978	69,152	69,152

*p<0.1; **p<0.05; ***p<0.01 Each column presents a difference in differences estimate for the probability that a home that is sold has conducted an ECAD audit. The ECAD audit disclosure program for all sales inside Austin took effect in June 2009. Columns (1) and (2) include all properties that were sold at least once during 1997-2014. Columns (3) and (4) include only properties that were sold more than once during 1997-2014. Figure 1 shows annual average ECAD audit rates by jurisdiction for this full sample. Standard errors in parentheses are clustered by property.

Figure A1: Map of the Austin, Texas study area



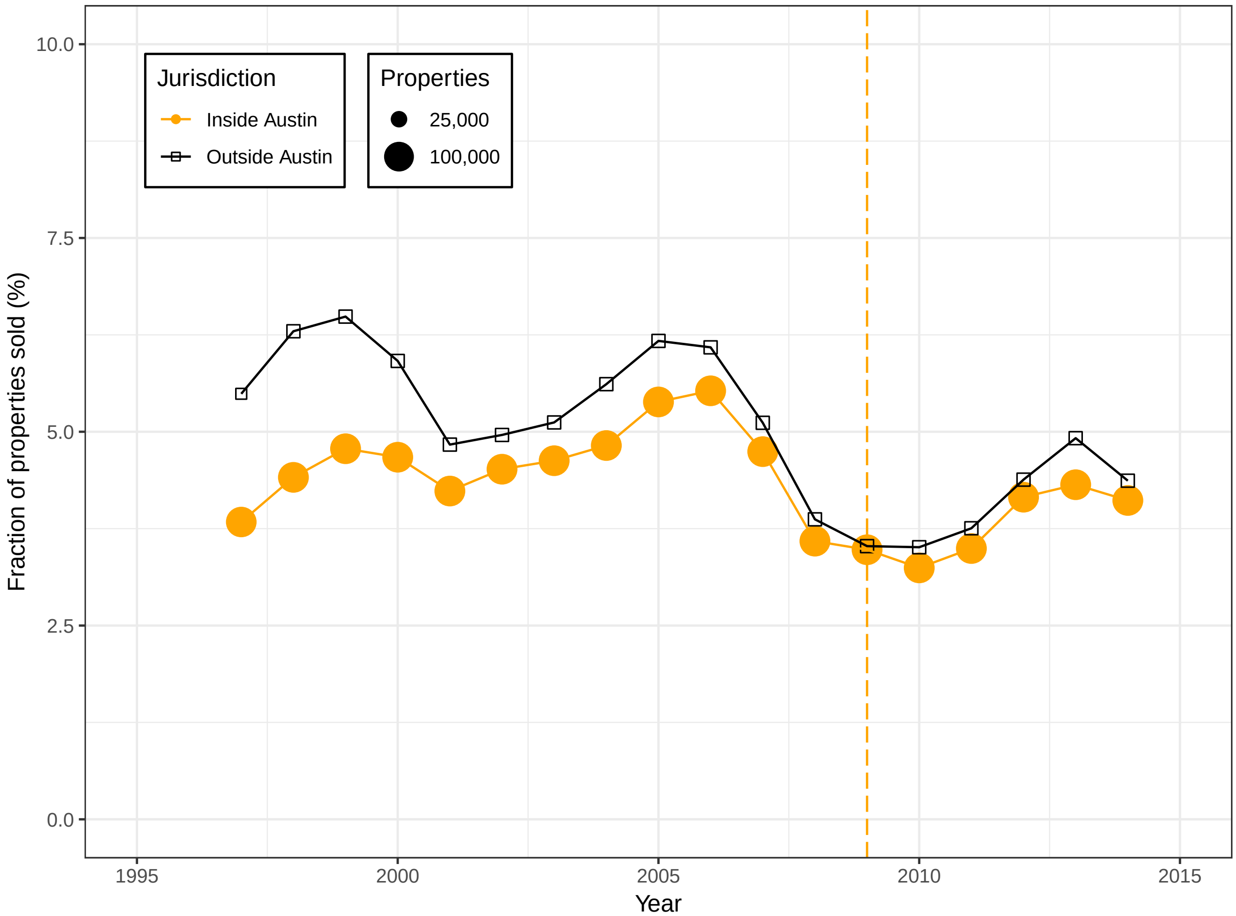
(a) Austin city limits (orange) and Travis county border (black)



(b) Properties included in empirical sample by jurisdictional designation

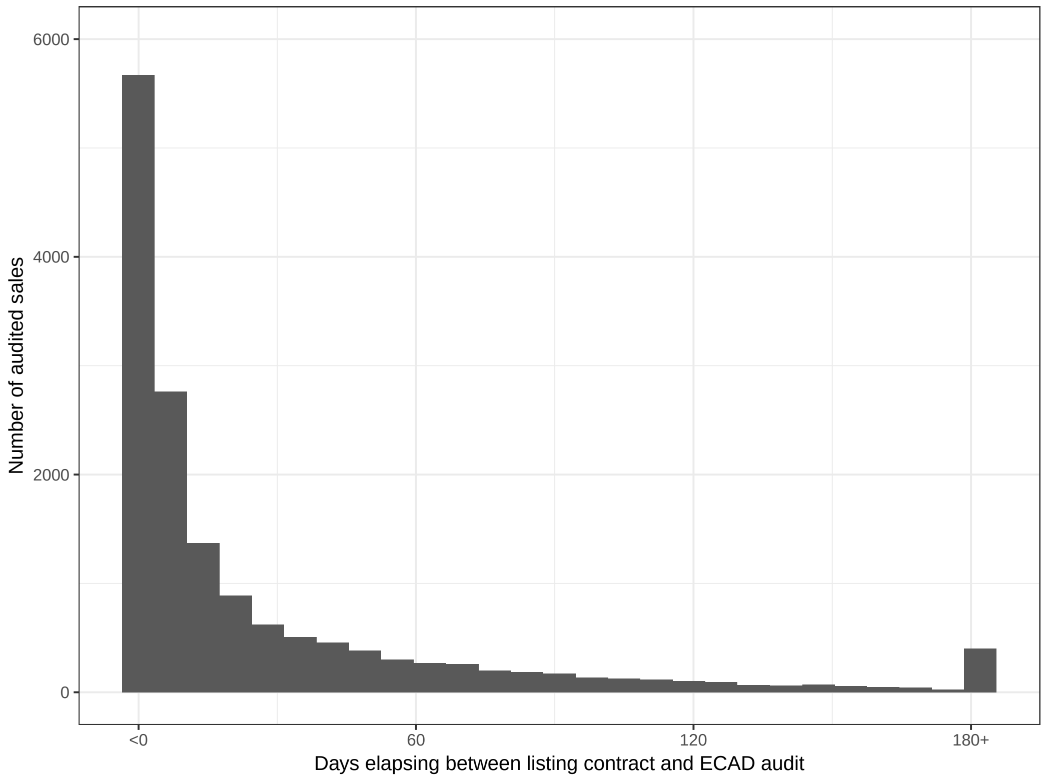
Notes: Appendix Figure A1 provides a map of our empirical study area. Panel (a) presents the jurisdictional coverage of Austin city limits, which excludes several "holes" as shown. Panel (b) plots points for each of the homes in our analysis sample, indicating by color each property's respective jurisdiction.

Figure A2: Fraction of in-sample homes sold each year inside Austin and outside city limits

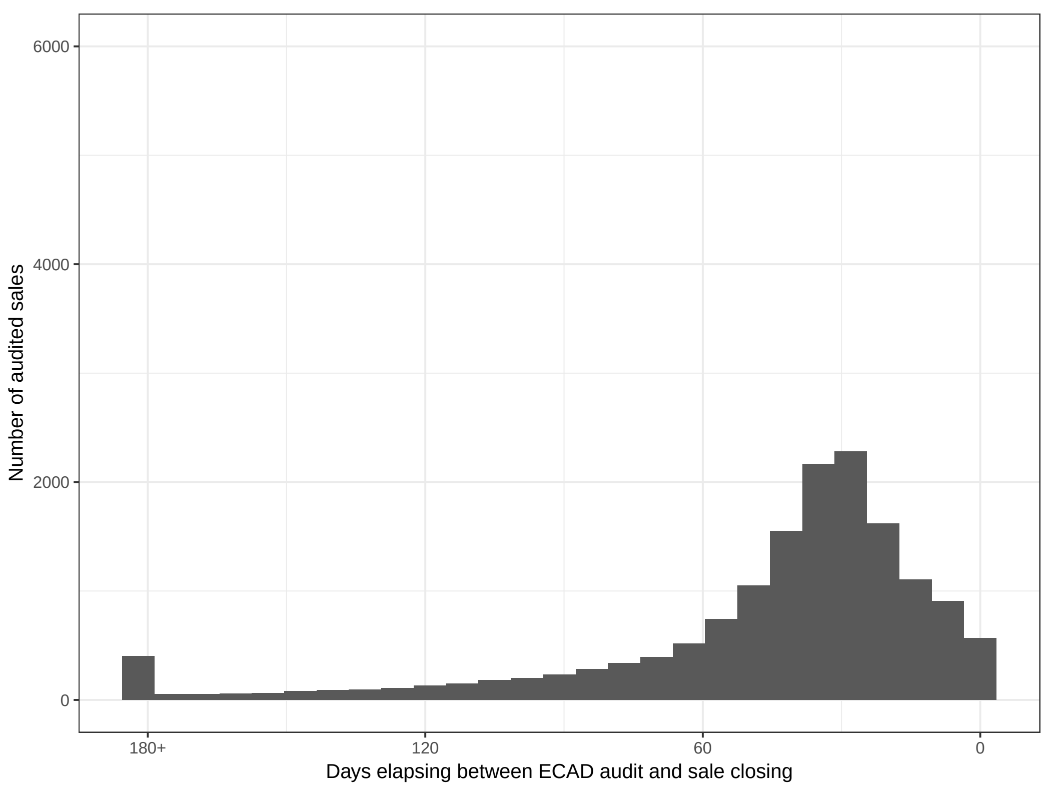


Notes: Figure A2 plots the annual fraction of in-sample homes sold by jurisdiction, inside Austin versus outside of the Austin city limits. The dashed vertical line at 2009 indicates when the ECAD residential energy efficiency audit and disclosure policy went into effect for homes aged 10 years or older sold inside Austin only. The sample includes single family residential properties constructed no later than 1998.

Figure A3: Timing of ECAD audits with respect to listing and sale contracts



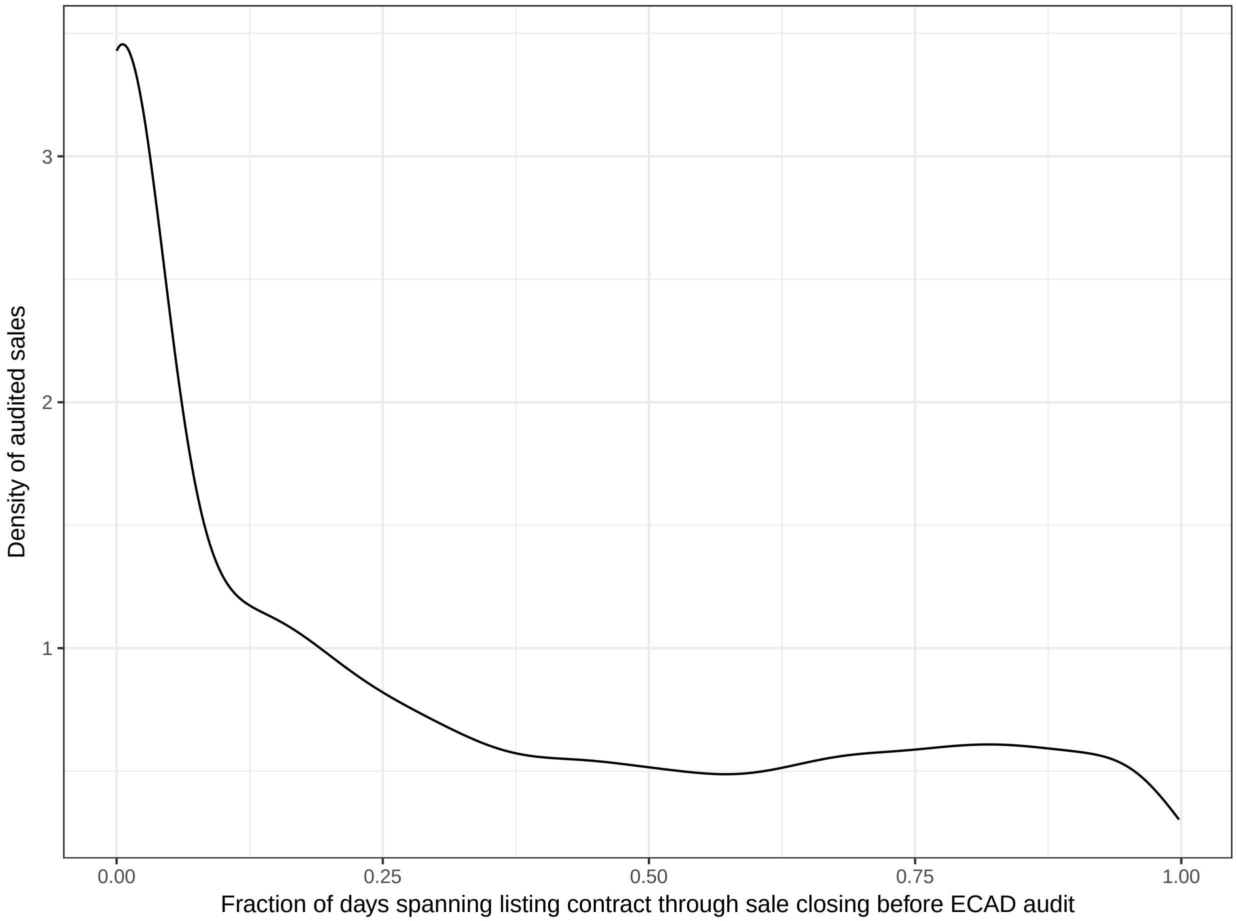
(a) Duration from listing contract to ECAD audit



(b) Duration from ECAD audit to sale closing

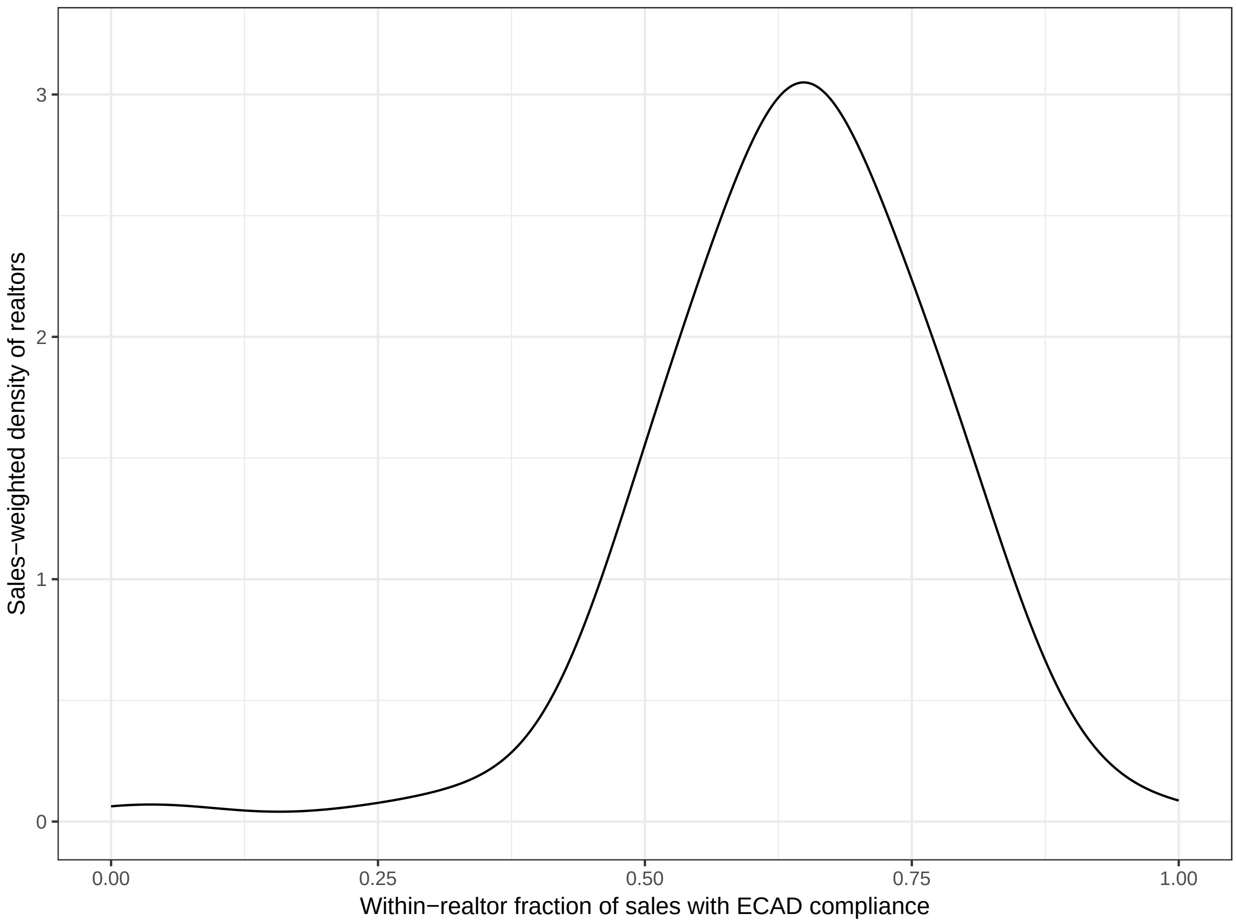
Notes: The date of the listing contract is when the seller formalizes an agreement with the seller's realtor to market the property, which typically occurs before any marketing activities. The date of the sale closing is the official closing date for the property sale transaction.

Figure A4: Timing of ECAD audits with respect to listing and sale contracts



Notes: Appendix Figure A4 shows the density of the fraction of days spanning between the listing contract and the ECAD audit with respect to the total number of days the property was marketed (spanning from the listing contract through the sale closing contract). For example, if a property was audited seven days after the listing contract was signed and was sold 28 days after the listing contract was signed, the value in the figure would be 0.25 for this sale. The date of the listing contract is when the seller formalizes an agreement with the seller's realtor to market the property, which typically occurs before any marketing activities. The date of the sale closing is the official closing date for the property sale transaction.

Figure A5: Density of ECAD compliance rates across realtors



Notes: Appendix Figure A5 shows the sales-weighted density of ECAD compliance for a random subset of realtors who handled home sales within-Austin after the ECAD policy was effective. To create this graph, we first took a one percent sample of post-ECAD sales within Austin City limits and matched each transaction to the seller's realtor using Zillow.com. Then, we determined the full set of properties sold inside Austin post-ECAD by each of these realtors, which we use to compute the compliance density depicted in the figure.

SINGLE FAMILY

ECAD Energy Audit Results

For Residence: Audit Date:

Thank you for complying with the City of Austin's ECAD Ordinance, which requires homeowners to provide these energy audit results to buyers.

SAVE THIS FORM! This ECAD audit is valid for 10 years after the audit date.

This audit helps you identify energy efficiency improvements that could lower your monthly energy costs and make your home more comfortable. Austin Energy's Home Performance with ENERGY STAR® program offers rebates and low-interest loans that make these improvements more affordable. Before you begin making any home energy efficiency improvements, be sure to get the latest program details from austinenergy.com or by calling 512-482-5346.

ENERGY AUDIT SUMMARY

	Action Recommended?	Potential Annual Savings*:
A. Windows and Shading		
B. Attic Insulation		
C. Air Infiltration and Duct Sealing		
D. Heating and Cooling System Efficiency (HVAC)		
	Total Annual Savings:	

HOME IMPROVEMENT RECOMMENDATIONS:

Austin Energy recommends the following actions based on the energy audit performed by

DISCLOSURES: Figures are based on an estimate from the average single-family house in Austin (1800 - 2000 sq. ft.) that has made improvements through an efficiency program by Austin Energy or Texas Gas Service. Weather, equipment installation and electric usage will all effect actual savings. There is no guarantee or warranty, either expressed or implied, as to the actual effectiveness, cost or utility savings, if you choose to implement these recommendations.

The Energy Conservation Audit and Disclosure is not required to be included in the sales contract nor the Seller's Disclosure form (Texas Real Estate Commission), but instead is a stand-alone requirement of the City of Austin.

In support of the City of Austin's
Energy Conservation Audit and Disclosure Ordinance
Austin City Code Chapter 6-7, June 2009

SINGLE FAMILY

Energy Audit Data

DATA SUMMARY

Submission Date:

PROPERTY

Austin Energy Electric Meter Number:
Owner Name:
Street Address:
City, State, Zip Code:

Tax Assessor's Property ID:
Year Built:
Estimated Square Footage:

AUDITOR

Auditor:
Company Name:

Phone Number:
Property Audit Date:

WINDOWS & SHADING

Type(s) of Window(s):
Type(s) of Existing Solar Shading:

ATTIC INSULATION

Attic Insulation Type:
Open Chases(s):

Average R-Value:

HEATING & COOLING AIR DUCT SYSTEM

HVAC SYSTEM:
Condenser: Manufacturing Date: Estimated EER:
Furnace/AH: Manufacturing Date: Estimated AFUE:
HVAC Duct Air Leakage: % Leakage:
Duct System Type(s)
Enrolled in the Austin Energy Power Partner Thermostat Program:

ADDITIONAL SYSTEM:
Condenser: Manufacturing Date: Estimated EER:
Furnace/AH: Manufacturing Date: Estimated AFUE:
HVAC Duct Air Leakage: % Leakage:
Duct System Type(s):
Enrolled in the Austin Energy Power Partner Thermostat Program:

AIR INFILTRATION/WEATHERIZATION

Exterior doors: weather-stripped?
Plumbing penetrations: sealed?

Attic access: weather-stripped?

ADDITIONAL AUDIT INFORMATION

Domestic Water Heater Type(s):
Type(s) of Toilet(s):

PROPERTY IDENTIFICATION

Outdoor Temperature F

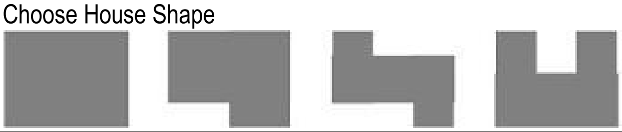
County | Property ID | Property Type | Building Count
Meter Number | Second Meter | Gas Type
Street # | Direction | Street Name | Suffix | Unit
City | State | Zip | Occupied By | Count of Occupants
Year Built | Foundation | Estimated Sq Footage | Average Duct Leakage
Levels | Bedrms | Baths | Fireplaces | Average Wall Height | Average Attic R-Value

WINDOWS & SHADING

Types of Windows | Single Pane | Double Pane | Low-e | Skylights | Other
Types of Shading | Solar Screens | Solar Film | Awnings | Skylights Cover | Other

Windows	S	SW	W	NW	N	NE	E	SE	Skylight
Needs Shade (sq ft)									

Choose House Shape



NW	N	NE
W	Bldg Front Orientation	E
SW	S	SE

APPLIANCES & WATER HEATER

APPLIANCES (Remaining in Home) | ’92 or older | ’93 or newer

- Refrigerators
- Freezers
- Clothes Washers
- Clothes Dryers
- Dish Washers
- Range/Stove/Ovens
- Inefficient Toilets (> 1.6 gal)
- Efficient Toilets (<= 1.6 gal)

Pool Pumps | Speed
Pool Pump Timers

Water Heaters
- WH1 | Fuel 1
- WH2 | Fuel 2

Water Heater Timers

MISC Lighting | Solar PV | Electric Vehicle Charger | Natural Gas Generator
Sprinklers | Year Installed | Rainwater Collector | Water Saving Devices

ATTIC INSULATION & AIR INFILTRATION

Roof Type | Roof Materials | Roof Color | Total Attic R-Value

Attic Insulation | Insulation Type | Secondary Insulation Type
Square Feet | Inches Deep | R-Value

Vaulted Ceiling Insulation | Insulation Type | Secondary Insulation Type
Square Feet | Inches Deep | R-Value

Cathedral Ceiling Insulation | Insulation Type
Square Feet | Inches Deep | R-Value

Attic/Knee Wall Insulation Status

Radiant Barrier | Chases
Plumbing Penetrations Sealed | Furnace & WH Closet Appropriately Sealed
Exterior Doors | # Doors Weather-stripped | Whole House Fan
Conditioned Stair Boxes/Hatches | # Insulated | # Weather-stripped

HEATING & COOLING (1)	Zone Description			Est. Sq. Ft. (Zone)	
COOLING Type				Thermostat	
Condenser Mfg Date		Est. EER	Est. Condenser BTUs		
Tonnage	From Mfg Spec	OR	Est. from Sq. Ft.	Sq. Ft. per Ton	
HEATING Type		Fuel Type	Location	Air Handler	
Furnace Mfg Date		Est. BTUs	Est. BTUs (other)	AFUE	
DUCT SYSTEM *(Check all that apply)*	NONE	Mylar Flex	Grey Flex	Duct Board	Sheet Metal
Duct Locations	Conditioned Space	Crawl Spaces	Furrdowns	Attic	
Duct Condition		R-Value			
	Return Air Sq. In.	Grille Type	Return Plenum Seal		
LEAKAGE	Target CFM		Current Est. CFM		
	Did Not Reach Pressure	Measured Pressure Test Leakage CFM		% Leakage	
	Supply Air Reading F	Return Air Reading F		Delta T	

HEATING & COOLING (2)	Zone Description			Est. Sq. Ft. (Zone)	
COOLING Type				Thermostat	
Condenser Mfg Date		Est. EER	Est. Condenser BTUs		
Tonnage	From Mfg Spec	OR	Est. from Sq. Ft.	Sq. Ft. per Ton	
HEATING Type		Fuel Type	Location	Air Handler	
Furnace Mfg Date		Est. BTUs	Est. BTUs (other)	AFUE	
DUCT SYSTEM *(Check all that apply)*	NONE	Mylar Flex	Grey Flex	Duct Board	Sheet Metal
Duct Locations	Conditioned Space	Crawl Spaces	Furrdowns	Attic	
Duct Condition		R-Value			
	Return Air Sq. In.	Grille Type	Return Plenum Seal		
LEAKAGE	Target CFM		Current Est. CFM		
	Did Not Reach Pressure	Measured Pressure Test Leakage CFM		% Leakage	
	Supply Air Reading F	Return Air Reading F		Delta T	

HEATING & COOLING (3)	Zone Description			Est. Sq. Ft. (Zone)	
COOLING Type				Thermostat	
Condenser Mfg Date		Est. EER	Est. Condenser BTUs		
Tonnage	From Mfg Spec	OR	Est. from Sq. Ft.	Sq. Ft. per Ton	
HEATING Type		Fuel Type	Location	Air Handler	
Furnace Mfg Date		Est. BTUs	Est. BTUs (other)	AFUE	
DUCT SYSTEM *(Check all that apply)*	NONE	Mylar Flex	Grey Flex	Duct Board	Sheet Metal
Duct Locations	Conditioned Space	Crawl Spaces	Furrdowns	Attic	
Duct Condition		R-Value			
	Return Air Sq. In.	Grille Type	Return Plenum Seal		
LEAKAGE	Target CFM		Current Est. CFM		
	Did Not Reach Pressure	Measured Pressure Test Leakage CFM		% Leakage	
	Supply Air Reading F	Return Air Reading F		Delta T	

HEATING & COOLING (4) Zone Description Est. Sq. Ft. (Zone)

COOLING Type Thermostat
Condenser Mfg Date Est. EER Est. Condenser BTUs
Tonnage From Mfg Spec OR Est. from Sq. Ft. Sq. Ft. per Ton

HEATING Type Fuel Type Location Air Handler
Furnace Mfg Date Est. BTUs Est. BTUs (other) AFUE

DUCT SYSTEM *(Check all that apply)* NONE Mylar Flex Grey Flex Duct Board Sheet Metal
Duct Locations Conditioned Space Crawl Spaces Furrdowns Attic
Duct Condition R-Value
Return Air Sq. In. Grille Type Return Plenum Seal

LEAKAGE Target CFM Current Est. CFM
Did Not Reach Pressure Measured Pressure Test Leakage CFM % Leakage
Supply Air Reading F Return Air Reading F Delta T

HEATING & COOLING (5) Zone Description Est. Sq. Ft. (Zone)

COOLING Type Thermostat
Condenser Mfg Date Est. EER Est. Condenser BTUs
Tonnage From Mfg Spec OR Est. from Sq. Ft. Sq. Ft. per Ton

HEATING Type Fuel Type Location Air Handler
Furnace Mfg Date Est. BTUs Est. BTUs (other) AFUE

DUCT SYSTEM *(Check all that apply)* NONE Mylar Flex Grey Flex Duct Board Sheet Metal
Duct Locations Conditioned Space Crawl Spaces Furrdowns Attic
Duct Condition R-Value
Return Air Sq. In. Grille Type Return Plenum Seal

LEAKAGE Target CFM Current Est. CFM
Did Not Reach Pressure Measured Pressure Test Leakage CFM % Leakage
Supply Air Reading F Return Air Reading F Delta T

NOTES & INSTRUCTIONS