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Mandatory Energy Efficiency Disclosure in Housing Markets

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Abstract

Mandatory disclosure policies are implemented broadly 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 premiums for energy efficiency and encourages energy-saving investments. We additionally present evidence highlighting the market failure – incomplete information by both buyers *and sellers* – that prevents widespread voluntary disclosure of energy efficiency in housing transactions. Our findings support that disclosure policies can improve market outcomes in settings with symmetrically incomplete information.

JEL: Q48, K32, R31, D83, L15

Keywords: disclosure policy evaluation, energy efficiency, real estate markets

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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 often 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. However, in practice, the literature finds minimal evidence supporting the efficacy of disclosure programs at improving market outcomes (see reviews in 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. These investments reduce the level of energy required for services such as space heating and cooling, water heating, or clothes washing. 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, enabling energy efficiency to deliver more than forty percent of targeted emissions reductions to mitigate global climate change (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 policies 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 mandatory

[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." Austin Energy's website states that the ordinance "promotes energy efficiency by identifying potential energy savings in homes, businesses and multifamily properties."

audit and disclosure programs 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 (Davis et al., 2014; Levinson, 2016; Allcott and Greenstone, 2017; Fowlie et al., 2018; Davis et al., 2019). In this paper, we investigate multiple potential sources of information-based market failures for investing in residential energy efficiency.

Our study evaluates the Energy Conservation Audit and Disclosure (ECAD) ordinance in Austin, Texas. As with similar disclosure policies, this regulation stipulates that home sellers must provide prospective buyers a standardized report of a certified technical energy efficiency audit of the property's building shell and appliances. Our empirical setting and administrative data enable us to make two unique contributions. First, our study is one of the first to our knowledge to find credibly-identified evidence of product quality improvements resulting from *any* disclosure policy. Second, we identify a specific market failure that contributes to under-provision of information and under-investment in energy efficiency, such that an audit and disclosure program may improve market outcomes: we find substantial evidence that there is *symmetric* incomplete information. Buyers are uninformed about quality, as in many other settings. But we show evidence that home sellers are also not fully informed about energy efficiency, which supports that private incentives to voluntarily disclose quality are inadequate to overcome information-related market failures.

It is challenging for researchers to empirically identify the effect of information provision on market prices and product quality. Product attributes that are unobservable to consumers in the absence of public disclosure are often unobservable to researchers as well. Without a sans-policy measure of these attributes, it is difficult to to isolate the effects of information itself separately from endogenous changes in quality that might result from a requirement to disclose said information (e.g. energy efficiency investments in anticipation of audit disclosure). Further, when disclosure policies are implemented at the state, provincial or national level, it is difficult to observe post-policy outcomes for comparable agents outside of the jurisdiction administering the requirement. Thus, it is often not possible to disentangle the effects of information from broader trends in consumer preferences.

Our empirical setting allows us to overcome both of these challenges. First, we directly observe a measure of each home's energy efficiency that is highly correlated with the features evaluated by the energy efficiency audit: electricity consumption per square foot. A home-level energy efficiency measure can be thought of as the level of energy services a household receives per unit of energy. Because more than half of household annual energy consumption is derived from space heating and cooling, envelope measures such as the level of attic and wall insulation, air sealing, and windows, along with furnace and air conditioner efficiency will drive this measure. We construct an energy efficiency proxy based on this measure for each home using consumption data from *before* the policy was enacted. Thus, we can isolate the effects of disclosed information about efficiency on market outcomes separately from endogenous upgrades to the home.

Second, we observe sales of the same homes at multiple points in time, which allows us to flexibly control for all time-invariant housing attributes that might be correlated with energy efficiency. Finally, because the disclosure policy applies only within Austin city limits, we are able to compare the outcomes for Austin homes to homes located just outside of the city but sold on the same real estate market and serviced by the same energy utility. We provide supporting evidence for this counterfactual in our difference-in-differences identification strategy; these homes have significant overlap in relevant attributes and we demonstrate that the jurisdictions exhibit parallel pre-policy trends for our outcomes of interest.

For our empirical analysis, we take advantage of several comprehensive data sources. For the 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. We first examine whether energy efficiency disclosure affects house prices. To do so, we estimate the effects of the ECAD disclosure program on the correlation between energy efficiency and home prices using a triple difference approach comparing how sale prices change within property for less versus more energy efficient homes, inside versus outside of Austin, before versus after the policy. We show that the policy significantly strengthens the correlation between energy efficiency and housing transaction prices. This suggests that home purchasers are not obtaining full information about homes' energy efficiency from other sources in the absence of a disclosure program and, further, that buyers pay attention to and value that information when it is made available. Next, we focus on the policy outcome of interest: improvement in quality. We show that the policy 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.

Our results offer one of the few empirical examples of a disclosure policy that demonstrably improves product quality (Loewenstein et al., 2014; Winston, 2008). To explore the economic mechanism(s) underlying the effects, we take advantage of the fact that there is imperfect compliance.[3] While the ECAD program is officially mandatory, in practice few resources are dedicated to enforcement and about 60 percent of targeted homes comply.[4] 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).[5] 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 very little across the energy efficiency distribution of homes sold inside of Austin post-policy. That is, we find no evidence of an unraveling effect in this market, despite significant financial stakes associated with 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 uninformed prospective home buyers being uniformly distributed across energy efficiency space. We find that disclosure generally occurs 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' disclosure propensities: sellers might be ignorant about their own properties' *relative* energy efficiency, and/or there might be large variation in sellers' disclosure costs (including psychic and other nonmonetary costs). To distinguish between these candidate

[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]This result is consistent with lack of complete voluntary disclosure of Energy Performance Certificates in Germany and Belgium (Frondel et al., 2017; Cornago and Dressler, 2020).

[5]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.

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 estimated price effects 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 other peer-to-peer markets where these strong assumptions likely do not hold and a disclosure mandate would similarly 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 also explores how the energy savings from technologies relates to property values (Aydin et al., 2020; Frondel et al., 2017; Walls et al., 2017; Myers, 2019).[6] Cassidy (2018) also examines capitalization in Austin's disclosure program. The study compares sales prices for the set of homes whose sellers chose to comply with the ECAD program, finding that less visible features such as the quality of air duct insulation correlate more strongly with sales prices after the policy is implemented, while the correlation with more easily observed features such as HVAC systems' energy efficiency ratings is less sensitive to the policy.

In this paper, we investigate a broader set of research questions. We estimate not only how the policy affects home prices, but also the effects of the audit information on the main outcome of interest for policymakers: housing quality improvements through energy efficiency investments. In addition, we study home sellers' audit compliance decisions in order to directly shed light on the underlying market failure, which we argue is symmetric incomplete information. By combining home sales data with energy consumption data, we are able to construct a measure of energy efficiency for all homes – including a control group of homes located outside of Austin's city limits – not just those sold by homeowners who selected into being audited. In addition, our use of pre-policy data allows us to form a measure of energy efficiency that is not shaped by endogenous upgrade decisions, which might change the estimated relationship between measured audit components and sale prices. Overall, our data and identification strategy allow us to understand the effects of the policy as a whole on housing prices, investments, and the underlying market failure.

To our knowledge, ours is the first study to consider (and find) that sellers' ignorance of their own goods' 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.

I 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

[6]Homeowners do appear to be informed about *some* aspects of home energy costs in the absence of mandated disclosure. For example, consumers appear to understand the relative cost of different types of home heating (Myers, 2019). Energy efficiency certification also appears to be correlated with higher housing prices, which is suggestive of consumer awareness when given explicit labeling (e.g. Brounen and Kok, 2011; Frondel et al., 2017; Walls et al., 2017). However, there is also evidence where labeling does not appear to improve capitalization of energy efficiency: Aydin et al. (2020) find efficiency correlates with sale prices in the Netherlands but that the European mandatory EPC program does not strengthen this correlation.

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.[7] 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. As we show below, most audits occur just after the seller contracts with a realtor to list the home – weeks or months before the home is sold.

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.[8] 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 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.

[7]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.

[8]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 see https://austinenergy.com/ae/energy-efficiency/ecad-ordinance/energy-professionals/energy-professionals.

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.[9] 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.

II 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 the two counties that Austin sits within. 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.[10] We pulled the universe of

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

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

transaction information for single-family homes sold in Travis and Williamson counties during 1997-2014.[11] 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. 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.[12] With few 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.

A Defining the energy efficiency proxy measure

Our study focuses on the energy efficiency of homes sold. Ideally, we would directly observe an engineering measurement providing a summarizing quantification of the efficiency for each home, but such data do not exist. 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 within the city limits of Austin – whereas our identification

[11]This time period reflects the scope of our data request in 2014.

[12]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.

strategies require a comprehensive measure of every in-sample property's energy efficiency.

We use *pre-policy* energy consumption data to construct an ordinal proxy measure of energy efficiency based on the average energy consumption per square foot for each home. As we describe in more detail below, this is a good proxy for efficiency in aggregate, in that it is correlated with the audited features of a home. However, because it will be affected by occupant behavior, the measure should be thought of as a noisy approximation of the true efficiency for any given home. Therefore, even if a prospective home buyer observed energy consumption information, perhaps from a prior bill, they would still not know the true energy efficiency as revealed by the audit.

To construct our ordinal proxy measure, we first use our data to measure 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.[13] Within each vintage (year built) of homes, we rank these kWh/SqFt values, pooled across jurisdictions, from highest to lowest. We scale this ordinal set to range from zero to one, so that one represents the most efficient.

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. In addition, as our proxy is ordinal rather than cardinal, it should be less sensitive to statistical outliers in energy consumption. Finally, since the measure is time-invariant and determined before the ordinance was passed, it does not reflect any potentially endogenous upgrades that may have been performed in response to the disclosure requirement.

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

[13]Because electricity billing is staggered across the month, we use linear interpolation to recenter the monthly energy billing data for each property to correspond to calendar months rather than billing cycles. 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. Using these recentered values and dividing by each property's square footage, we calculate each home's average monthly electricity consumption per square foot.

with our proxy term. For instance, a ten percent improvement in our proxy is associated with: a 1.1 percentage point (three percent of the mean) increase in the probability that the home has double-pane or low-emissivity windows; a 0.19 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 0.18 percentage point (one 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 well-suited to serve as a tractable measure. In addition, we ensure that our results are not dependent on our particular choice of energy efficiency proxy by demonstrating robustness of our home price results to using the natural log of homes' pre-policy annual electricity use per square foot directly as an alternative proxy measure for energy efficiency.

B Sample compilation and summary statistics

We combine the data from our various sources using the unique tax appraisal id (parcel number) for each property. In compiling our sample, we restrict our analysis 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 131,050 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 Figure 1. We observe 65,470 (50 percent) of sample homes sold on the MLS at some point during 1997-2014, generating a total of 106,045 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 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 $316 thousand outside the city limits. "Pre-sale EE rebates ($)," 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 $29.7 and $27.5, 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. Appendix Figure A1 plots the average annual pre-policy electricity costs across the energy efficiency distribution for each jurisdiction. The pattern in energy consumption is quite similar across the two jurisdictions, though consumption is somewhat higher outside of Austin. Some of this may be driven by the difference size across the jurisdictions or the difference in the distribution of vintage. Interestingly, there is not much difference across jurisdictions in either energy use per square foot or energy efficiency. Regardless, in our preferred regression specifications, we control for property, vintage-by-month, and jurisdiction-by-month fixed effects. This allows us to account for any systematic time-invariant differences across jurisdictions in the composition of properties and for how consumer preferences might change particular to different vintages of homes or jurisdiction over time.

III Empirical strategy and results

A Effects of energy efficiency disclosure on house prices

Our first empirical question is whether the ECAD program affects housing prices. If disclosing energy efficiency audit information changes housing prices, this would suggest that: 1) home buyers did not already have complete access to this information in the absence of the policy and 2) the housing market is attentive to and values this information when it is provided. To estimate the effects of the ECAD policy on housing prices, we use a triple difference identification strategy comparing sale prices of more versus less efficient 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 market participants pay attention to and value the ECAD audit, then we should see the price spread between less- and more-efficient homes increase by more inside Austin than for the counterfactual.[14] Because

[14]Conceivably, one might use a regression discontinuity design at the ten-year-old home age treatment cutoff. The first drawback 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.

we can only proxy for homes' true energy efficiency (discussed in Section A), we do not view our estimates as capturing the exact magnitude of the effect of the program on *capitalization* of energy efficiency and associated energy cost differences into home prices. For example the magnitude of the estimates would be sensitive to whether the audit is also giving information about building quality, which may be valued in itself, or if occupant usage is correlated with energy efficiency. Therefore, the goal of this empirical exercise is to determine whether or not the policy induced a stronger correlation of our proxy – and by extension homes' true energy efficiency – with sale prices as a result of ECAD, thus indicating a strengthened market valuation of the information.

We begin by exploring several prerequisites for the validity of our identification strategy. Figure 1 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 policy, Figure 2 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 homeowner curiosity or beliefs about their home's efficiency.[15] However, the figure displays a substantial spread of about 45 percentage points 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 first estimation of interest examines

[15] 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.

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.

In order to estimate the program's effect on housing prices, 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 pre-determined, time-invariant 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. Throughout the analysis, we cluster standard errors at the level of jurisdiction-by-sale year-by-quartile of energy efficiency.

The house fixed effects control for all time-invariant qualities of a house that might affect its price. As the overall composition of the ages of the homes is somewhat different inside versus outside of Austin, we include vintage-by-month fixed effects to control for any possible differences in sales prices between the jurisdictions that are driven by 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 rich 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. The identifying assumption for this to represent the causal effect of ECAD on the correlation between energy efficiency and housing price is that the price-efficiency slope is on parallel trends in the two jurisdictions. Because the energy efficiency proxy is pre-determined, the coefficient of interest purely reflects how the policy affects the spread of prices and does not capture any endogenous energy efficiency investments that homeowners might make in response to the disclosure requirement.

Figure 3 provides a graphical representation of the relationship between energy efficiency and sales prices for each jurisdiction over time. We plot year-specific estimates for the treatment and comparison group of the correlation between house price and the energy efficiency proxy conditional on property, jurisdiction-by-year, and vintage-by-year fixed effects.[16] The magnitude of each point estimate is relative to the omitted year, 1997. The year-on-year movements in the price-efficiency slope appear to be on parallel trends in the two jurisdictions, with the exception of one discontinuous shift in 2009. Importantly, the timing of the shift lines up with the introduction of the policy and is driven by an increase in the correlation inside (rather than outside) Austin. In addition, in Appendix Figure A3 we show that the difference in the price efficiency slope between Austin and the comparison group appears to be statistically indistinguishable prior to the introduction of the policy, then discontinuously becomes positive post policy.[17] Taken together, this evidence suggests that the disclosure policy results in larger price premiums for more energy efficient homes.

Given that the two jurisdictions are on parallel trends, the treatment effect depicted Figure 3 represents the "intention-to-treat effect": the differential effect of the disclosure being mandatory in one jurisdiction and not the other. This effect could be driven by the information in the audits themselves, the mandate causing a relative shift in energy efficiency awareness inside Austin, or a combination of the two. If it were the case that the program only affected the correlation between energy efficiency and price through homeowners receiving audit information, then we could recover the local average treatment effect of the audit on price using the ECAD policy as an instrument. However, if this exclusion restriction did not hold – such as if the program being mandatory inside of Austin leads to a stronger correlation between energy efficiency and price even in the absence of specific audit information – then the instrumental variables approach likely overestimates the price effect. As our focus here is qualitatively whether the ECAD program significantly affects home prices, we present both the intention-to-treat and 2SLS estimates and view these magnitudes as roughly bounding the effect of audit information on prices.

For the 2SLS approach, we use the ECAD policy to instrument for whether each specific

[16] Mechanically, we plot coefficients $\beta_{1998} - \beta_{2014}$ and $\gamma_{1998} - \gamma_{2014}$ from the following regression, where all variables are defined as in Equation 1:
$ln(P_{ivjt}) = \sum_{t=1998}^{2014} \beta_t EEProxy_i \times Austin_j + \sum_{t=1998}^{2014} \gamma_t EEProxy_i \times OutsideAustin_j + \mu_i + \tau_{vt} + \zeta_{jt} + \varepsilon_{ivjt}$.

[17] We plot coefficients $\eta_{1998} - \eta_{2014}$ from the following regression, where all variables are defined as in Equation 1: $ln(P_{ivjt}) = \sum_{t=1998}^{2014} \eta_t EEProxy_i \times Austin_j + \sum_{t=1998}^{2014} \theta_t EEProxy_i + \mu_i + \tau_{vt} + \zeta_{jt} + \varepsilon_{ivjt}$. These coefficients represent year-specific estimates of the *difference* in the price-efficiency slope between Austin and the comparison group.

home sale included an ECAD audit ($Audit_{it}$), where the first and second stages are as follows.

First Stage:

$$\begin{aligned} EEProxy_i \times Audit_{it} = \;& \alpha_1 EEProxy_i \times Post_t \; + \\ & \alpha_2 EEProxy_i \times Austin_j \times Post_t + \mu_i + \tau_{vt} + \zeta_{jt} + \varepsilon_{ivjt} \end{aligned} \tag{2}$$

Second Stage (2SLS):

$$\begin{aligned} ln(P_{ivjt}) = \;& \gamma_1 EEProxy_i \times Post_t \; + \\ & \gamma_2 \widehat{EEProxy_i \times} Audit_{it} + \mu_i + \tau_{vt} + \zeta_{jt} + \varepsilon_{ivjt} \end{aligned} \tag{3}$$

Panel [A] in Table 2 displays the intention-to-treat estimates from Equation 1. Panel [B] reports the 2SLS results of the local average treatment effect of the *audit* on the correlation between energy efficiency and sale price for those homes that sold with an ECAD audit because of the mandate to do so.

The specifications for Column (1) include the full sample of sales, with jurisdiction and vintage-by-month of sample fixed effects. For Column (2), we estimate models that include property fixed effects rather than jurisdiction fixed effects, which limits the sample to include only homes sold more than once between 1997 and 2014. As discussed above, 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-month of sample fixed effects rather than vintage-by-month of sample fixed effects. Finally, Column (4) displays the results from our preferred and most saturated specifications including property fixed effects and both vintage-by-month of sample and jurisdiction-by-month of sample fixed effects.

Beginning with Panel [A], the second row in the panel displays estimates for our coefficient of interest (β_2): 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 more efficient homes receive a higher price premium as a result of the ECAD policy being applicable inside of Austin but not outside of Austin. The point estimate in Column (2) of .097 log-points is only half the magnitude of that in Column (1) of .188, suggesting that 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 3, 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). Our preferred specification estimates suggest that a ten percent increase in relative energy efficiency leads to about a 0.81 percent increase in sales price. We provide further interpretation of the magnitude of this estimate below.

The first row in Panel [A] of 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 statistically insignificant. Once we include property fixed effects to control for any changes in the composition of homes' time-invariant qualities (Columns (2-4)), the effect remains neither statistically nor economically distinguishable from zero. This suggests that there was little change in the relationship between housing price and energy efficiency outside of Austin post policy relative to pre-policy.

Panel [B] displays the 2SLS estimates of the local average treatment effect of the audit information on the correlation between energy efficiency and housing prices for the ECAD policy compliers. The point estimates on the coefficient of interest are roughly two and half times larger than in Panel [A], reflecting that the reduced form estimates are being rescaled by the 45 percentage point difference in the post-policy audit rate between the two jurisdictions. Overall, the results in Table 2 indicate that the policy had a strong effect on market transactions. This means that the policy provides consumers access to new information that they were not receiving in the absence of the policy, and importantly, that consumers are attentive to this information and value it when it is made available.

To explore the mechanisms driving these findings, in Appendix Table A4, we provide results of a placebo test where we estimate our preferred specification for homes that are built after 1998.[18] We exclude these homes from our main sample because they were younger than 10 years at the start of the sample, and thus not required to comply with the policy. We find that, as with the main sample, energy efficiency is not capitalized any differently into prices post-policy outside of Austin. However, for Austin homes, the capitalization effects for the placebo group are much smaller than for the main sample and statistically insignificant. This suggests that, while there may be some effect of the policy on overall buyer attention to energy efficiency, the primary driver of the effects we observe is likely the information received in the Audit.

[18]Specifically, we use homes built between 1998 and 2005. While we have sales data on younger homes, we can only construct pre-policy energy efficiency proxy information for homes built before 2006.

In addition we perform a robustness test where we potentially improve the comparability of the housing stock between the two jurisdictions by limiting the sample to a 50 percent sub-sample of the homes that are closest to the city border. The price results using this "border sample" are quite similar to those using the full sample, as shown in Appendix Figure A4 and Appendix Table A5.

As discussed above, because we use a proxy for energy efficiency rather than a direct measure, it is not our intention to directly interpret the point estimates in terms of the difference-in-differences in capitalization of energy efficiency between the two jurisdictions. However, we consider a back-of-the-envelope calculation as a check that the size of the estimates are in a reasonable range. Our preferred reduced-form and LATE specifications suggest that homeowners are willing to spend an additional $1994 and $4535 in home purchase price, respectively, to obtain an expected savings in annual energy costs of approximately $153.[19] If we take these estimates literally, the implied discount rates from the change in price for a flow of lower energy payments would be about 8.3% and 3.5% for the reduced form and LATE estimates respectively over a 100-year home lifetime. The national average 30 year fixed *real* mortgage interest rate during our sample period was 2.7%.[20] While the proxy is an imperfect measure of true efficiency, these calculations suggest that the policy induces an increase in the capitalization of energy efficiency that is sizable and in a plausible range: around 37 percentage points according to the reduced form and 82 percentage points according to the LATE estimates.

One worry with using a linear proxy for energy efficiency is that the price results could potentially be driven by the tail(s) of the distribution or by functional form assumptions. We evaluate this potential concern by allowing for a more flexible relationship between the efficiency proxy and price. Specifically, in Figure 4 we plot the coefficients from an estimation where, rather than the $EEProxy$ variable entering Equation 1 linearly, we use nine indicator variables for each decile of the energy efficiency proxy (excluding the lowest decile as an omitted category). Importantly, the slope of the coefficient estimates for the energy efficiency proxy decile indicators interacted with an indicator for post policy is quite flat. This suggests that there was little change across the full efficiency distribution of homes

[19]Our reduced-form and LATE estimates in Table 2 show that a ten percent increase in energy efficiency obtains a 0.0081 or 0.0184 log-point increase in sale price, respectively. These magnitudes translate into $1979 and $4496 at the average price of $244,343 (Table 2). A ten percent increase in the proxy is associated with approximately $153 difference in energy costs.

[20]Calculations were made using data from Freddie Mac for the nominal national average 30 year fixed mortgage interest rate for the years 2009-2014. To get real mortgage interest rates, we adjusted for inflation using the Consumer Price Index (CPI) from the Bureau of Labor Statistics (BLS).

in the relationship between housing price and energy efficiency outside of Austin post policy relative to pre-policy.

Moreover, there is an increasing and fairly linear relationship between the coefficients for the energy efficiency proxy decile indicators interacted with both an indicator for post policy and an indicator for inside of Austin. This further confirms the policy effect on the relationship between housing price and energy efficiency inside of Austin and suggests that the linear functional form assumption in Equation 1 is not a biasing factor in our preferred estimation.

In addition, in Appendix Table A6, we further test the sensitivity of our estimates to using a non-ordinal energy efficiency proxy. We provide estimates of the price effects of the policy using the actual (natural log of) pre-policy energy consumption per square foot as an alternative energy efficiency proxy, finding results that are quite consistent in significance and magnitude with those using our ordinal proxy term. Therefore, our results do not appear to be sensitive to how we constructed the measure for energy efficiency.[21]

B Effects on investment in energy efficiency

We next explore how the ECAD disclosure program impacts the main outcome of interest for policymakers: housing quality improvements through energy efficiency investments. In order to capture changes in investment behavior on both the extensive and intensive margins, 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 homeowner.[22]

We start by using the 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 creates a stronger incentive for sellers to invest in higher quality prior to listing their home for sale. As our outcome variable, we use the total dollar value of rebates

[21] We perform a similar back-of-the envelope calculation using estimates from Appendix Table A6, which uses the natural log of homes' pre-policy annual electricity use per square foot as an alternative energy efficiency proxy measure. The results are quite consistent with our main results. We find implied discount rates of about 9.7% and 3.8% for the reduced-form and LATE respectively. These estimates imply a 32 percentage point increase in capitalization for the reduced form and 75 percentage point increase for the LATE.

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

paid per property for any program participation within the two years prior to sale. Because our energy efficiency program participation data start in 2006, we focus on this relatively short window to give us a clean pre- versus post-policy comparison of investment behavior. After 2009, ninety-four percent of sellers in our sample had not received energy rebates.

Figure 5 plots the annual inside-Austin coefficients from regressing these rebate dollars on vintage-by-year fixed effects and annual inside-Austin 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 5.[23] As indicated by the 95 percent confidence intervals for each plotted coefficient, each of these year-specific estimates is noisy. Table 3 shows more formal difference-in-differences evaluations of these investment effects, where we estimate the following model.

$$Rebate_{ivjt} = \beta_1 Austin_j \times Post_t + \nu_j + \tau_{vt} + \varepsilon_{ivjt} \tag{4}$$

The econometric specification regresses the total two-years pre-sale dollar value of rebates paid to each homeowner (inclusive of zeros) on an interaction for the sale occurring inside Austin and post-June 2009 ($Austin_j \times Post_t$), controlling for jurisdiction (ν_j) and vintage-by-month of sample fixed effects (τ_{vt}), where ε_{ivjt} is the error term. In Column (1) of Table 3, we estimate the post-pre difference between the coefficients plotted in Figure 5.[24] This difference-in-differences coefficient of interest (β_1) is an economically and statistically significant \$13.19 average effect of the policy on total energy efficiency investment rebate dollars paid to soon-to-be home sellers. Because the post-policy average for this outcome variable is \$42.39, this reduced-form treatment effect equates to 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 sellers 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 are most closely tied to ECAD report values. Here, we find an effect on HPWES-specific investment by home sellers that is larger in

[23]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.

[24]As with the capitalization results, the investment results are quite similar if we limit the sample to more comparable housing stock, i.e. a 50% sub-sample that is closest to the border (see Appendix Table A7).

both point estimate ($16.48) 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 influence negotiated home sale prices when energy efficiency may be credibly disclosed.[25]

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. The point estimate is positive ($13.5) and statistically significant at the ten percent level, although it is smaller proportionately (18 percent) 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 $22.47 (37 percent of the mean). These findings suggest that the ECAD ordinance induces investment in energy efficiency improvements for home buyers and is consistent with buyers as well as sellers being uninformed about energy efficiency in the absence of the audit.[26]

IV Market failures and value of mandatory disclosure

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

[25]Because homes must be 10 years or older to participate in any of the major rebate programs, we cannot perform the placebo test with newer homes that we do for the house price effects.

[26]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.

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

Second, the voluntary disclosure theories would imply a sharp relationship between the energy efficiency of homes and the disclosure decision. However, we find only a very weak relationship. Figure 6 plots the share of in-sample homes sold for both inside and outside Austin post-June 2009 that obtained and disclosed 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 for homes both inside and outside of Austin. In both cases, the first decile does have the lowest average disclosure rate; however, the most efficient decile's average disclosure rate is less than 5 percentage points higher.[27]

In this section, we construct an alternative model of disclosure that predicts these two empirical regularities. We offer evidence suggesting that the mechanism by which mandatory disclosure increases the strength of the relationship between energy efficiency and sale prices is that both buyers *and sellers* have incomplete information about quality. Specifically, some sellers do not know the relative 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.

In essence, our model and evidence below show that when some sellers are uninformed about the relative energy efficiency of their homes, the relationship between energy efficiency and disclosure propensity can be weak.

Before turning to our model of disclosure in Section B, we rule out several other possible explanations for the empirically flat relationship between energy efficiency and disclosure propensity. The first possibility is that our proxy for homes' energy efficiency might be a

[27] Appendix Figure A5 shows very similar flat disclosure propensity patterns across vintage both for homes inside and outside of Austin.

poor or relatively meaningless one. However, it is difficult to argue that this is the case. For one, as shown and discussed in Section II 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 our proxy measure is significantly capitalized among treated homes post-policy relative to counterfactual, and we show that our results are robust to instead using pre-policy energy bills per square foot to capture this same residential heterogeneity.

A second possibility is that buyers might be 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 A6 and A7). A related potential explanation is that the decision to disclose might be 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 A8.[28]

Finally, another potential explanation is that many sellers might be simply uninformed about the requirements of the ECAD program. However, this explanation has minimal support given that these are all sales via realtors, who are well informed about ECAD.[29] If sellers were well-informed about the efficiency 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 understands the program, there are two plausible explanations for the empirical pattern of disclosure, which we model and evaluate below: (1) sellers are not aware of the relative energy efficiency of their homes and/or (2) there is substantial heterogeneity in the cost of disclosure where those costs include the time, effort and psychological costs of disclosure. Note that this disclosure cost might be negative for some sellers. For example, if a seller feels very strongly about the need to comply with the

[28]We also verified a similar flat slope as shown in Figure 6 when restricting to sales that used realtors who have within-realtor average compliance rates of no more than 20 percentage points different from the overall sample mean compliance rate.

[29]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.

law or if the seller supports the policy's environmental goals, then the cost of compliance is less than zero.

B Model of ECAD compliance decision

We present a simple model of the seller's decision of whether or not to comply with a mandatory disclosure policy. This model shows that when both the buyers and *some sellers* are uninformed about relative product quality, the 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 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 compared to that of 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.

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.[30] Therefore, if no audit is conducted then the buyer's beliefs are given by $q^b = \hat{q^b}$, but if an audit occurs, the buyer knows the true quality ($q^b = q$).

Beliefs about quality determine the buyer's and seller's beliefs about the dollar value of the home as given by $b(q^b)$ and $b(q^s)$. Nash Bargaining determines how these 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 costs of obtaining an audit

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

versus not obtaining an audit be given by c. Importantly, this c is a comprehensive measure of costs that includes the dollar costs of paying for the audit process plus any time, effort, and psychological costs of disclosure net of any expected penalty for not obtaining an audit. As discussed above, this broad measure of costs can be either positive or negative.

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 net of the disclosure cost is greater than the expected Nash Bargaining opportunity cost. An uninformed seller faces a similar tradeoff but evaluates expected benefits based upon her beliefs of the house quality. Thus, an uninformed seller discloses iff $b(\hat{q}^s) - c \geq \frac{1}{2}[b(\hat{q}^s) + b(\hat{q}^b)]$, where $\hat{q}^s$ may not necessarily be true quality q.

Given this model, we illustrate how compliance can be incomplete and only weakly related to quality. Figure 7 presents several scenarios. In the illustration, we set the domain of $b(\cdot) \in [0, \bar{b}]$ and assume that $b(\cdot)$ is linear in quality. We calculate the Bayesian Nash equilibrium where: (1) sellers are rationally choosing whether to disclose based on the decision criteria above, and (2) both buyers and sellers hold beliefs about quality that are consistent with the equilibrium level of disclosure. In order to calculate these equilibrium outcomes, we simulate disclosure costs for houses of varying quality and apply the seller decision criteria, imposing that beliefs are consistent with the observed disclosure behavior.

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 $c = \bar{b}/8$. 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 7. In this scenario, the sellers of all houses of sufficiently high quality disclose quality to the buyer. This outcome signals to the market 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 the second scenario, all sellers are informed but there is heterogeneity in the cost of disclosure. Cost heterogeneity reflects the fact that sellers vary in the time, effort, and psychological costs of disclosing and the perception of expected penalties of non-compliance. In this illustration, the disclosure cost is drawn from a normal distribution around $\bar{b}/8$: $c \sim N(\bar{b}/8, \bar{b}/8)$. 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. The important insight is that the relationship between disclosure probability and quality is relatively steep when the seller is informed with certainty, despite sizable variation in disclosure cost.

Next we allow for the major innovation of this exercise – sellers can be uninformed about the relative quality of their own homes. We continue to model disclosure costs as heterogeneous as in the scenario above, but only half of sellers are informed about their quality (Φ=0.50). An uninformed seller believes her house to be of median quality, i.e. $b(\hat{q}^s) = \bar{b}/2$. The Bayesian Nash equilibrium level of disclosure is shown by the short-dashed yellow line. The relationship between quality and disclosure significantly flattens when a significant number of buyers are uninformed.

And finally we show equilibrium outcomes when half of the buyers are uninformed and the dispersion of compliance costs increases, shown in the dotted yellow line. In this scenario, the relationship between quality and disclosure is very weak with the higher quality home owners only slightly more likely to disclose than the low quality home owners.

The theoretical scenarios illustrated in Figure 7 demonstrate an important insight, which we take to our data. For the relationship between disclosure probability and energy efficiency to be quite flat requires either large dispersion in disclosure costs or a high probability that the seller is uninformed (or both).

C Computational simulation

Next we conduct a simulation exercise that connects our reduced-form empirical findings to the theoretical model presented just above. Our computational exercise simulates draws of audit costs for each home sale inside of Austin post-policy and uses these simulated cost values – along with data on homes' observed 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 decision criteria of the model.

Our starting point for the simulation is the solution to the seller's disclosure problem in Section B. 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 $i \sim$ Bernoulli(Φ) and Φ taken as exogenous to the model. The seller's decision to disclose

$d \in \{0, 1\}$ can be summarized as a function of the seller's information status:

$$d = \begin{cases} 1 & \text{if} \quad i \cdot b(q) + (1-i) \cdot b(\hat{q^s}) \geq 2c + b(\hat{q^b}) \\ 0 & \text{if} \quad i \cdot b(q) + (1-i) \cdot b(\hat{q^s}) < 2c + b(\hat{q^b}) \end{cases} \tag{5}$$

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. Using observed disclosure decisions in the data (d), the relationship estimated in Section A between disclosed energy efficiency and sales price to provide a disclosure benefit value $b(q)$ for each property, and the assumption that $b(\hat{q^b})$ is equal to the average quality of homes that do not disclose in the data, we can infer whether or not sellers are *plausibly* informed for a given cost draw, c:

$$i \equiv \begin{cases} 0 & \text{if} \quad d = 0 \quad \text{and} \quad b(q) \geq 2c + b(\hat{q^b}) \\ 0 & \text{if} \quad d = 1 \quad \text{and} \quad b(q) < 2c + b(\hat{q^b}) \\ 1 & \text{if} \quad d = 1 \quad \text{and} \quad b(q) \geq 2c + b(\hat{q^b}) \\ 1 & \text{if} \quad d = 0 \quad \text{and} \quad b(q) < 2c + b(\hat{q^b}) \end{cases} \tag{6}$$

If either of the first two scenarios in Equation (6) hold, the seller can be categorized as uninformed, as it would be mechanically true per the model. Whereas if either of the latter two hold, it only indicates that the seller is plausibly informed. This means they made the correct disclosure decision, but we cannot determine whether it was due to being informed, or happenstance. Drawing values of the effective disclosure cost $2c$ from a particular distribution, we can use a computational simulation exercise to bound the level of sellers that are plausibly informed as follows.

First, we compute $b(q)$ for each home sale using the local average treatment effect estimates from Table 2 (discussed in Section A). Specifically, we assign $b(q) = \$50,376 \cdot (q - 0.5)$ for $q \in [0, 1]$, set such that a home with mean energy efficiency has $b(q) = 0$. The average quality of homes that do not disclose in the data is almost exactly the average quality in the sample, so we set buyer beliefs to reflect realized disclosure $b(\hat{q^b}) = 0$. Next, we assume that effective disclosure costs ($2c$) are normally distributed with a mean value of \$200 (a typical statutory audit cost is \$100) and a standard deviation of $\sigma \geq 0$. We hold average effective disclosure cost fixed across all simulations and, within each simulation loop, we specify a value of σ and simulate a cost vector. Rather than randomly assigning these simulated cost values to home sales, we sort the cost vector such that the maximum plausible share of sellers could be informed per Equation (6).[31]

Thus, for specified values of $\sigma \geq 0$ and observed vectors of values of $d \in \{0, 1\}$ and $b(q) = \$50,376 \cdot (q - 0.5)$, the steps of each simulation loop are:

1. Draw a vector of gross effective disclosure cost values from $2c \sim N(\$200, \sigma)$.
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 (6).
3. Store the aggregate value for this maximum possible fraction of informed sellers.

Figure 8 presents some results from this computational simulation exercise. Each line in the graph shows the distribution of simulated $N(\$200, \sigma)$ audit costs for the smallest σ value that supports a specific share of sellers being plausibly informed per the model. The vertical orange line denotes the statutory audit cost of \$200. To minimize the influence of simulation variation, we run 1000 iterations of the simulation loop for each value of σ. The dotted line in Figure 8 shows that $N(\$200, \$800)$ is the most narrow distribution that supports at least 55 percent of sellers being plausibly informed per Equation (6).[32] For 70 percent of sellers to be plausibly informed requires $N(\$200, \$4200)$, as shown in the dashed line. Finally, 100 percent of sellers can be plausibly informed in the solid line only if the simulated audit costs have a spread of at least $N(\$200, \$5900)$.[33]

The purpose of this exercise is not to determine the "true" specific share of plausibly informed sellers; rather, we present these results as evidence that the spread of audit costs needs to be very large to support a high share of sellers being informed about their own relative energy efficiency. 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 \$100 fee. However, this explanation is challenging to support

[31] 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.

[32] Note that any share less than 50 percent of sellers being plausibly informed could be supported even without cost heterogeneity, which is why the range we consider in Figure 8 starts with 55%.

[33] Appendix Figure A9 presents an analogous version using the reduced-form estimate of \$21,039 rather than the LATE of \$50,376. There, 55 percent of sellers can be plausibly informed with costs of $N(\$200, \$400)$, 70 percent with costs of $N(\$200, \$1800)$, and 100 percent with costs of $N(\$200, \$2500)$.

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 that shown above.

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.

D 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).

V Conclusions

In this paper, we show that encouraging home sellers to provide potential buyers with certified energy audits affects consumers' willingness to pay for homes. We also show that information disclosure 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 Austin's ECAD program. 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 sales price 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.

This study yields 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 findings indicate that home purchasers understand and care about residential energy efficiency information when it is made available. Thus, mandatory disclosure can 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 improve market outcomes 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.

Disclaimer

This report was prepared as an account of work with the City of Austin and Austin Energy. Austin Energy provided the authors access to the data used in the study in consideration for research that may improve efficiency, reduce cost, support adoption of new technologies, launch new products and services and institute best practices to better serve Austin Energy customers. The study was conducted independently of Austin Energy. Austin Energy had no involvement in the design, analysis, and interpretation of the data; in writing of the report; or in the decision to submit for publication. Neither the City of Austin nor Austin Energy, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference in this report to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the City of Austin or Austin Energy. The views and opinions of authors expressed herein do not necessarily state or reflect those of the City of Austin, the Austin/Central Texas Realty Information Services (ACTRIS), or Austin Energy. The authors have no material financial interests related to this study.

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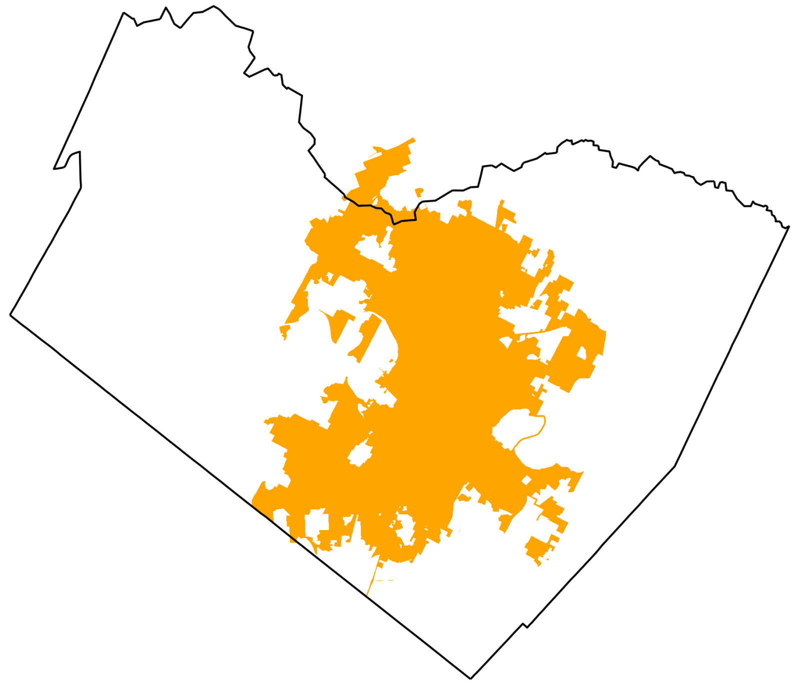
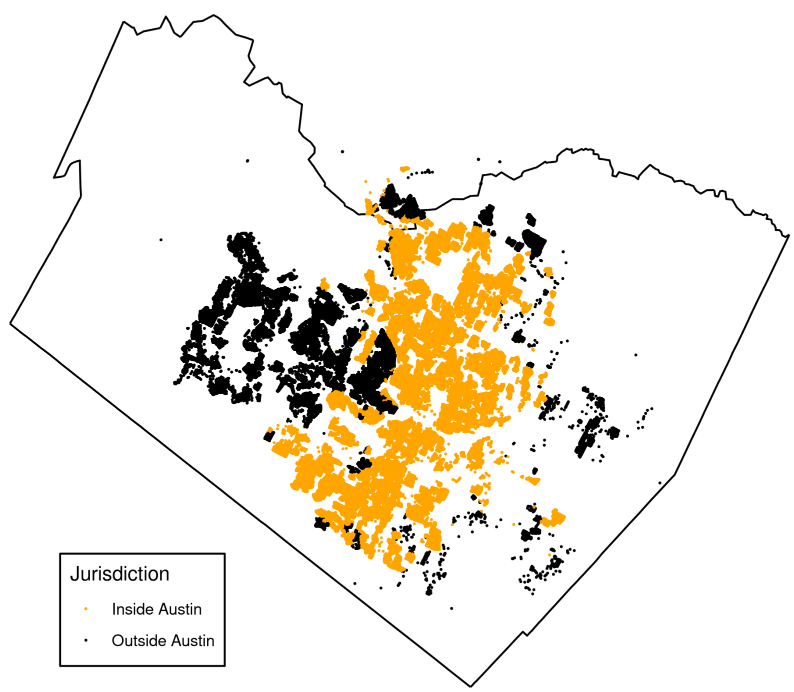
Figure 1: Map of the Austin, Texas study area



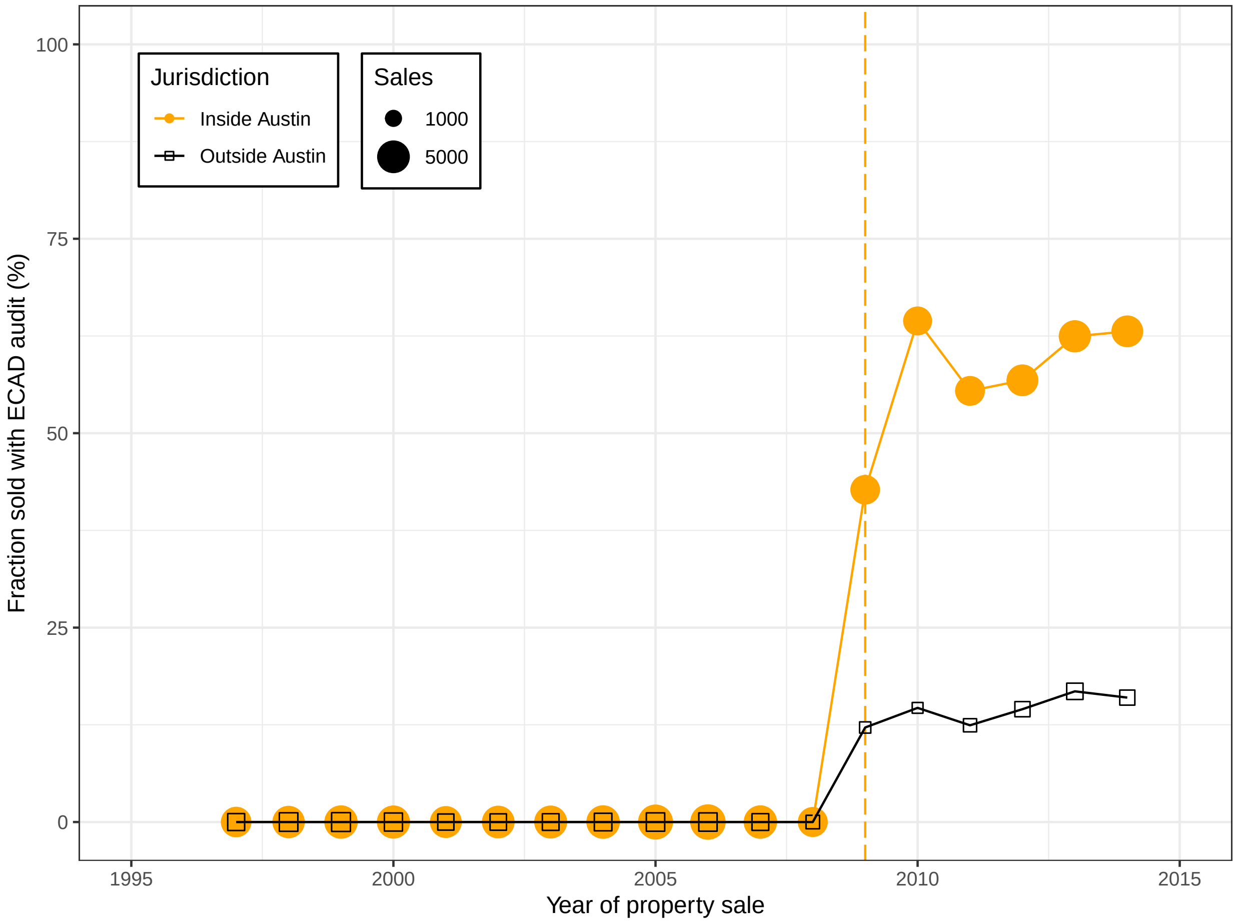
(a) Austin city limits (orange) and Travis county border (black)



(b) Properties included in empirical sample by jurisdictional designation

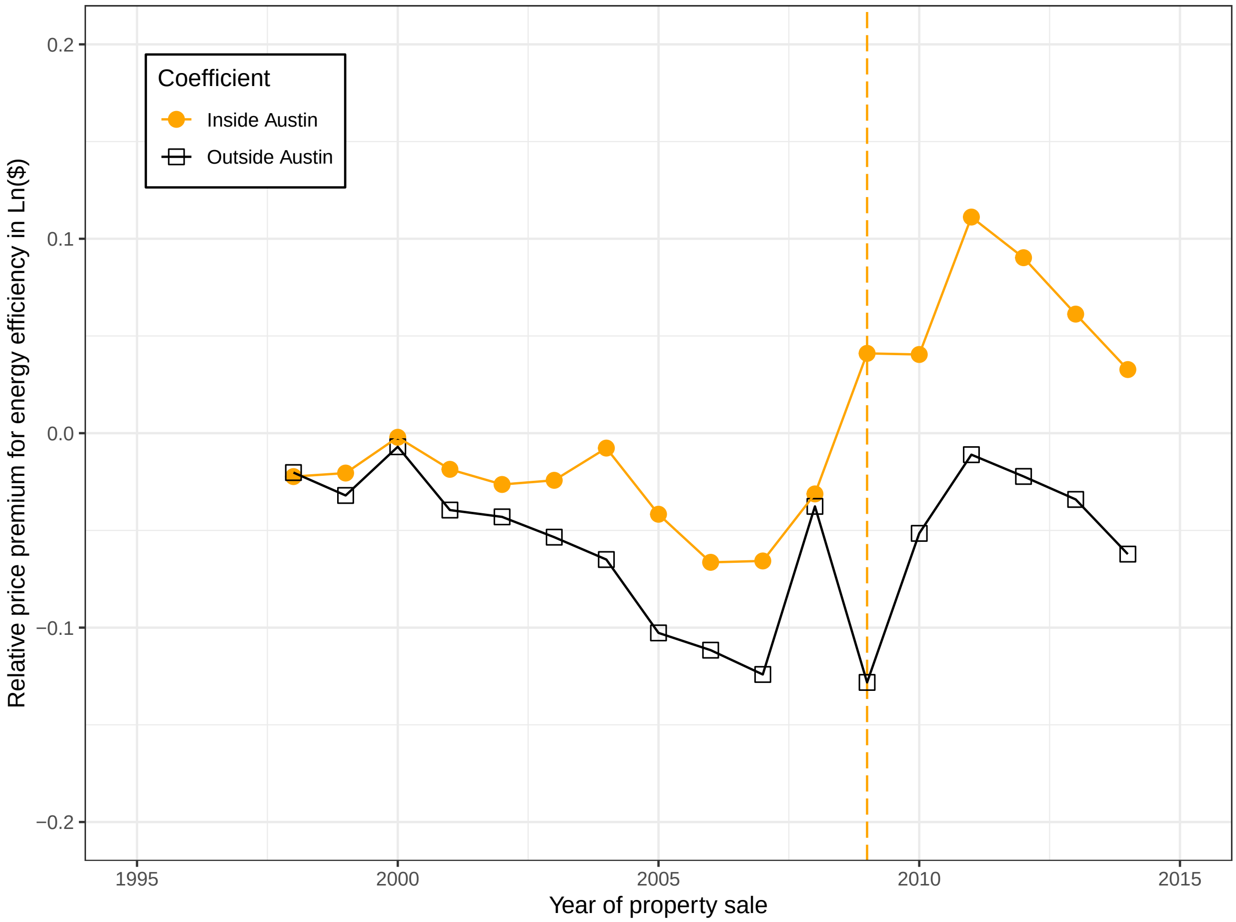
Notes: Figure 1 provides a map of our empirical study area. Panel (a) presents the jurisdictional coverage of Austin city limits, which excludes several "holes" as shown. Panel (b) plots points for each of the homes in our analysis sample, indicating by color each property's respective jurisdiction.

Figure 2: Fraction of in-sample home sales each year that had conducted ECAD audit



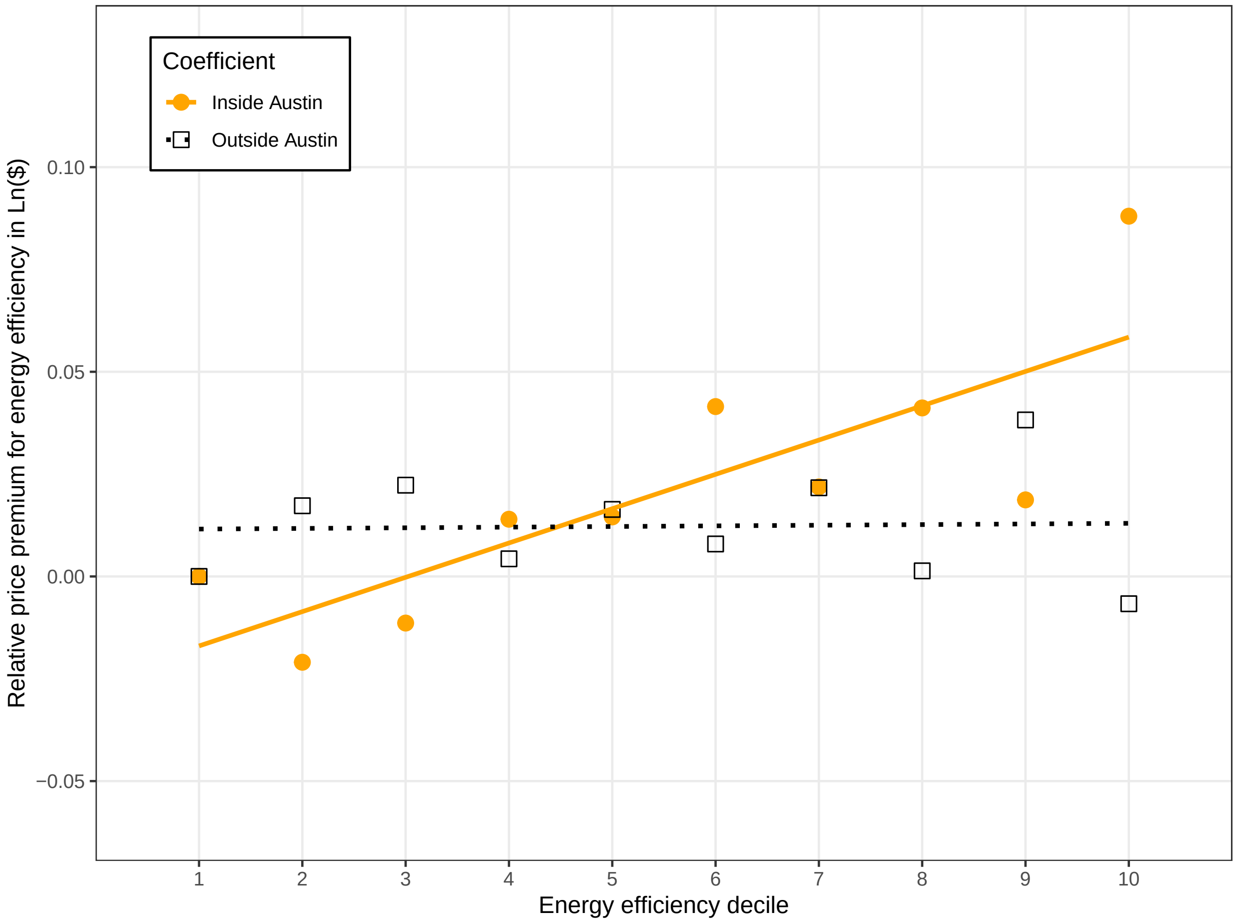
Notes: Figure 2 plots the annual fraction of in-sample home sales by jurisdiction – inside Austin versus outside of the Austin city limits – that had conducted an ECAD energy efficiency audit prior to the closing date of the sale. The dashed vertical line at 2009 indicates when the ECAD audit and disclosure 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 3: Estimated relative energy efficiency price premiums by jurisdiction



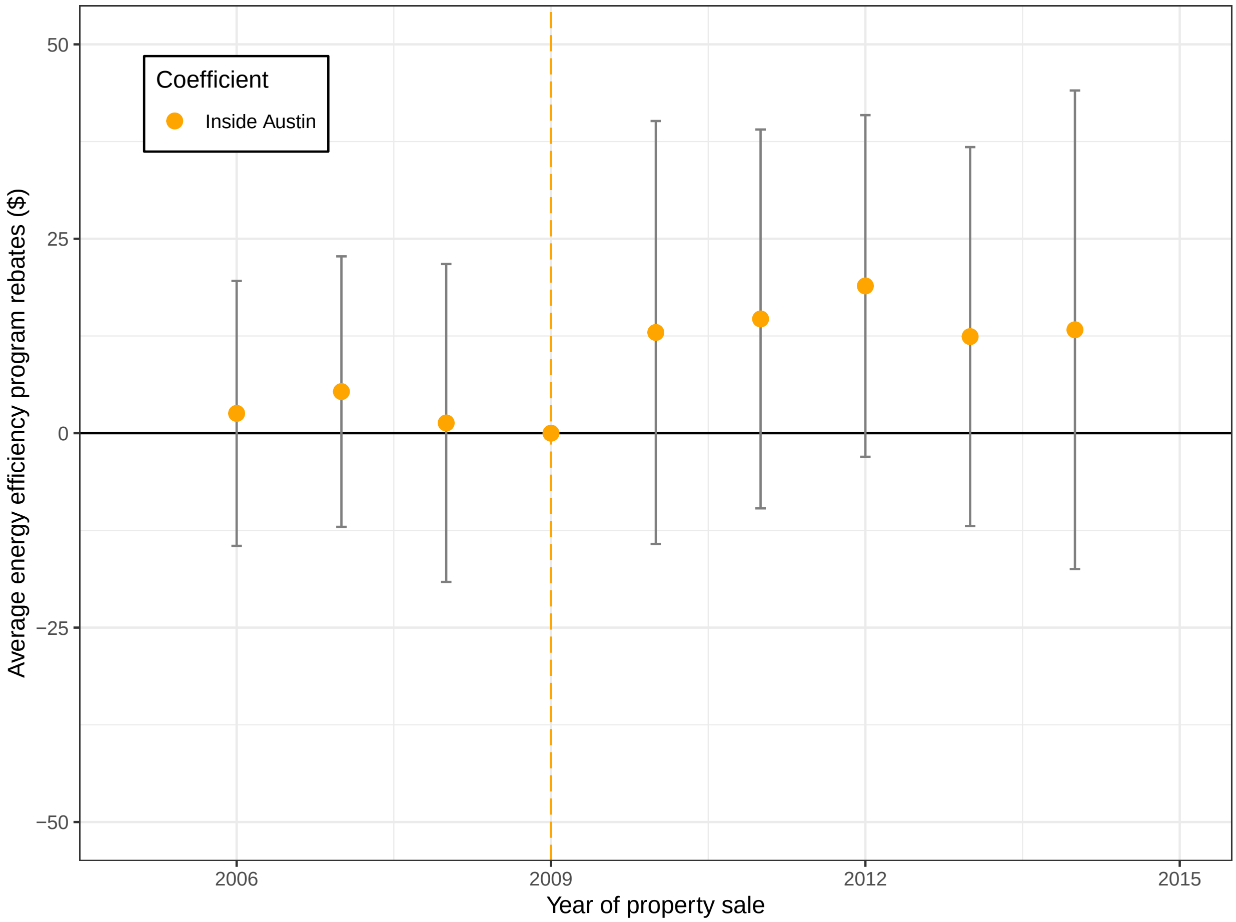
Notes: Figure 3 plots coefficient estimates of interactions between efficiency proxy (ranges from zero to one) and year from regressing the natural log of homes' sale prices on those interaction terms while controlling for property, vintage-by-year and jurisdiction-by-year fixed effects. The omitted base-year is 1997. The ECAD audit disclosure program for all sales inside Austin took effect in June 2009.

Figure 4: Estimated difference-in-differences price premium coefficients by decile



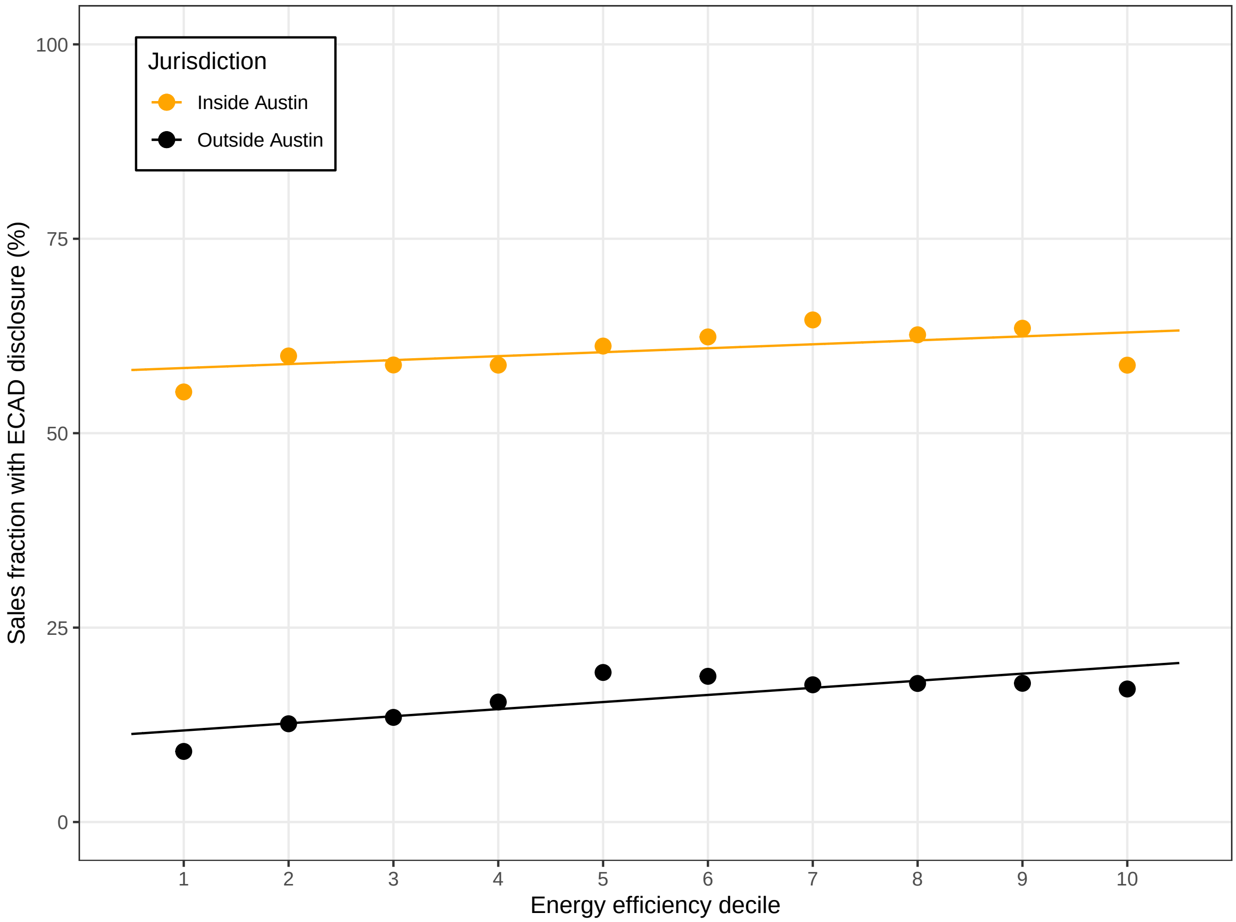
Notes: Figure 4 plots difference-in-differences coefficients by jurisdiction – inside Austin versus outside of the Austin city limits – from regressing the natural log of homes' sale prices on the homes' energy efficiency, a term that ranges continuously from zero to one and indicates each home's fixed energy efficiency quantile, interacted with an indicator for the post-policy period. These coefficients show by decile the corresponding estimates presented in Table 2. The underlying regression includes property fixed effects as well as jurisdiction-by-year fixed effects. The ECAD audit disclosure program for all sales inside Austin took effect in June 2009. The lines are linear best-fit lines for the plotted point estimates.

Figure 5: Inside Austin coefficients by year for pre-sale energy efficiency rebate dollars



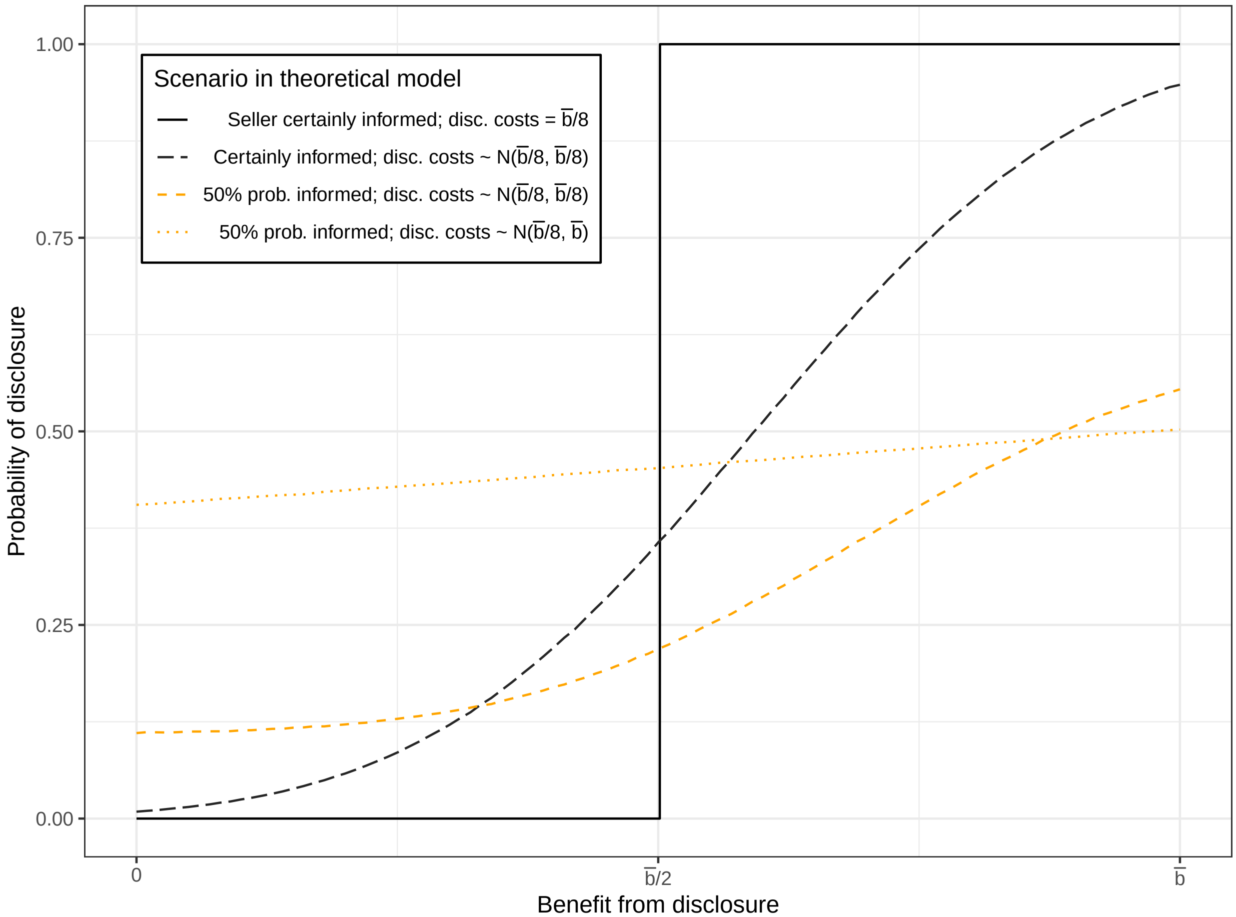
Notes: Figure 5 plots the annual inside Austin coefficients from regressing pre-sale energy efficiency rebate dollars on vintage-by-year fixed effects and annual jurisdiction indicators. The grey bars show the 95 percent confidence intervals. The 2009 policy change year is the omitted base-year. The 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 6: ECAD audit disclosure propensity by energy efficiency of home sold



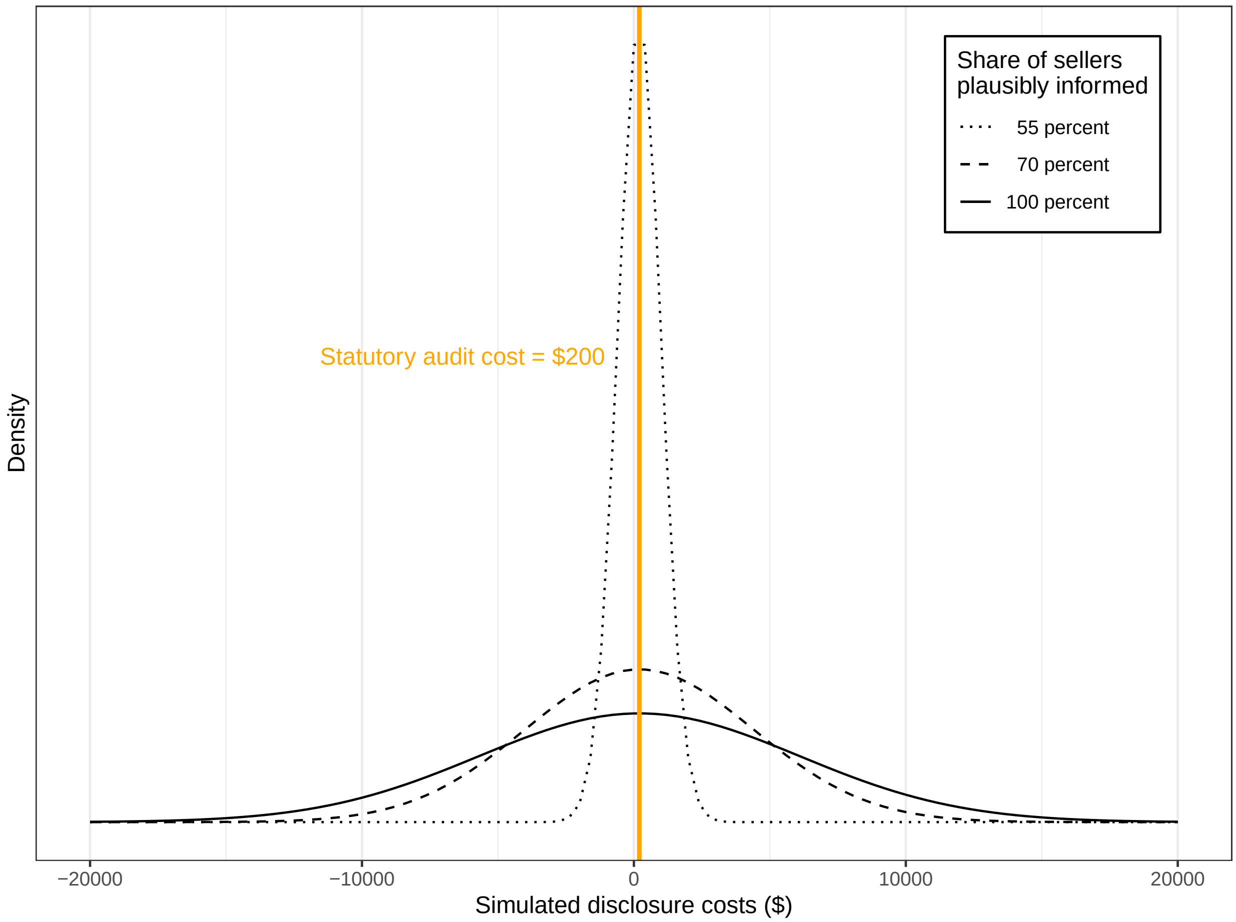
Notes: Figure 6 plots the share of in-sample homes sold inside Austin and outside Austin, separately, post-June 2009 that complied with the ECAD policy by obtaining and disclosing an energy efficiency audit, across the homes' energy efficiency quantiles. Each point depicts a local average compliance rate for the respective energy efficiency decile. The line shows the linear fit to the underlying microdata.

Figure 7: Illustration of various scenarios in theoretical model



Notes: Figure 7 depicts four scenarios in illustration of the theoretical model described in Section B. The solid line illustrates the scenario with non-stochastic costs 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 50 percent probability and further expands the scope of variation in the audit cost across sellers.

Figure 8: Simulation results: Plausible share of Informed sellers by audit cost heterogeneity



Notes: Figure 8 plots results from simulations of the model for the maximum share of plausibly informed sellers at various given spreads in audit compliance costs. We set the mean disclosure cost fixed at $200, representing the statutory typical direct cost of obtaining an audit. We then simulate distributions of audit costs drawn from a normal distribution with this mean and a specified standard deviation. Using increments of $100 for the standard deviation, we increase the spread of the normal distribution until a given share (e.g. 55 percent) of sellers could be plausibly informed in the framework of the benefit-cost model. 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	0.810	1.607	1.686
	(1.004)	(0.830)	(0.875)
# Times sold: post-June 2009	0.222	0.447	0.432
	(0.471)	(0.590)	(0.572)
Year built (vintage)	1973	1972	1987
	(17.52)	(17.33)	(9.39)
Square feet	1839	1779	2422
	(931.4)	(759.5)	(1143.4)
Energy efficiency proxy	0.499	0.534	0.448
	(0.289)	(0.275)	(0.286)
Monthly electricity use (kWh)	1178	1085	1650
(2006-2014 only)	(711.5)	(580.1)	(1024.0)
Monthly kWh/SqFt	0.673	0.635	0.693
(2006-2014 only)	(0.293)	(0.249)	(0.269)
Sale price ($)		228,009	316,015
		(185,215)	(312,892)
Pre-sale EE rebates ($)		29.65	27.51
(2006-2014 only)		(187.7)	(176.2)
Properties	131,050	53,766	11,697

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 effect of energy audit disclosure on the natural log of homes' sale price

	Dependent variable: Natural log of sale price			
	(1)	(2)	(3)	(4)
Panel [A]: Reduced-form estimates				
Energy efficiency	0.044	−0.009	0.005	0.003
X I{Post June-2009}	(0.040)	(0.014)	(0.015)	(0.017)
Energy efficiency				
X I{Inside Austin}	0.188***	0.097***	0.071***	0.081***
X I{Post June-2009}	(0.032)	(0.011)	(0.022)	(0.022)
Panel [B]: Average treatment effects				
Energy efficiency	0.414***	0.217***	0.163***	0.184***
X I{ECAD-audited}	(0.073)	(0.025)	(0.052)	(0.049)
Sales sample	All	Repeat	Repeat	Repeat
Spatial fixed effects	Jurisdiction	Property	Property	Property
Time fixed effects	Vint-month	Vint-month	Juris-month	V-M and J-M
Mean sale price ($)	244,343	249,367	249,367	249,367
Number of homes	65,462	28,639	28,639	28,639
Observations	106,045	69,222	69,222	69,222

*p<0.1; **p<0.05; ***p<0.01 Each column presents estimates for the effect of energy audit disclosure on the natural log of homes' sale price. Panel [A] shows reduced-form estimates and Panel [B] shows the average treatment effects for specifications in which the Energy efficiency X I{Inside Austin} X I{Post June-2009} term is used as the instrument. 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 3 shows annual coefficients for energy efficiency capitalization for each jurisdiction. Standard errors in parentheses are clustered at the level of energy efficiency quartile by jurisdiction by sale year.

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

	Dependent variable: Total energy efficiency rebate dollars			
	By seller: within 2-years pre-sale		By buyer: within 2-years post-sale	
	All programs	HPWES	All programs	HPWES
	(1)	(2)	(3)	(4)
I{Inside Austin} X I{Post June-2009}	13.2*** (4.3)	16.5*** (4.2)	13.5* (7.1)	22.5*** (6.4)
Post June-2009 mean	42.4	26.8	83.3	61.3
Spatial fixed effects	Jurisdiction	Jurisdiction	Jurisdiction	Jurisdiction
Time fixed effects	Vint-month	Vint-month	Vint-month	Vint-month
Number of homes	65,462	65,462	65,462	65,462
Observations	106,045	106,045	106,045	106,045

*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. HPWES is the Home Performance with Energy Star program for home weatherization. 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 5 shows the coefficients by year corresponding to Column (1). Standard errors in parentheses are clustered at the level of energy efficiency quartile by jurisdiction by sale year.

Mandatory Energy Efficiency Disclosure in Housing Markets

Erica Myers, Steven Puller, and Jeremy West

Online Appendix

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	0.114***	0.059***	−0.179***	1.886***	−1.755***
	(0.015)	(0.015)	(0.010)	(0.289)	(0.358)
Mean	0.380	0.614	0.113	21.63	18.80
Std. Dev.	0.485	0.487	0.317	8.932	11.07
Observations	13,215	13,036	13,110	12,464	12,605

*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	0.0023*
	(0.0017)	(0.0047)	(0.0015)	(0.0018)	(0.0014)
I{Inside Austin} X I{Post 2009}	0.0063***	0.0012	−0.0006	0.0008	−0.0015
	(0.0021)	(0.0048)	(0.0019)	(0.0023)	(0.0018)
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	131,050	131,050	131,050	65,620	65,430
Observations	2,357,046	1,180,071	2,357,046	1,179,976	1,177,070

*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 at the level of energy efficiency quartile by jurisdiction by sale year.

Table A3: ECAD audit disclosure: Difference in differences estimates

	Dependent variable: Indicator for ECAD audit			
	(1)	(2)	(3)	(4)
I{Inside Austin} X I{Post June-2009}	0.455*** (0.010)	0.461*** (0.010)	0.455*** (0.011)	0.452*** (0.012)
Sales sample	All	All	Repeat	Repeat
Spatial fixed effects	Jurisdiction	Jurisdiction	Property	Property
Time fixed effects	Sample month	Vint-month	Sample month	Vint-month
Number of homes	65,462	65,462	28,639	28,639
Observations	106,045	106,045	69,222	69,222

*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 2 shows annual average ECAD audit rates by jurisdiction for this full sample. Standard errors in parentheses are clustered at the level of energy efficiency quartile by jurisdiction by sale year.

Table A4: Estimated price capitalization of energy efficiency due to ECAD policy

	Dependent variable: Natural log of sale price	
	(1)	(2)
Energy efficiency	0.003	−0.005
X I{Post June-2009}	(0.017)	(0.017)
Energy efficiency		
X I{Inside Austin}	0.081***	0.035
X I{Post June-2009}	(0.022)	(0.025)
Sales sample	Actual	Placebo
Spatial fixed effects	Property	Property
Time fixed effects	V-M and J-M	V-M and J-M
Mean sale price ($)	249,367	379,938
Number of homes	28,639	5,723
Observations	69,222	13,415

*p<0.1; **p<0.05; ***p<0.01 The placebo sample is homes constructed between 1999 and 2005. Standard errors in parentheses are clustered at the level of energy efficiency quartile by jurisdiction by sale year.

Table A5: Estimated effect of energy audit disclosure on the natural log of homes' sale price—Border sample

	Dependent variable: Natural log of sale price			
	(1)	(2)	(3)	(4)
Panel [A]: Reduced-form estimates				
Energy efficiency	0.009	−0.011	−0.026	−0.012
X I{Post June-2009}	(0.046)	(0.014)	(0.017)	(0.017)
Energy efficiency				
X I{Inside Austin}	0.153***	0.073***	0.104***	0.075***
X I{Post June-2009}	(0.036)	(0.011)	(0.023)	(0.025)
Panel [B]: Average treatment effects				
Energy efficiency	0.356***	0.182***	0.249***	0.176***
X I{ECAD-audited}	(0.088)	(0.028)	(0.057)	(0.060)
Sales sample	All	Repeat	Repeat	Repeat
Spatial fixed effects	Jurisdiction	Property	Property	Property
Time fixed effects	Vint-month	Vint-month	Juris-month	V-M and J-M
Mean sale price ($)	260,286	263,681	263,681	263,681
Number of homes	35,694	15,757	15,757	15,757
Observations	58,022	38,085	38,085	38,085

*p<0.1; **p<0.05; ***p<0.01 Each column presents estimates for the effect of energy audit disclosure on the natural log of homes' sale price. Panel [A] shows reduced-form estimates and Panel [B] shows the average treatment effects for specifications in which the Energy efficiency X I{Inside Austin} X I{Post June-2009} term is used as the instrument. 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. Only the fifty percent of properties closest to the Austin border are included. Standard errors in parentheses are clustered at the level of energy efficiency quartile by jurisdiction by sale year.

Table A6: Estimated price capitalization of energy bills due to ECAD policy

	Dependent variable: Natural log of sale price			
	(1)	(2)	(3)	(4)
Panel [A]: Reduced-form estimates				
Log(annual bill/sqft)	0.019	0.033***	0.019	0.006
X I{Post June-2009}	(0.024)	(0.011)	(0.013)	(0.013)
Log(annual bill/sqft)				
X I{Inside Austin}	−0.148***	−0.095***	−0.074***	−0.064***
X I{Post June-2009}	(0.025)	(0.011)	(0.017)	(0.016)
Panel [B]: Average treatment effects				
Log(annual bill/sqft)	−0.327***	−0.212***	−0.174***	−0.148***
X I{ECAD-audited}	(0.059)	(0.025)	(0.044)	(0.038)
Sales sample	All	Repeat	Repeat	Repeat
Spatial fixed effects	Jurisdiction	Property	Property	Property
Time fixed effects	Vint-month	Vint-month	Juris-month	V-M and J-M
Mean sale price ($)	244,343	249,367	249,367	249,367
Mean annual bill/sqft ($)	0.714	0.706	0.706	0.706
Mean square footage	1908	1925	1925	1925
Number of homes	65,462	28,639	28,639	28,639
Observations	106,045	69,222	69,222	69,222

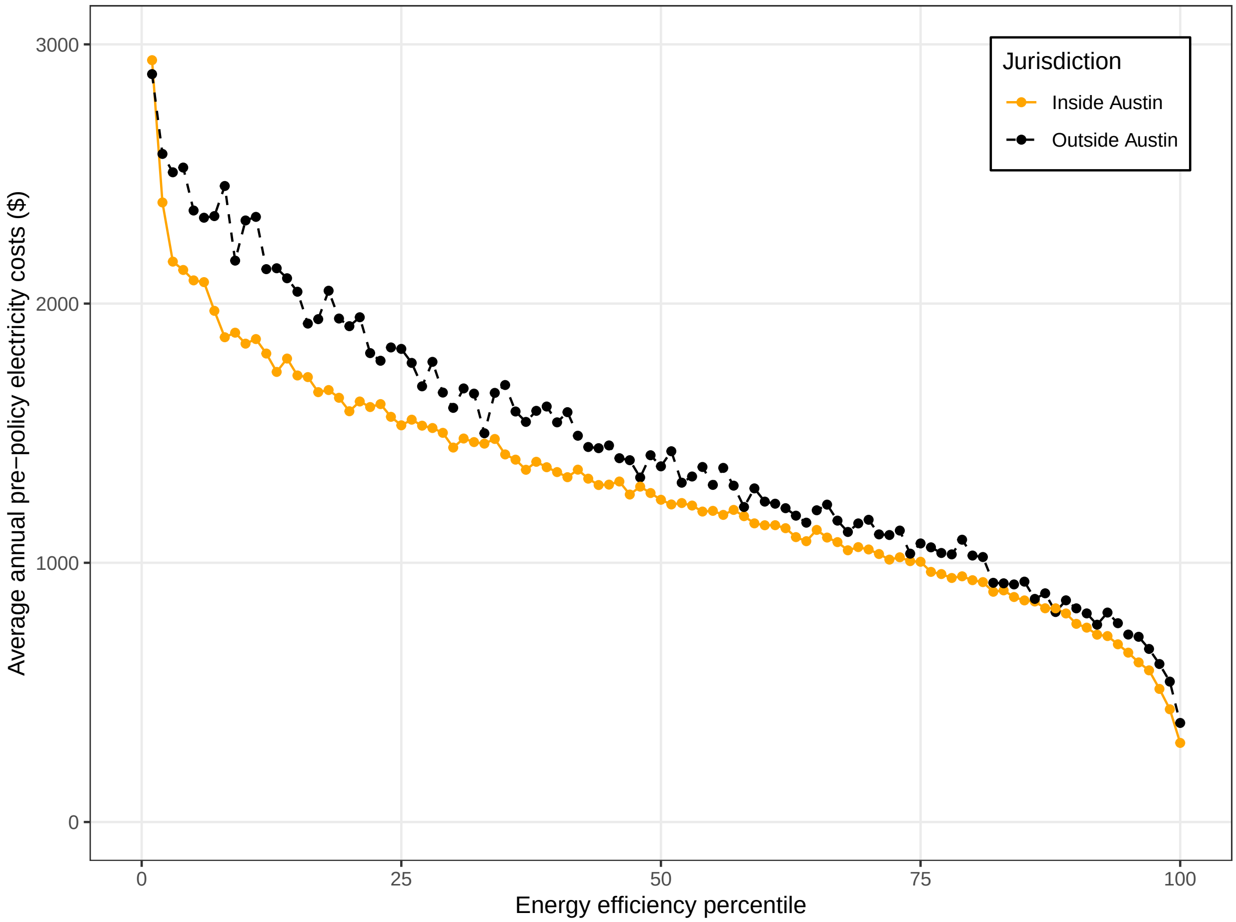
*p<0.1; **p<0.05; ***p<0.01 Each column presents estimates for the capitalization of pre-policy energy bills per square foot into home sale prices. Panel [A] shows reduced-form estimates and Panel [B] shows the average treatment effects for specifications in which the Log(annual bill/sqft) X I{Inside Austin} X I{Post June-2009} term is used as the instrument. The ECAD audit disclosure program for all sales inside Austin took effect in June 2009. Figure 3 shows annual coefficients for energy efficiency capitalization for each jurisdiction. Standard errors in parentheses are clustered at the level of energy efficiency quartile by jurisdiction by sale year.

Table A7: Energy efficiency program rebates: Difference in differences estimates—Border sample

	Dependent variable: Total energy efficiency rebate dollars			
	By seller: within 2-years pre-sale		By buyer: within 2-years post-sale	
	All programs	HPWES	All programs	HPWES
	(1)	(2)	(3)	(4)
I{Inside Austin}	16.6***	18.2***	19.8**	28.6***
X I{Post June-2009}	(5.0)	(5.1)	(9.3)	(8.4)
Post June-2009 mean	47.0	28.7	89.6	64.6
Spatial fixed effects	Jurisdiction	Jurisdiction	Jurisdiction	Jurisdiction
Time fixed effects	Vint-month	Vint-month	Vint-month	Vint-month
Number of homes	35,694	35,694	35,694	35,694
Observations	58,022	58,022	58,022	58,022

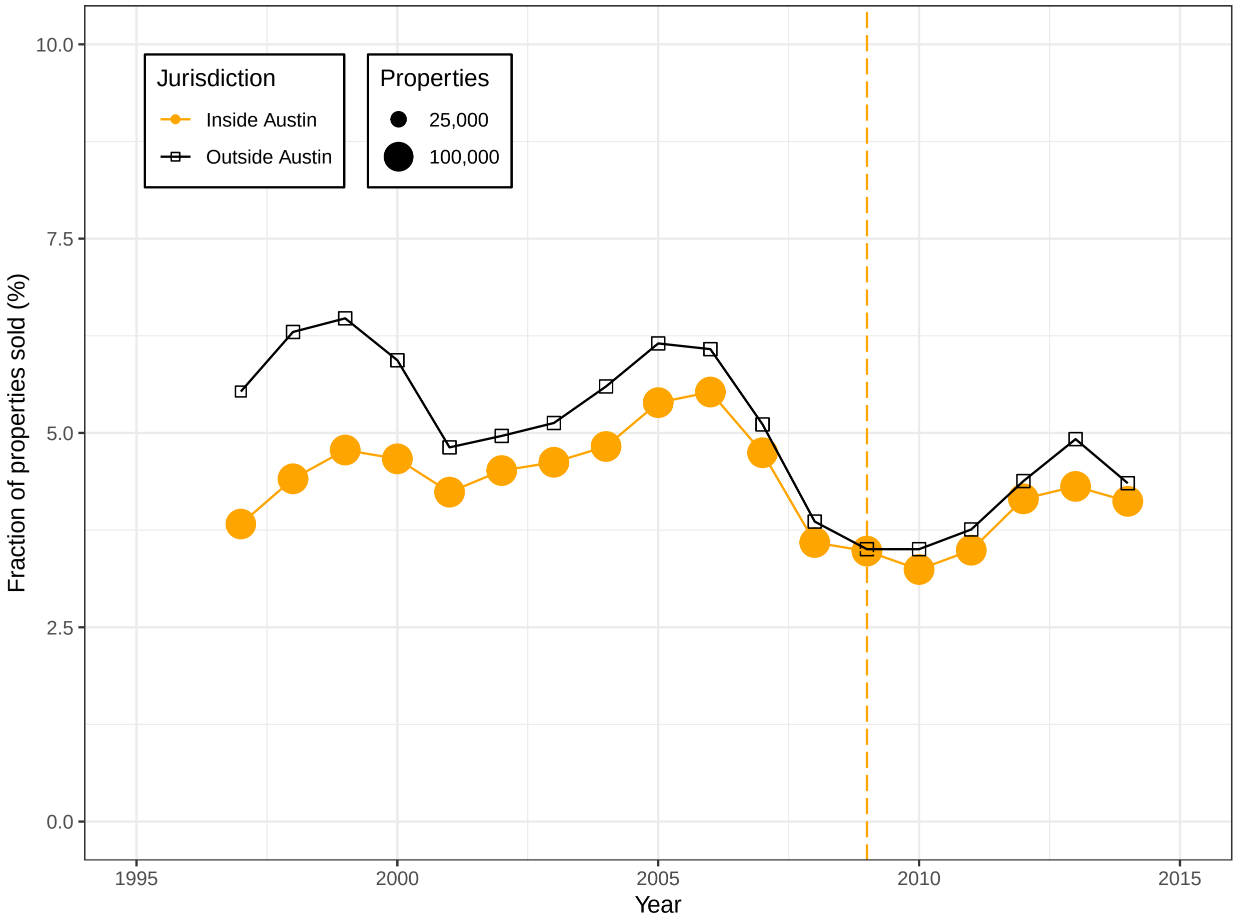
*p<0.1; **p<0.05; ***p<0.01 Each column presents a difference in differences estimate for the total energy efficiency program rebate dollars paid to the property owner for participation in the indicated energy efficiency program(s) during the indicated time period. Columns (1) and (2) evaluate rebates 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. Only the fifty percent of properties closest to the Austin border are included. Standard errors in parentheses are clustered at the level of energy efficiency quartile by jurisdiction by sale year.

Figure A1: Average Annual Energy Bill by Energy Efficiency Percentile



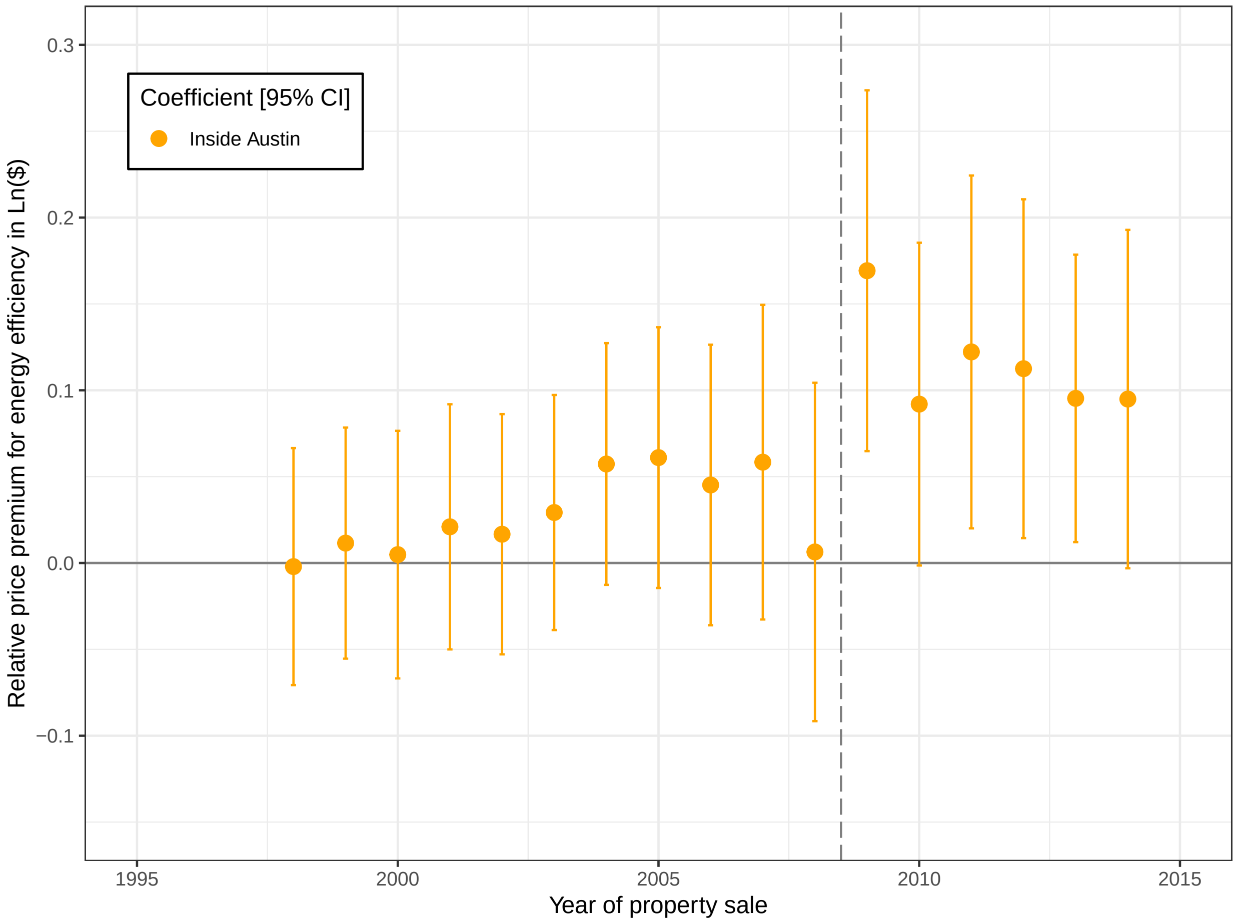
Notes: Figure A1 plots average annual pre-policy electricity costs for each percentile of the energy efficiency proxy in each jurisdiction.

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



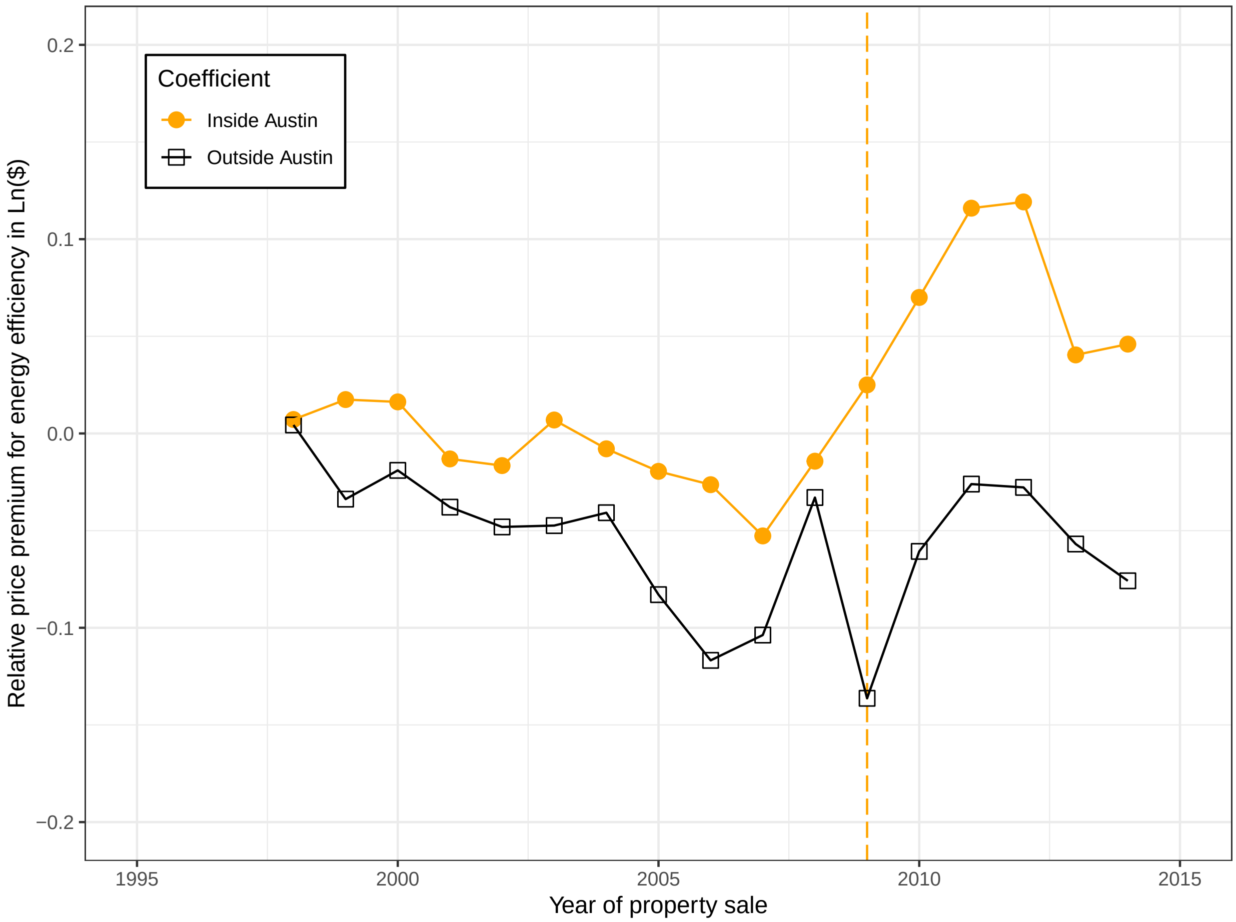
Notes: Figure A2 plots the annual fraction of in-sample homes sold by jurisdiction, inside Austin versus outside of the Austin city limits. The dashed vertical line at 2009 indicates when the ECAD residential energy efficiency audit and disclosure policy went into effect for homes aged 10 years or older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

Figure A3: Event Study of the Difference in the House Price-Efficiency Slope Between Austin and Outside Austin



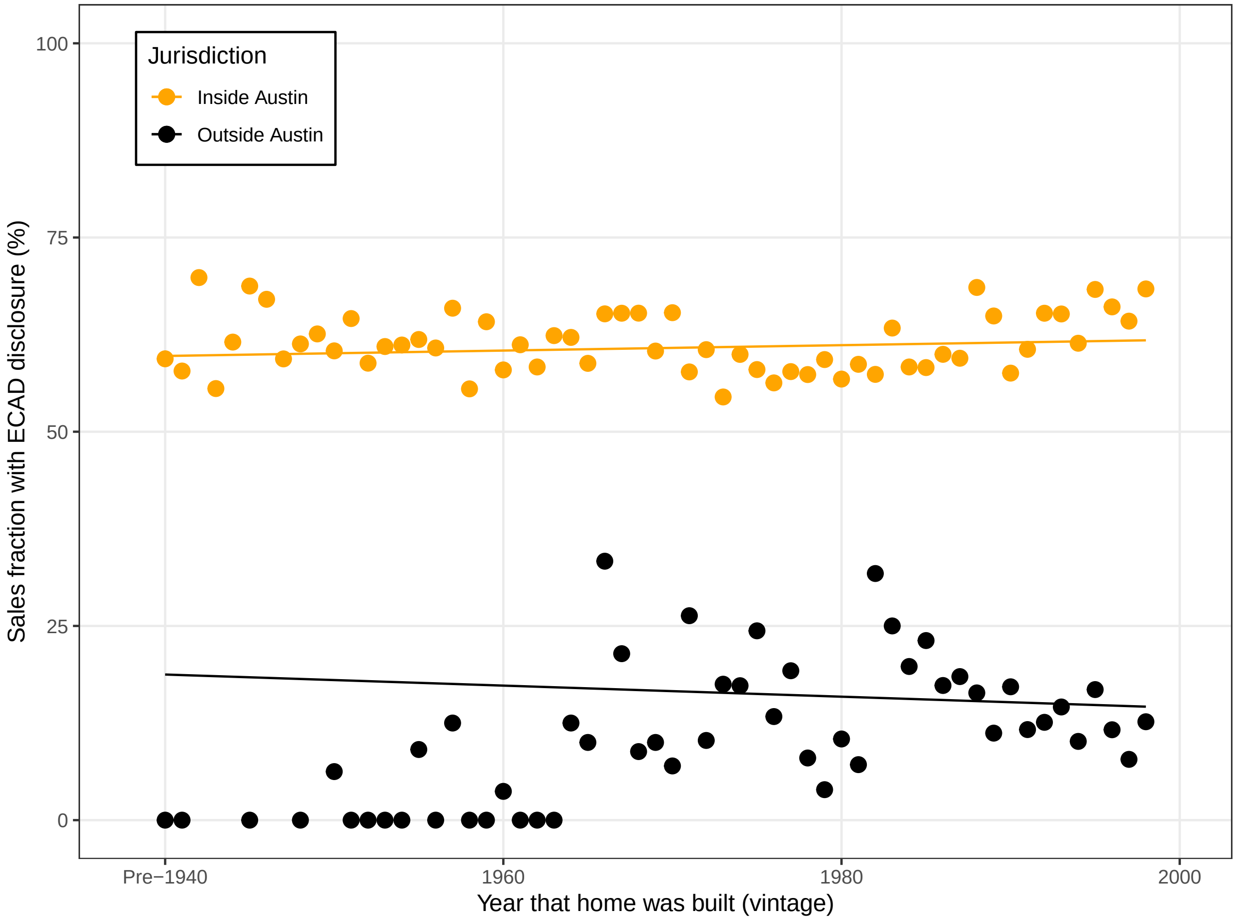
Notes: Figure A3 plots coefficients $\eta_{1998} - \eta_{2014}$ from the following regression, where all variables are defined as in Equation 1 in the main text: $ln(P_{ivjt}) = \sum_{1998}^{2014} \eta_t EEProxy_i \times Austin_j + \sum_{1998}^{2014} \theta_t EEProxy_i + \mu_i + \tau_{vt} + \zeta_{jt} + \varepsilon_{ivjt}$. The omitted base-year is 1997. These coefficients represent year-specific estimates of the difference in the price-efficiency slope between Austin and the comparison group.

Figure A4: Estimated relative energy efficiency price premiums by jurisdiction—Border sample



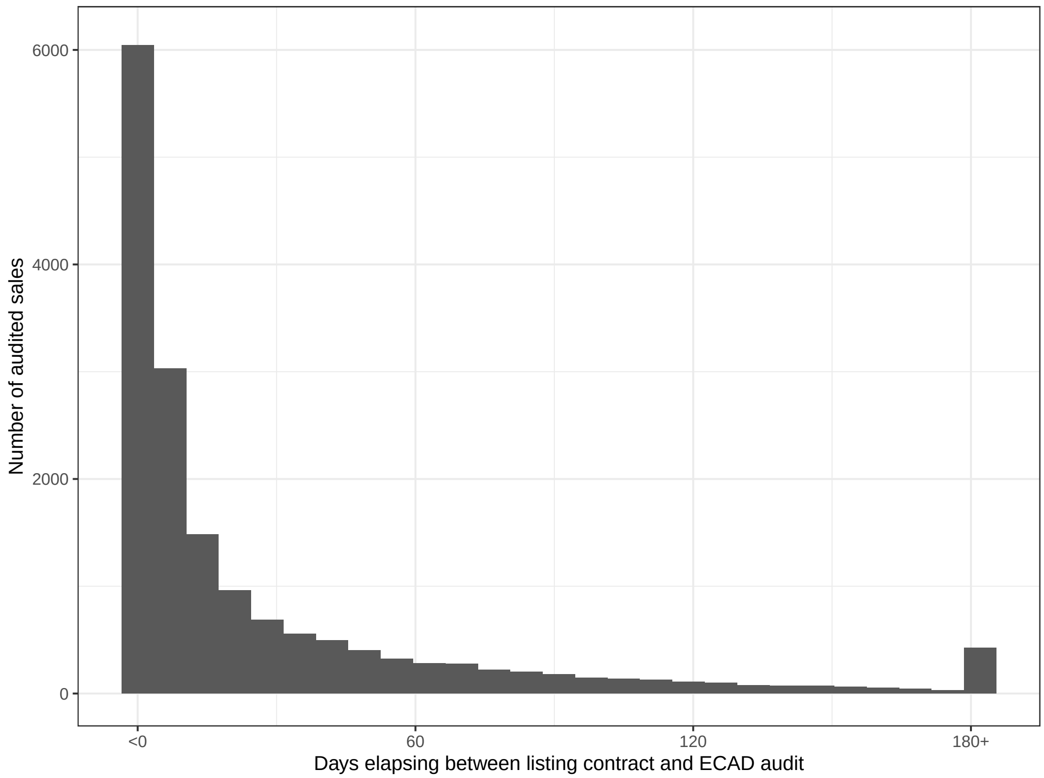
Notes: Figure A4 plots coefficients by jurisdiction – inside Austin versus outside of the Austin city limits – from regressing the natural log of homes' sale prices on the homes' energy efficiency, a term that ranges continuously from zero to one and indicates each home's fixed energy efficiency quantile. 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. Only the fifty percent of properties closest to the Austin border are included.

Figure A5: ECAD audit disclosure propensity by vintage for each jurisdiction

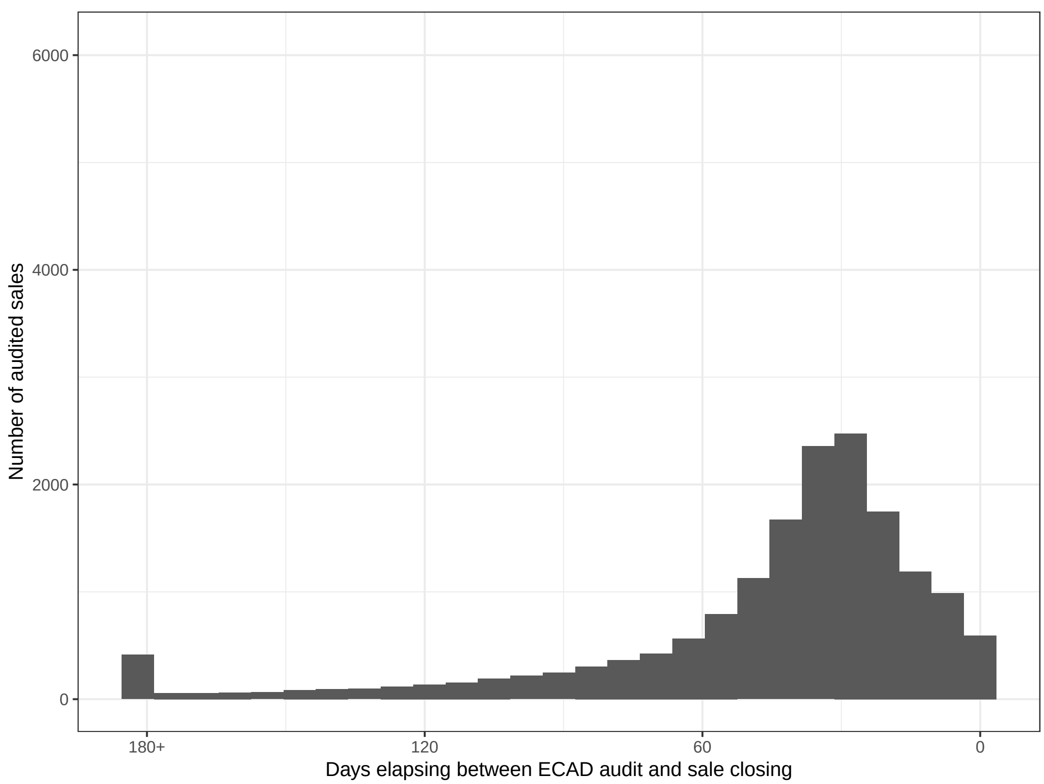


Notes: Figure A5 plots the share of in-sample homes sold inside/outside Austin post-June 2009 that obtained and disclosed an ECAD energy efficiency audit, across vintages. Each point depicts a local average compliance rate for the respective year built. The line shows the linear fit to the underlying microdata.

Figure A6: Timing of ECAD audits with respect to listing and sale contracts



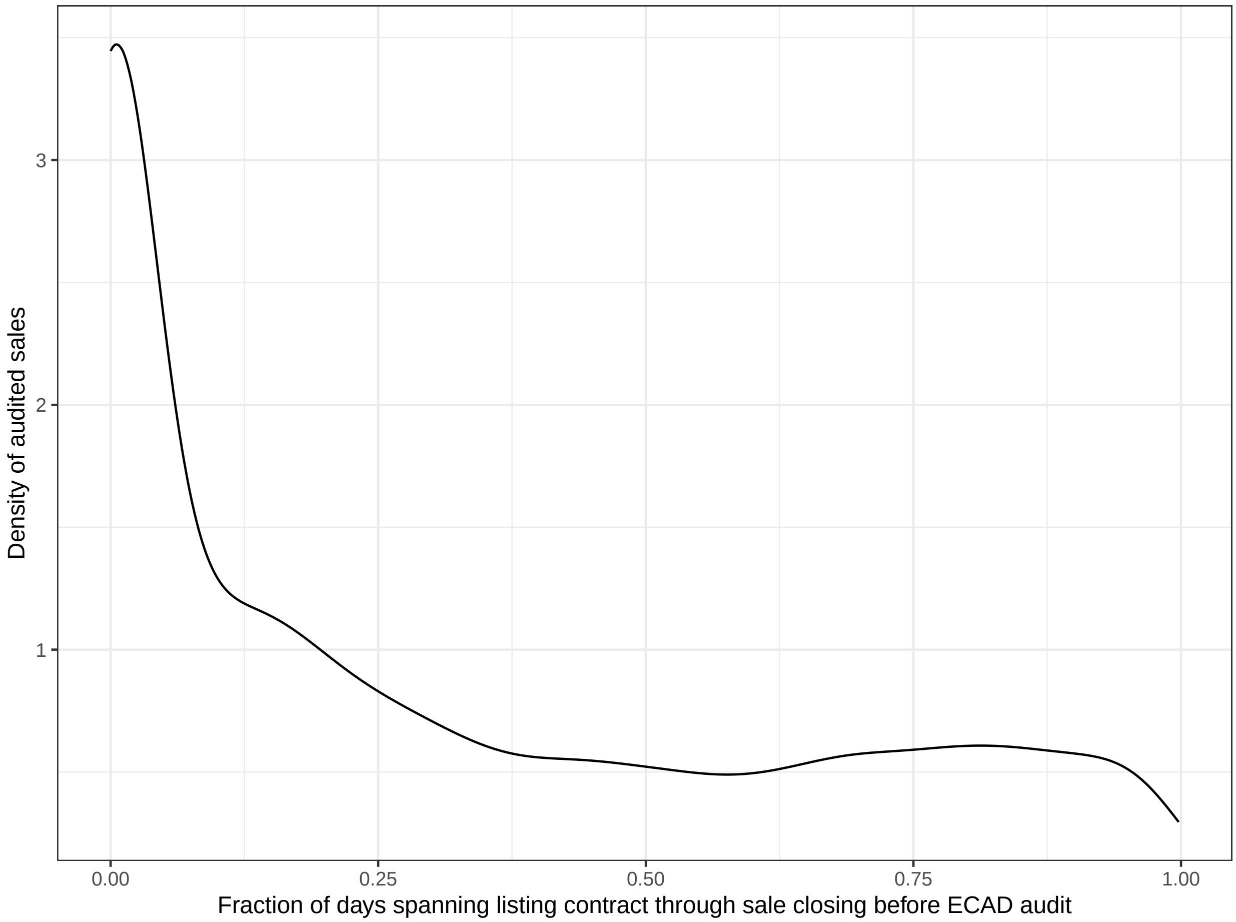
(a) Duration from listing contract to ECAD audit



(b) Duration from ECAD audit to sale closing

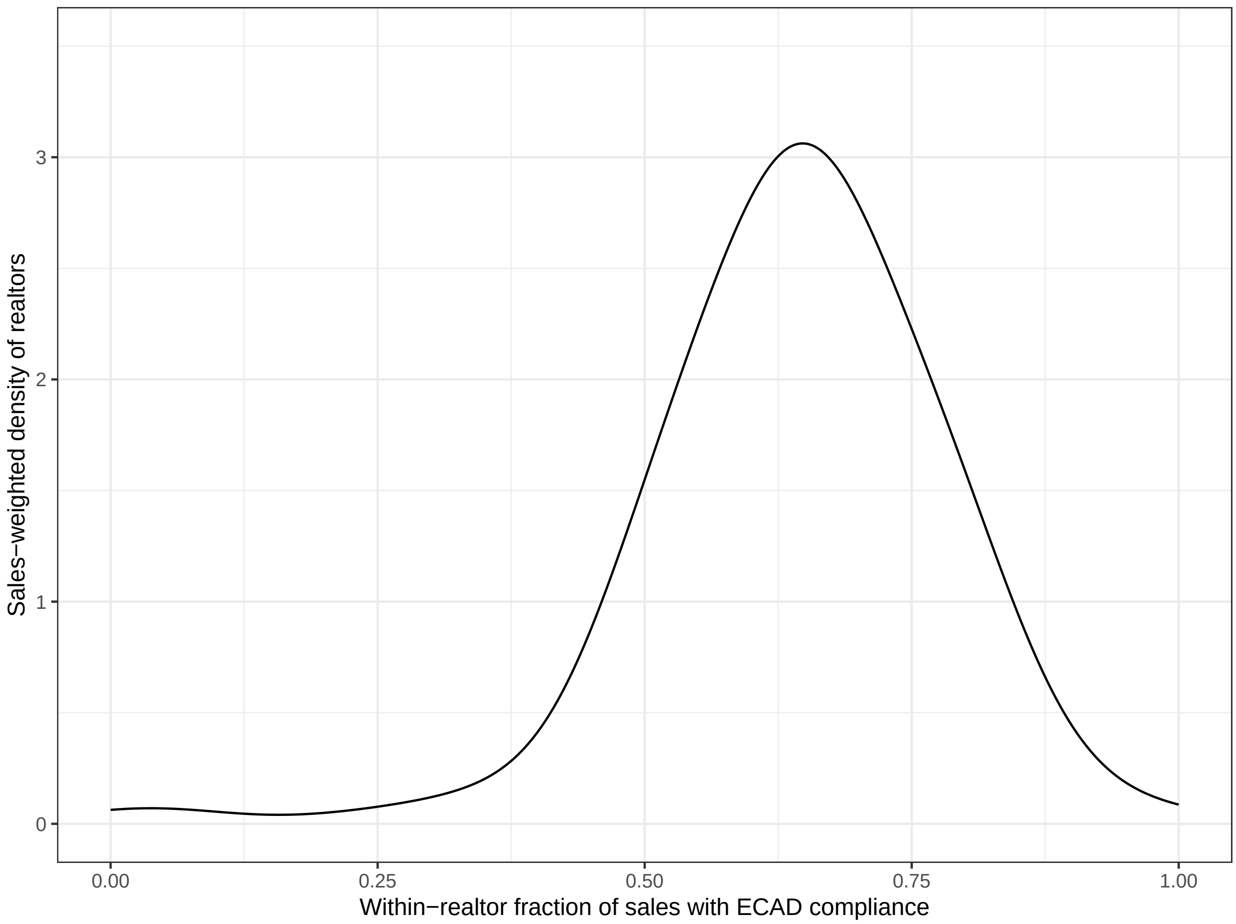
Notes: The date of the listing contract is when the seller formalizes an agreement with the seller's realtor to market the property, which typically occurs before any marketing activities. The date of the sale closing is the official closing date for the property sale transaction.

Figure A7: Timing of ECAD audits with respect to listing and sale contracts



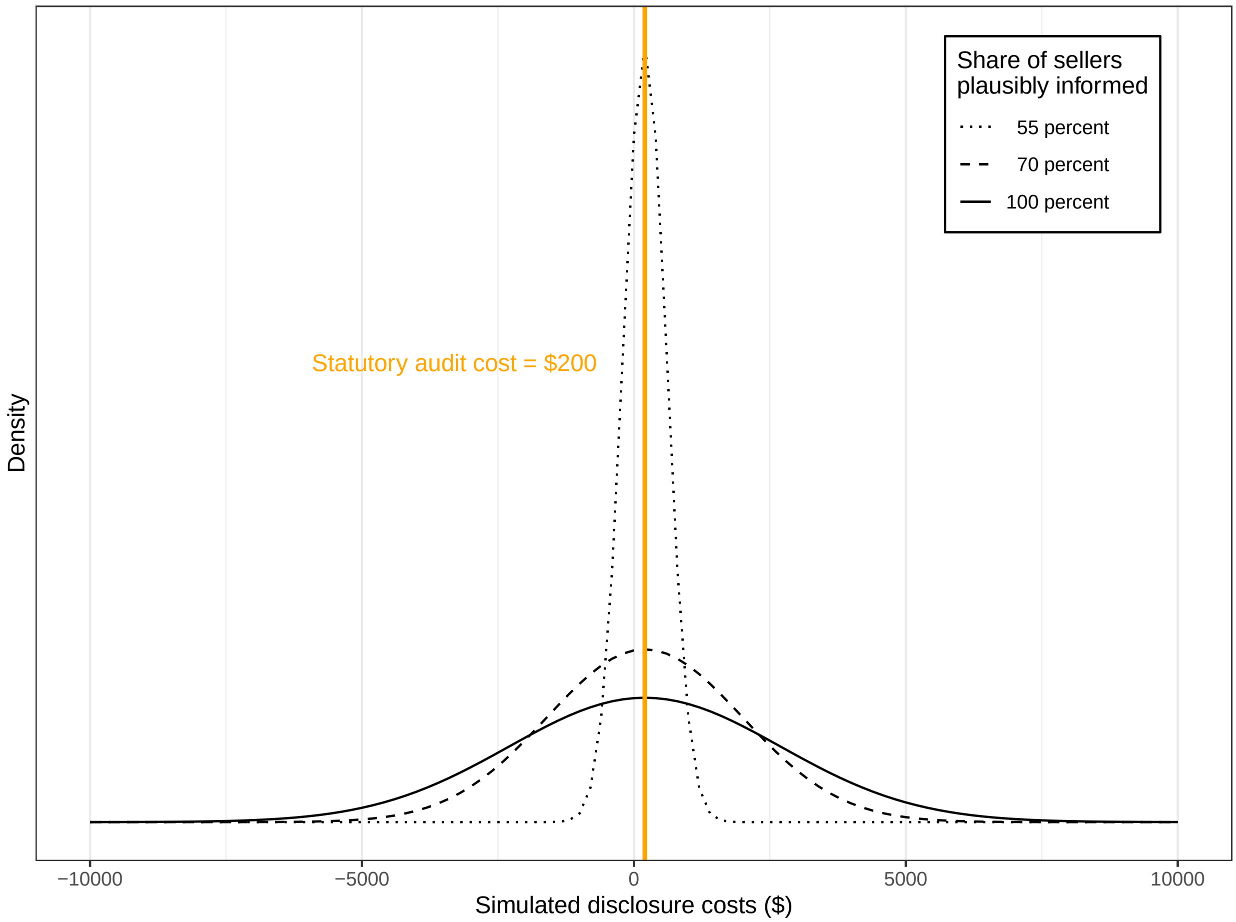
Notes: Appendix Figure A7 shows the density of the fraction of days spanning between the listing contract and the ECAD audit with respect to the total number of days the property was marketed (spanning from the listing contract through the sale closing contract). For example, if a property was audited 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 A8: Density of ECAD compliance rates across realtors



Notes: Appendix Figure A8 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.

Figure A9: Simulation results: Plausible share of Informed sellers by audit cost heterogeneity—using reduced-form price estimates



Notes: Conducts the same simulation as in Figure A9 but uses reduced-form estimates for the price-energy efficiency effects of the ECAD policy.

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.

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

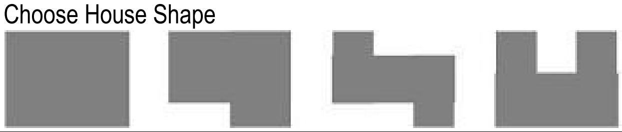
WINDOWS & SHADING

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