Does the Housing Market Value Energy Efficient Residential Homes? Evidence from the Energy Star Program †

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Abstract

The "Energy Star" certification of residential homes is a recent attempt in the United States to improve energy efficiency in the residential sector by incentivizing homebuilders to "build green." We examine the effectiveness of this program by estimating homeowners' marginal willingness to pay for Energy Star residences in Gainesville, Florida. We use single-family residential property sales in Gainesville, Florida between 1997 and 2009 using the hedonic method. We find that homeowners are willing to pay a premium for new Energy Star residences, but that this premium fades rapidly in the resale market.

Keywords: Energy Star; Hedonic Method; Housing Prices; Repeat Sales.

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1. Introduction

Residential energy use accounts for nearly a quarter of total energy consumption in the United States. Homeowners use more electricity and natural gas than the commercial, industrial, or transportation sectors of the economy.[1] This voracious appetite for energy means that homeowners in the U.S. devote on average 7.5 percent of their total spending to utility bills.[2] Improving energy efficiency in the residential sector of the economy has been an important goal of energy policy in the United States in the last 15 years. However, with the increased awareness of pollution externalities and the sense of urgency stirred up by the debate over global warming, public discussion about economic, health, and environmental issues related to residential energy use has increased dramatically in recent years.

Policymakers have used two key strategies to improve the energy efficiency of residential homes. The first strategy has been to simply regulate the energy efficiency of new residential homes. Most states have state-wide residential building codes that specify how energy efficient new residential homes must be. These building codes apply to all residential homes and have become stricter over time in many states. The second strategy is a voluntary certification program more recently implemented by the Environmental Protection Agency (EPA) and the US Department of Energy (DOE). This program uses the “Energy Star” label that was initially used to certify computers, printers and fax machines in the early 1990’s. Since 1995 it was announced that homebuilders can certify their new residential homes with the Energy Star label, indicating

[1] These statistics were obtained from the Energy Information Administration; electricity data can be accessed electronically at http://www.eia.gov/energyexplained/index.cfm?page=electricity_use, and natural gas data can be accessed at http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm.
[2] Data on household spending was obtained from the US Bureau of Labor Statistics and can be accessed electronically at http://www.bls.gov/cex/csxreport.htm#annual.

that these residences achieved a 30% efficiency improvement over the model energy code.[3] The basic premise of this program is that by providing information on the energy efficiency of new residences in a low-cost way through the Energy Star label, problems of asymmetric information and costly search can be alleviated, causing increased demand for energy efficient residential homes from homebuyers and thereby incentivizing homebuilders to build more energy efficient residences. A key marketing point of the Energy Star program for residential residences is that besides the benefits to a homeowner of lower utility bills, enhanced performance, and the warm-glow they may get from "being green", Energy Star residences resell for more than less efficient residences.[4] Nonetheless, this important claim that Energy Star residential residences would maintain a price premium in the housing market has not been tested in the literature. Our study tests this claim by examining how energy efficiency and the Energy Star label are capitalized into housing prices. We use actual transaction data from the housing market in Gainesville, Florida to estimate buyers' marginal willingness to pay for both new and used Energy Star residences. To our knowledge, our study is the first to examine the Energy Star resale premium in *any* market.

Previous studies have found that energy efficiency affects sale and rental premiums of residences and office buildings. Laquatra et al. (2002) survey 11 studies that consistently show that energy efficient residences do command a sale price premium. However, data limitations and technological changes since the 70s and 80s (when several of the studies were conducted)

[3] Energy Star certification usually happens before the first owner moves in and begins using electricity, so the label is awarded based on *estimated* efficiency improvements. We discuss the implications of this for the value of the label in subsequent sections of this paper.

[4] Marketing brochures for Energy Star homes provided by the EPA quote a current Energy Star homeowner as saying "My biggest selling point for buying an Energy Star home was resale value. I would highly recommend Energy Star to anyone because it will definitely save them money in the long run." Another marketing brochure on the Energy Star website says "And should the time come to consider selling your home, the trusted Energy Star label will set it apart as something better: a home of genuine quality, comfort and efficiency." The brochure can be found at: www.energystar.gov/ia/partners/downloads/consumer_brochure.pdf

make results difficult to interpret and compare. For example Nevin and Watson (1998) show that a $1 per year increase in savings from utility bills is associated with a $25 increase in residence value. However, the authors have no information about construction characteristics (i.e. how efficient the residence is) and rely on self-reported utility bills, which might be endogenous with residence price. They also lack important neighborhood-level variables such as school quality and crime. Another study, Banfi et al. (2008), uses stated-preference methods, not actual market transactions to evaluate whether or not homeowners and renters would be willing to pay for improved energy efficient features in their residence. Other previous studies on the price premiums for energy efficient construction face similar data challenges.

More recently, Eicholtz, Kok, and Quigley (2010) find that Energy Star and LEED (another energy efficient label) office buildings command a 3 percent rent premium and a 16 percent sale premium relative to conventional office buildings. Kahn and Kok (2013) show that Energy Star, LEED, and GreenPoint Rated residences in California sell for a 4 percent premium relative to baseline residences. These price premiums depend on factors such as local climate and neighborhood hybrid vehicle ownership. Bloom, Nobe, and Nobe (2011) also find that Energy Star residences in Colorado have an initial sale price that is about $8.66/sq. foot above the price of conventional residences in the area. Deng, Li and Quigley (2012) analyze the economics of green buildings (Green Mark) in the residential sector for 250 projects in the city of Singapore.

Our research makes two specific contributions to the Energy efficiency literature: (1) we reexamine the Energy Star premium for new residences with a dataset that overcomes many of the problems faced by earlier researchers, and (2) we are the first to examine the change in the Energy Star price premium over time. These contributions help us to understand the success of the Energy Star program at encouraging green construction and to more broadly understand how energy efficiency is capitalized into housing prices. Our study finds that new Energy Star residences sell for more than similar conventional residences, but that Energy Star residences resell for approximately the same amount as conventional residences. Although we are unable to completely pin down the mechanism by which the Energy Star premium deteriorates over time, we discuss several possibilities. Our results have implications for the long-term role of the Energy Star program in promoting green construction, and they will be important to address the causes of the deterioration of the Energy Star premium for used residences if the label in the housing market will be successful in the coming decades.

The remainder of this study is organized as follows: Section 2 presents background information on the Energy Star program and describes the features included in new Energy Star residences, Section 3 describes our study area and data, Section 4 presents our econometric model, Section 5 discusses the results and the implications of our findings, and Section 6 concludes.

2. Background on the Energy Star Program for Residential Homes

The Energy Star label for new residential homes was introduced in October 1995 by the Environmental Protection Agency (EPA), and the first Energy Star home was built in Gainesville, FL, in 1997.[5] The label had already achieved a large market share in household appliances such as personal computers, printers, and monitors, and the extension of the label to

[5] Information about the history of the Energy Star program can be found online at http://www.energystar.gov/index.cfm?c=about.ab_milestones.

new homes signaled the popularity and pervasiveness of energy consciousness. By 2010 the EPA reported that over 25 percent of new residences across the US met Energy Star standards.[6]

The program operates through a voluntary labeling system; builders have the opportunity but not the obligation to hire an independent auditor to certify their residential homes to receive the Energy Star label. A home energy rating involves an analysis of the residence's design and plans, as well as onsite inspections. To evaluate the design, an energy auditor will use a special software package that estimates a pre-construction Home Energy Rating System (HERS) Score.[7] Following the plan review, the auditor will work with the builder to identify the energy efficient improvements needed to ensure the house will meet Energy Star performance guidelines (e.g. more insulation, better air sealing, etc). These extra features may reduce air leakages under doors or through the roof and windows, thereby reducing energy consumption. Finally, the auditor will perform onsite inspections, typically including a blower door test and a duct test. Results from these tests and inspections, along with inputs derived from the plan review, are used to generate the HERS Score for the new home.[8] The first Energy Star homes were required to use 20 percent less energy than homes built under Florida's 1993 building code and 30 percent less energy than the national building code; the standards for Energy Star labeled homes in Florida were raised in 2007 because of the increasingly strict requirements of the state building code.

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[6] Statistics for the Energy Star market share for new homes can be found at http://www.energystar.gov/index.cfm?fuseaction=qhmi.showHomesMarketIndex.

[7] There are three scales to measure a home's energy performance. The Home Energy Rating System (HERS) Score is the oldest of the three metrics; higher HERS Scores correspond to more energy efficient homes. This scale was replaced by the HERS Index in 2006—the HERS Index is inverted relative to the HERS Score, so lower values on the HERS Index correspond to more energy efficient homes. A third scale, the EnergySmart Home Scale (E-scale), replaced the HERS Index in 2009. Analogous to the HERS Score, higher values on the E-scale correspond to more efficient homes.

[8] Because of the durability of the housing stock, it is easier to build a new Energy Star home than upgrade an existing home to meet the Energy Star requirements; this means that the Energy Star label primarily encourages new green construction.

An effective Energy Star label overcomes several failures in the housing market. By potentially raising sale and resale prices, it permits builders and buyers to consider lifetime residential home costs rather than just upfront capital and purchase costs. The label also reduces search and transaction costs for both buyers and sellers, making the market for homes more efficient (Gilman, 1989). Independent certification and the label's dependable reputation could make it easier for sellers to sell residences for a price that reflects the value of their energy-saving features. Additionally, the label potentially simplifies the decision process for a homebuyer. Since buyers deal with so many inputs in the home buying decision, a model of limited attention would suggest that some buyers may not optimally consider energy efficiency. The Energy Star label combines all of a residence's energy efficient features into a readily identifiable label, potentially making it much easier to market energy-efficient houses.

2.1 Energy Star Upgrades and Estimated Savings

To understand the features that make Energy Star residences more efficient than conventional residences, we visited the websites of several builders in the Gainesville area. Although many builders include environmentally-friendly features (for example, one of the builders, G.W. Robinson selects native, low-maintenance trees and plants), several distinguishing features seemed to be included in all new Energy Star residences.[9] All of the builders in our sample used low-e windows,[10] high R-value insulation in the walls and attic,[11]

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[9] For a list of some of the Energy Star builders in Florida, see http://www.energystar.gov/index.cfm?fuseaction=new_homes_partners.showStateResults&s_code=FL.

[10] Low-e windows have a thin metallic coat that prevents heat energy from entering the residence. The Department of Energy estimates that upgrading to these windows can translate into savings of close to $300 per year in heating climates such as the Northeast; estimated savings in Florida were approximately $60 to $70. More information can be found at http://www.energystar.gov/index.cfm?c=windows_doors.pr_benefits.

[11] R-Value is a measure of insulation's ability to resist heat traveling through it. The higher the R-Value the better the thermal performance of the insulation. Thus, a high R-value insulation transfers less heat than low R-value

and properly sized heating, ventilation, and air conditioning (HVAC) systems. Across the board, builders also installed tankless water heaters in all new Energy Star homes.[12] Although it does not provide a full picture of energy star savings overtime, Table 1 provides monetary estimates of the relative importance of each of these features.

The overwhelming consensus based on technical predictions is that Energy Star residences save money relative to conventional residences. In fact, homeowners might be able to afford bigger mortgages due to lower operating costs of efficient residences; in most cases, it is cheaper (both in terms of the initial cash outlay and the operating costs) to own an efficient residence than it is to own a conventional residence. Economic theory suggests that the benefits of an Energy Star residential home should create a price premium relative to a conventional residence.

2.2 Actual Savings from Energy Efficient Residential Homes

Although the technical predictions of builders and manufactures are helpful, ultimately the most important aspect of an energy efficient residence is the amount of energy that it *actually* saves relative to a conventional residence.[13] Several studies have examined this issue: Smith and Jones (2003), Jones et. al (2008), Jones et al. (2010), and Jacobsen and Kotchen (2013) are good examples that use residential homes in the Gainesville area.

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insulation. For more information, see http://www.energystar.gov/?c=home_sealing.hm_improvement_insulation_table

[12] The Energy Information Administration (EIA) estimates that in 2005, over 20 percent of residential energy consumption was from water heating, so tankless heaters that can be up to 40 percent more efficient can potentially save a lot of money. According to Consumer Reports, savings can be in the range of $70-$80 a year. See http://www.consumerreports.org/cro/appliances/heating-cooling-and-air/water-heaters/tankless-water-heaters/overview/tankless-water-heaters-ov.htm for more details.

[13] Although there does seem to be consensus that homes engineered to be efficient do save energy, there is research to suggest that some of the savings estimates are too optimistic. For example, Metcalf and Hassett (1999) find evidence to suggest that actual savings are frequently lower than projected savings; this helps to explain part of the low amount of green investment in the housing sector.

Smith and Jones (2003) combine billing data for several subdivisions in Gainesville with a list of Energy Star certified residences to determine the savings associated with energy efficient construction. Using an analysis of variance (ANOVA) framework, they show that Energy Star residences consume on average between 10 and 16 percent less electricity per year and between 17 and 21 percent less gas per year. Based on energy prices in 2000 and 2001, they estimate that Energy star residences cost about $180 less each year to operate than conventional residences in the study, translating to a payback period for investing in an Energy Star residence of about 6 years. They also suggest that the present value of these savings is on the order of $4,500, and that owners of energy efficient homes could afford a mortgage of $2,255 more than owners of conventional residences. These findings lead them to conclude that housing policy should not only consider upfront costs of residences, but also operating expenses.

In a follow up to Smith and Jones (2003), Jones et al. (2008) and Jones et al. (2010) examine how energy use in the same sample of Energy Star residences changed relative to conventional residences from 2000 to 2006. The authors find that although new Energy Star residences are more efficient than conventional residences of the same vintage, the energy use of both types of residences converges over time (i.e. occupants of Energy Star residences that are five years old use about as much electricity as occupants of conventional residences that are five years old). Although the authors suggest that this might be due to deterioration of the Energy Star capital, it also seems possible that this phenomenon could be driven by a rebound effect, which is a behavioral response of the occupants. For example, studies such as Greene et al. (1999) have shown that increased automobile efficiency induces drivers to travel more. Hence efficiency improvements are offset by increased travel or energy consumption. The same phenomenon likely affects the actual savings of Energy Star residences.

These papers show that savings from Energy Star residences decrease over time relative to conventional residences; this is a first step towards understanding the effectiveness of the label, but it gives an incomplete picture. If homeowners are offsetting energy efficiency by consuming more, they are better off. By supplementing these studies with an examination of the price premiums of Energy Star residences, we will be able to determine the value that the marginal buyer places on Energy Star residences and have a better idea of the welfare benefits of the Energy Star label.[14]

Another study that uses homes in Gainesville is Jacobsen and Kotchen (2013). This study takes advantage of a change in Florida's building code to estimate the causal effect of efficient construction on energy savings. The authors find that the 2001 (effective March 2002) change in Florida's building code caused a 4 percent decrease in electricity consumption and a 6 percent decrease in gas consumption. We seek to build upon the foundational work performed by these four papers; rather than examine savings from energy efficient features, we will try to determine the price premium commanded by Energy Star residences. This will supplement previous studies that examine the actual performance of existing green construction and help us to understand the value of efficient residences to consumers.

3. Study Area and Data

3.1 The Study Area: Gainesville, Florida

To estimate the price premium for Energy Star homes, our research also uses data from Gainesville; this area is popular for studies on energy efficient homes because of a rich database

[14] Although we don't assume any particular functional form for utility (and hence are not able to directly perform welfare calculations), loosely speaking, consumers are better off if the value of goods and services they consume increases.

of efficient homes maintained by the Florida Solar Energy Center. Gainesville is located in northern Florida, half way between the Gulf of Mexico and the Atlantic Ocean. Its warm, humid climate places Gainesville in the 70th percentile of counties in terms of the total number of degree-days annually (See Figure 1).[15] Since energy expenditures are lower in cooling climates such as Florida than they are in heating climates like the Northeast, we think our estimate of the value of the Energy Star label in Florida may be lower than the average value of Energy Star certification in the rest of the US.[16] Another factor that might reduce the magnitude of our estimates of the Energy Star premium is Florida's aggressive building code; in states where the local building code is not as stringent as Florida, it might be reasonable to observe a higher premium for Energy Star residences.

3.2 Assessor Data

Our study uses two primary sources of data to identify Energy Star residences in the Gainesville area. The first dataset was purchased from the Alachua County Property Appraiser's Office. This dataset includes nearly 6,000 observations of sale prices of single transactions of residential homes that occurred between January 1998 and August 2009 in Gainesville. It also includes hedonic characteristics such as age, number of bathrooms, lot acreage, heated and unheated square-footage, type of roof, type of exterior, type of flooring, type of interior wall, construction style and quality, and heating method.

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[15] Degree-days measure the amount of energy needed to heat and cool a building. There are two types of degree-days, heating degree-days, and cooling degree-days. More degree-days mean a higher energy requirement to keep buildings at a comfortable temperature.

[16] In 2005, for example, residents of the Northeast spent on average 99 cents per square foot on energy, while those in the South spent 81 cents per square foot. Average expenditures in the West and Midwest were 84 and 74 cents per square foot respectively. This data was obtained from the EIA and can be accessed online at http://www.eia.gov/consumption/residential/data/2005/c&e/summary/pdf/tableus1part1.pdf.

3.3 Energy Star Data

The second data set was graciously provided by Pierce Jones and was obtained from the Florida Solar Energy Center.[17] This data set includes HERS Scores for many homes in Alachua, as well as tax parcel identification numbers. The tax parcel identification numbers allow homes in both datasets to be matched. For our analysis, we need to assume that homes were not remodeled or damaged in such a way that the HERS scores that were measured prior to 2003 are still valid for homes that were sold after 2003. The residences in our dataset that scored above 86 on the HERS scale were all certified as Energy Star homes. [18]

Residential homes in the dataset are located primarily in five subdivisions in Gainesville: Mentone, Stillwind, Capri, Eagle Point, and Broadmoor. See Figure 1, for a location of each of these subdivisions within the Gainesville area. Buyers of new houses in these subdivisions had the opportunity to upgrade to an Energy Star home for about $1,200, and the largest concentration of Energy Star houses was in the Mentone subdivision (although all five subdivisions have both Energy Star and non-Energy Star homes). Because the houses come from only a few (mostly single-builder) subdivisions, there are fewer idiosyncratic differences in construction quality and technique. This allows us to control for unwanted within-community variation in quality. Although we can control for builder specific attributes, we assume throughout the study that builders did not systematically bundle the Energy Star label with desirable features (unobserved to us) that do not affect a house's HERS Score. Finally, since we lack data on the buyers of these residences, we are unable to examine demographic differences between buyers who upgraded and buyers who did not. The data are compiled so the unit of

[17] This is the dataset used in Smith and Jones (2003).
[18] We contacted the offices of the builders included in our sample; they confirmed by phone interviews that it was their practice to obtain an Energy Star Label if the residence obtained a HERS score of 86 or above.

observation is the sale of a house; each sale of a residence that sold more than once is included in the dataset. Summary statistics for the residences used in our analysis can be found in Table 2.

4. Econometric Methodology

We use the hedonic model to estimate the Energy Star sale price premium for residential homes. The hedonic model has been widely used to understand the value of urban and environmental amenities. In his seminal paper, Rosen (1974) describes how implicit (i.e. hedonic) prices can be ascribed to non-market goods based on observed transactions in related markets. Since the early work of Ridker and Henning (1967) many studies have analyzed the impact of air pollution and other disamenities on residential property values (see Palmquist (2005) for a review of the hedonic method).

The hedonic method can identify the value of a particular attribute of interest, in our case the Energy Star Label, when the housing market is perfectly competitive and is in equilibrium. The relaxation of the perfect competition assumption will make it impossible to identify homebuyers' *exact* marginal willingness to pay for the Energy Star label, but estimates will still give us an idea about the direction and magnitude of the effect.[19]

Analysis of the Energy Star premium lends itself nicely to the hedonic model. Since there is no direct market for the Energy Star label, its value cannot be observed as the equilibrium of supply and demand forces—the Energy Star label is always bought and sold in conjunction with an entire bundle of housing characteristics. To determine the value of the label, the hedonic model assumes that each feature of the house (such as the Energy Star label, the square footage, the location, etc.) contributes to the market value of the entire house. The value of any particular

[19] See Kuminoff and Pope (forthcoming) for an expanded discussion on these key assumptions in the hedonic model.

feature such as the Energy Star status can be implicitly identified by comparing houses that are similar except for Energy Star status. The average difference in market value for similar homes with the Energy Star label and those without is the implied market value of the label.

4.1 Basic pooled OLS Models

The basic linear regression model typically used in the hedonic literature to calculate the implicit price of hedonic characteristics takes the following form

$$ln(price_i) = \beta Energy\ Star_i + \Theta HousingAttributes_i + \alpha + \varepsilon_i \qquad (1)$$

The dependent variable $ln(price_i)$ is the logarithm of the selling price of residence i; $Energy\ Star_i$ is an indicator variable for whether the residence is certified as an energy star house; $HousingAttributes_i$ is a matrix of hedonic structural characteristics, including age (Age), number of bathrooms (Bathrooms), heated square footage (Heated Sq. Feet), unheated square footage (Unheated Sq. Feet), and five sets of dummy variables measuring home quality, exterior material, roof type, floor type, and type of heating; α is a constant; and ε_i is an error term. The key parameter of interest, β, captures both a pure information effect of the energy star label (pure information effect) and the effect of a more energy efficient residence (energy saving and comfort effect). An estimate of β greater than zero would be consistent with the idea that homeowners are willing to pay a higher price for an energy star certified residence. However, with our data we cannot disentangle if homeowners pay a higher price due to the pure information or the energy savings effect.

A key assumption to obtain asymptotically consistent estimates from equation (1) is that the error term ε_i must be uncorrelated with the covariates. This assumption implies that all factors that systematically affect equilibrium home prices are included in the regression. In order to mitigate potential omitted variable bias, we allow for the individual effects to vary by time and neighborhood by using a more flexible model of the form

$$\ln(price_{ijt}) = \beta Energy\ Star_i + \Theta HousingAttributes_i + \Gamma Neighborhood_j + \Psi YearMonth_t + \alpha + \varepsilon_{ijt} \qquad (2)$$

where we include neighborhood fixed effects ($Neighborhood_j$), which are indicator variables for 50 small subdivisions in our sample, and year-by-month time fixed effects ($YearMonth_t$). By including both, spatial and temporal fixed effects, we control for neighborhood attributes such as distance to urban and natural amenities, school quality, and crime that are correlated with local housing prices. While distance from urban disamenities (proximity to congested roads or crime level) is hypothesized to lower residential housing values, distance from natural amenities, such as proximity to parks and recreation areas, is hypothesized to increase residential values. In addition, the time dummies allow us to control for temporal effects and time-trends in housing prices in a flexible way.

4.2 Energy Star Second Sale Models

Beyond including spatial and temporal variables in the model, multiple sales of many of the residences in the dataset permit an analysis of the depreciation of Energy Star capital.[20] In order to analyze the depreciation of the Energy Star label, we create four additional energy star variables. The first variable ($1st\ Sale\ Energy\ Star_i$) is an indicator variable that takes the value of one if the residence transaction occurs when the house is brand new and the residence has the Energy Star label, and zero otherwise. The second variable ($1st\ Sale\ Non-Energy\ Star_i$) is an indicator variable that takes the value of one if the residence transaction occurs for a brand

[20] In our sample, we observe that 65.02% of the residences have sold once; 25.49% have sold exactly twice; 7.56 have sold three times; 1.72% have sold four times; and 0.21% have sold 5 times.

new conventional residence, and zero otherwise. Thus, $1st\ Sale\ Energy\ Star_i$ indicates the sale premium for brand new Energy Star residences whereas $1st\ Sale\ Non-Energy\ Star_i$ indicates the sale premium for new conventional residences. The third variable ($2nd\ Sale\ Energy\ Star_i$) is also an indicator variable that will take the value of one if the transaction corresponds to a used house and is labeled as Energy star, and zero otherwise. Finally, ($2nd\ Sale\ Non-Energy\ Star_i$) is an indicator variable that will take the value of one if the transaction corresponds to a used house that does not have the Energy star label, and zero otherwise. $2nd\ Sale\ Energy\ Star_i$ indicates the resale premium for Energy Star residences and $2nd\ Sale\ Non-Energy\ Star_i$ indicates the resale value of conventional residences. The model now takes the form:

$$\ln(price_{ijt}) = \beta_1 1^{st} Sale\ Energy\ Star_i + \beta_2 2^{nd} Sale\ Energy\ Star_i + \beta_3 2^{nd} Sale\ NonEnergy\ Star_i + \Theta HousingAttributes_i + \Gamma Neighborhood_j + \Psi YearMonth_t + \alpha + \varepsilon_{ijt} \quad (3)$$

where the omitted category is $1st\ Sale\ Non-Energy\ Star_i$. Thus the coefficient β_1 is an indication of the price premium for new Energy Star residences compared to new conventional residences, β_2 is an estimate of the price premium for used Energy Star residences compared to new conventional residences, and β_3 is an estimate of the price premium for used conventional residences compared to new conventional residences.

To better understand the mechanism by which the price premium for Energy Star homes changes after the first sale, we modify equation (3) to include two interaction terms between the 2^{nd} sale of Energy Star houses and age of the house at the time of the transaction ($2nd\ Sale\ Energy\ Star_i * Age_{it}$) and 2^{nd} sale of Non-Energy Star houses and age of the house at the time of the transaction ($2nd\ Sale\ Non-Energy\ Star_i * Age_{it}$). This model takes the form

$$\ln(price_{ijt}) = \beta_1 1^{st} Sale\ Energy\ Star_i + \beta_2 2^{nd} Sale\ Energy\ Star_i + \beta_3 2^{nd} Sale\ NonEnergy\ Star_i + \beta_4 2^{nd} Sale\ Energy\ Star_i * Age_t + \beta_5 2^{nd} Sale\ NonEnergy\ Star_i * Age_{it} + \Theta HousingAttributes_i + \Gamma Neighborhood_j + \Psi YearMonth_t + \alpha + \varepsilon_{ijt} \quad (4)$$

where the coefficients β_4 and β_5 will provide an estimate of the annual depreciation rate for Energy Star and conventional residences, respectively. In principle, one may want to relax the linearity of depreciation by e.g. interacting with indicator variables for age of the house at the time of the transaction. Unfortunately, such flexibility cannot be allowed with our relatively limited number of repeated transactions.

4.3 Energy Star and Building Code Model

Equation (4) imposes restrictions on the nature of the Energy Star premium over time that could be unrealistic in Florida. In particular, Equation 4 asserts that the Energy Star premium is constant for new houses during our ten years of observed transactions. Also, the only two factors that are systematically allowed to affect the price of used houses over time are the houses' age and quality. These features of Equation 4 mean that changes in the Florida State building codes over time will not be accounted in the estimation of the Energy Star premium.

To check the robustness of our four primary models, we follow the lead of Jacobsen and Kotchen (2013) and examine how the Energy Star premium changes under different building codes. This is done by taking into account whether the residences were built under the building code regimes of from 1997, 2001 and 2004.[21] We introduce interaction terms that will take the value of one if the house is Energy Star and it was built during each of these building code

[21] These codes have changed as a response to hurricanes affecting the area of study. For a complete description of these codes, please refer to Jacobsen and Kotchen (2013). We omit the 2007 policy that did not go into effect until 2009 because we do not have any new Energy Star homes in our data that sold after the policy went into effect.

regimes (1997, 2001 and 2004) and zero otherwise. For instance, $Energy\ Star_i\ *\ Policy_{\ 2001}$ takes the value of one if the residence is labeled as Energy Star and was built between 2001 and 2003, and zero otherwise. $Energy\ Star_i\ *\ Policy_{\ 2004}$ takes the value of one if the residence is labeled as Energy Star and was built sometime between 2004 and 2006, and zero otherwise. The same set of interaction between conventional residences and the building code regimes is included as well. That is:

$$\ln(price_{ijt}) = \mathrm{B}_1\ Energy\ Star_i * Policy_t + \mathrm{B}_2 Non\ Energy\ Star_i * Policy_{t\_97} + \Theta HousingAttributes_i + \Gamma Neighborhood_j + \Psi YearMonth_t + \alpha + \varepsilon_{ijt} \qquad (5)$$

The omitted category is conventional houses built under the 1997 Policy regime. $Policy_t$ is a set of dummy variables for the 1997, 2001, and 2004 building codes and $Policy_{t\_97}$ excludes the 1997 regime. The vector of parameters B_1 represents the Energy Star price premium under each of these building codes compared to conventional homes built under the 1997 regime, and B_2 represents the price premium for conventional houses built under the 2001, and 2004 regime compared to conventional houses built under the 1997 regime.

In order to separately determine the price premiums obtained at the first and second sale of Energy Star houses built under each policy regime, we expand the model in equation (5) and include our indicator variables for first and second sale of houses ($1st\ Sale\ Energy\ Star_i$, $1st\ Sale\ Non-Energy\ Star_i$, $2nd\ Sale\ Energy\ Star_i$, and $2nd\ Sale\ Non-Energy\ Star_i$) interacted separately with each policy regime variable. This model takes the form:

$$\ln(price_{ijt}) = \mathrm{B}_1 1stSale\ Energy\ Star_i * Policy_t + \mathrm{B}_2 2ndSale\ Energy\ Star_i * Policy_t + \mathrm{B}_3 2ndSale\ NonEnergy\ Star_i * Policy_{t_{97}} + \mathrm{B}_4 1stSale\ NonEnergy\ Star_i * Policy_{t_{97}} + \Theta HousingAttributes_i + \Gamma Neighborhood_j + \Psi YearMonth_t + \alpha + \varepsilon_{ijt} \qquad (6)$$

where our omitted category is first sale of conventional houses built under the 1997 regime.

Finally, we also measure the rate of depreciation of residences built under different policy regimes by expanding the model in equation (6) by including the second sale interactions with the age of the house at which the transaction occurred as in equation (4), $2nd\ Sale\ Energy\ Star_i\ * Age_{it}$ and $2nd\ Sale\ Non-Energy\ Star_{\ i} * Age_{it}$. The model takes the form:

$$\ln(price_{ijt}) = \mathrm{B}_1 1stSale\ Energy\ Star_i * Policy_t + \mathrm{B}_2 2ndSale\ Energy\ Star_i * Policy_t + \mathrm{B}_3 2ndSale\ NonEnergy\ Star_i * Policy_{t_{97}} + \mathrm{B}_4 1stSale\ NonEnergy\ Star_i * Policy_{t_{97}} + \beta_4 2ndSale\ Energy\ Star_i * Age_{it} + \beta_5 2ndSale\ NonEnergy\ Star_i * Age_{it} + \Theta HousingAttributes_i + \Gamma Neighborhood_j + \Psi YearMonth_t + \alpha + \varepsilon_{ijt} \qquad (7)$$

4.4 Modified Repeat Sales Approach Model

Initially proposed by Bailey, Muth and Nourse (1963), the repeat sales approach utilizes time-varying information on identical residences, which have been sold more than once, to mitigate the risk of omitted variable bias.[22] In our sample, we observe 1,895 residences that sold at least twice in our time period. Out of these, 316 residences were labeled as Energy Star. This represents about 6 percent of our sample.

In a standard linear repeat sales approach, we would estimate the model in first differences to eliminate an individual fixed effect. However, our variable of interest, Energy Star, is a time invariant characteristic, which means that once a house is certified Energy Star it retains this characteristic over time. Therefore, we follow McMillen (2003) and add interaction

[22] Some examples of the repeat sales approach and some extensions include Case et al. (1991), Case and Schiller (1987,1989), Follain and Calhoun (1997) Case and Quigley (1991).

terms between ($Energy\ Star_i$) and indicators for the number of years since last sale ($YSLS$). The dependent variable is the difference in log price of two different sales at two different time periods, where ($s < t$) for the same residence i. The model takes the following form:

$$\ln(price_{it}/price_{is}) = \alpha_t - \alpha_s + \beta(YSLS_t * Energy\ Star_i) + \Psi YearMonth_t - \Gamma YearMonth_s + \varepsilon_{it} - \varepsilon_{is} \quad (8)$$

where the coefficients from these interactions will provide an index of energy star gradients (McMillen, 2003), *i.e.* the change in price between first and second sales for Energy Star homes relative to conventional homes while holding the two sale dates fixed.

Given that the Energy Star price premium might be affected by the change in building codes in Florida, we estimate the following equation:

$$\ln(price_{it}/price_{is}) = \alpha_t - \alpha_s + \beta_1(YSLS_t * Energy\ Star_i * Policy_t) + \beta_2\left(YSLS_t * Non - Energy\ Star_i * Policy_{t\_97}\right) + \Psi YearMonth_t - \Gamma YearMonth_s + \varepsilon_{it} - \varepsilon_{is} \quad (9)$$

where $Policy_t$ is a set of dummy variables for the 1997, 2001, and 2004 building codes and $Policy_{t\_97}$ excludes the 1997 regime. We also introduce the corresponding interactions for residences that are not categorized as Energy Star.

Finally, we note that the repeat sales models might be subject to sample selection bias since some types of houses may trade more frequently on the market than other types. When some types of houses are frequently sold, these are over-represented in the repeat sales sample, relative to the stock of houses or the sales during the same period. Nevertheless, the repeat sales approach can provide further evidence on the evolution of the energy star label over time.

5. Results

5.1 Energy Star Price Premium: Basic Pooled OLS Analysis

We first consider equation (1) to obtain an estimate for the sale premium of Energy Star residences using a pooled OLS analysis. Table 3, column 1 reports the results of the baseline hedonic model estimation, in which we make no attempt to control for other sources of bias. The estimated premium for Energy Star homes is approximately 4.9 percent. This model indicates that holding hedonic characteristics of a home (*e.g.* age, square feet, lot size, quality, etc.) constant, Energy Star homes sell for 4.9 percent more on average than their non-Energy Star counterparts. This model explains approximately 75 percent of the variation in the log of sales price. We report robust standard errors. We also test for robustness with alternative specifications.[23] In this model, the structural characteristics of a residence are statistically significant and conform to expectations, with the exception of age of the residence. Prices increase with the square footage of the residence and lot size. In addition, there is an increase in the price of the residence as quality of the residence increases. However, since housing prices are also affected by spatial characteristics (*e.g.* neighborhood schools, proximity to workplaces, crime, etc.) and temporal characteristics (year and month of sale), the omission of these variables from the model will bias the estimates of the Energy Star premium.

Next, we report results for equation (2), which only includes neighborhood fixed effects, in Table 3 Column 2. Using this model specification, we capture the unobserved (time-invariant) price premium of neighborhoods with increased access to amenities such as better schools, access to places of work and recreation, and less crime. The price premium for Energy Star homes in this specification falls from 4.9 percent to 1.6 percent, which is more consistent with

[23] The qualitative results of alternative specifications are very similar to the estimates we present and they are available upon request.

the value of future energy savings that an Energy Star homeowner can expect to realize in the first 7 years of home ownership.[24] Table 3, column 3 reports the estimates of the same model that only controls for the temporal fixed effects but excludes neighborhood fixed effects; the estimated Energy Star premium is about 1.8 percent (about $4,300). This premium is comparable to the present value of $4,500 estimated by Smith and Jones (2003).

A more robust cross-sectional model that includes both neighborhood and time fixed effects is presented in column (4). The estimated Energy star premium is about 1.2 percent (about $2,900), the magnitude of this premium is again consistent with energy savings possible with the present value of savings in the first few years of home ownership. Additionally, the R^2 of .96 indicates that this model is explaining 96 percent of the variation in housing prices. This is suggestive evidence that the model may not be severely affected by omitted variable bias.

5.2 Energy Star Resale Premium: Second Sale Analysis

While the pooled analysis in the previous section provides an answer to the first major question about the effect of the Energy Star label (the initial sale price premium) on residence prices, it is also helpful to understand the evolution of the Energy Star premium over time to obtain a more holistic view of the label's effect on prices. We examine the resale premium for Energy Star homes using the regression model in equation (3), where we add three additional categorical variables corresponding to interactions of Energy Star indicator and a second sale indicator, with the omitted category being $1st\ Sale\ Non-Energy\ Star_i$. Thus, our parameter

[24] Since the average home sold for $238,000, the 1.6 percent Energy Star premium corresponds to an increase of approximately $3,800. This is close to the present value of 20% annual savings on the average 2009 utility bill for a period of 7 years. This present value calculation was made with the annuity formula:

$$PV = \frac{P}{r}\left(1 - \frac{1}{(1+r)^T}\right)$$

where P is the annual savings on utility bills ($695), r is the discount rate, and T is the number of years. The discount rate was assumed to be .05, corresponding roughly to the interest rate of a 30-year fixed rate mortgage.

estimates on the three dummy variables measure the proportionate difference in prices relative to first sales of conventional residences. The coefficient of $1st\ Sale\ Energy\ Star_i$ variable is positive and significant in all four specifications in Table 4. Columns (1) and (2) differ in the inclusion of two interactions of 2^{nd} Sale Energy Star indicator with Age; while columns (3) and (4) restrict the sample to houses sold up to 2 times in the sample. This means that on average new residences that are labeled as Energy Star sell for about 1.27 percent more (column 1) than new residences that do not have the Energy Star label, holding other characteristics fixed. This result is expected since it indicates that builders are selling Energy Star residences at a premium over similar new conventional residences. However, the coefficient corresponding to $2nd\ Sale\ Energy\ Star_i$ variable is not significantly different from zero; this indicates that homeowners are not re-selling Energy Star residences at a premium over new conventional residences, our omitted category.

To investigate further the re-sale premium of Energy Star residences compared to the re-sale premium of conventional residences, we estimate the proportionate difference between $2nd\ sale\ Energy\ Star_i$ and $2nd\ sale\ Non-Energy\ Star_i$ variables. The estimate difference is .0116 $(-0.0017-(-0.0133))$, which means that second sale of Energy Star residences sell for about one percent more than conventional residences. This estimated difference is statistically different from zero at the two percent level. This would suggest that although homeowners are not reselling their houses with a premium over brand new conventional residences, they are reselling their Energy Star houses with a comparable premium compared to used conventional residences.

In order to understand how this premium changes after the first sale in houses of the same vintage, we estimate equation (4) and report results in column (2). We find that both

$2nd\ Sale\ Energy\ Star_i * Age_{it}$ and $2nd\ Sale\ Non - Energy\ Star_i * Age_{it}$ coefficients are negative and statistically significant. This result is expected due to the normal depreciation of a residential home. However, the magnitude of the corresponding coefficient for Energy Star residences is larger than that for conventional residences. This suggests that Energy star premium disappears 1.2 percentage points each year, whereas the premium for conventional residences decreases only 0.67 percentage points each year. In addition, the estimated proportionate difference between these two coefficients is -0.0053 ($-0.0120 - (-0.0067)$) and statistically significant. Therefore, Energy Star homes sell for 0.53 percent less than conventional homes overtime. This means that the Energy Star premium would have completely disappeared only after one year.

As a robustness check, we repeat the previous analysis but restrict our sample to residences that sold less than three times during our sample period. We present these estimates in Table 4 columns 3 and 4. By restricting our analysis to residences that have sold less than three times, we possibly eliminate residences with unobservable characteristics that cause them to be sold a high number of times. The main results from the first two columns hold in columns 3 and 4, although the smaller sample size increases the standard error of the interaction between the second sale and the age of the home.

5.3 Energy Star Premium and Changes in Building Code

As previously mentioned, building codes in Florida changed during our sample period. To account for these changes, we examine the extent to which the Energy Star premium changes under the different building codes in Gainesville.[25] We report the results for equation (5) in Table 5. The omitted category in the models presented in Table 5 is Non-Energy Star residences that were built when the 1997 building code was active. The model in column 1 indicates that Energy Star residences built under the 1997 building code regime sell 2.82 percent higher than conventional residences built under the same regime. However, Energy Star residences built under the 2004 building code regime (which is considered a more stringent code than the 1997 code) are selling at a discount over conventional residences built under the less stringent building code of 1997. Conventional residences built under the 2001 and 2004) building code regime are not selling at a premium over conventional residences built under the 1997 regime. The estimated percentage price difference between an Energy Star house built under the 1997 and the 2004 building codes is 0.53 percent and statistically significant. This suggests that the premium of the Energy Star labeled residences disappeared as the building code became more stringent.

In column 2, we present the model in equation (6), where we account for sales of new and used Energy Star and conventional houses. The omitted category for this model is $1st\ Sale\ Energy\ Star_i\ *\ Policy\ _{1997}$. Once again, the original sale premium for new Energy Star houses compared to conventional houses built under the same 1997 building code is similar in magnitude, positive and statistically significant. New Energy star residences sell for about 2.26 percent more than conventional residences built under the same building code. Although the label generates a significant premium for new Energy Star residences, the premium seems to disappear when houses are re-sold and the building code becomes more stringent.

[25] We consider the years the residence was built to determine the building code a residence correspond to. We also created these variables using the date of the transaction as opposed to the date the residence was built. The results are similar to the ones presented here and are available upon request.

In column 3, we also control for the depreciation of the residence by interacting with age and estimate equation (7). The rate of depreciation of Energy Star residences is higher than the rate for conventional homes. The coefficient for the interaction between the Energy Star label and the age of the residence when it was sold in column 3 is larger than the same interaction for conventional residences. The estimated percentage price difference suggests that an Energy Star residence depreciates 1.2 $(-0.0190 - (-0.0070))$ percent more each year than a conventional residence, this result is statistically significant. When building codes are controlled for, the magnitude of the rate of depreciation is higher (compared to the estimated difference in Table 4, of about 0.53%).

These results suggest that the Florida building codes may have been responsible for much of the disappearance of the price premiums of both conventional and Energy Star residences. Note that these results control for the economic crisis that began at the end of 2007 through the inclusion of temporal dummy variables. It is interesting to note that the crisis may have depressed the Energy Star premium more than the premium of conventional homes (Kahn and Kotchen, 2013). Also, since the number of residences sold and the price of residential homes changes over time, the Energy Star premium in these regressions might be affected by the composition of residences sold during each period. To sidestep the second problem, we repeatedly estimate Equation 5 with only homes that were built before March 2002 (when the 2001 building code became effective). We only observe 3,235 residences that were built before March 2002. Although this approach decreases the statistical power of our estimates, it is our best available method for understanding how changing building codes affect the resale premium for Energy Star homes. This approach suggests that there was an initial decline in resale premium for Energy Star homes followed by a stabilization in resale premium (see Figure 2).

5.4 Repeat Sales Approach

We present estimates from the model in equation (8) in Table 6. Column 1 presents a model where we estimate the rate of depreciation of the Energy star label between sales. [26] We find that the premium for Energy Star Homes decreases overtime, at a rate of 0.4 percent between sales. This result is consistent but smaller in magnitude when compared to the result presented in Table 4 column 3, which represented a depreciation of 1.3 percent.

In the second column, we present a specification where we group repeated sales that occurred between 1 to 4 years of each other ($1-4YSLS_t * Star_i$ and $1-4YSLS_t * Non-Energy\ Star_i$) and repeat sales that occurred 5 years or more of each other for Energy Star and conventional residences ($5-10YSLS_t * Star_i$ and $5-11YSLS_t * Non-Energy\ Star_i$). The omitted category in this case is conventional residences that were sold twice within 4 years ($1-4YSLS_t * Non-Energy\ Star_i$). This specification points out that Energy Star residences which were sold twice in a 4 year period compared to conventional residences with the same resale pattern, sold at a lower price than conventional homes. The estimated difference represents 2.7 percent, which would correspond to $6,426. On the other hand, Energy Star residences, which were sold twice in a period of 5 years or more, sold at 0.31 percent more than a conventional residence sold twice with the same resale pattern. This estimated difference corresponds to $737. Furthermore, the proportionate difference between Energy Star residences that sold twice in a period of 5 years or more is 5.65 percent (this is about $13,500) more than Energy Star residences that sold twice in a 4 year period. This same proportionate difference for

[26] On average, the time between sales is about 3 years and four months. An alternative specification is the number of months between sales. The results are similar and available upon request. However, there are instances where we do not have transactions taking place in a given month.

conventional residences is only 2.63 percent (this is about $6,259). These results indicate that Energy star residences appreciate much slower than conventional homes but retain the price premium longer than conventional homes.

To investigate further the rate of depreciation of homes, we present a more flexible specification in Column 3 by disaggregating the time into years since last transaction. For instance, if an Energy Star residence sold twice within a time period of 7 years, the $7YSLS_t * Energy\ Star_i$ takes the value of one, and zero otherwise. The omitted category for this model is conventional residence repeat sales that occurred within 1 year of each other. The estimated proportionate price difference between Energy Star and conventional residences that sold repeatedly in two years is about 5.45 percent ($(-0.0205 - 0.0340)$) and is statistically different from zero. This difference disappears as the time lapse between sales increases. We still find a small but positive proportionate price difference between Energy Star and conventional residences. This suggests that the Energy Star appreciation increases at a slower pace than the appreciation of a conventional residence. Since this method controls for unobservable (time-invariant) features of the residences and presents the most flexible specification, it is reassuring that we still arrive at the same conclusion about the Energy Star premium over time in the model for equation 5.

Given the previous evidence that the Energy star premium and appreciation might be affected by the change in building codes in Florida, Table 7 presents results for a repeat sales model that includes these changes in building codes. Column (1) presents results for a very flexible model that interacts the last specification in Table 6 with building code indicators. We note that this specification can be too demanding of the data. The proportionate difference between energy star residences and not energy star residences that were built under the 1997 building code regime and were sold twice at about the same time period is not statistically different from zero. The proportionate difference between energy star residences and non energy star residences that were built under the 2001 building code regime and were sold two, three and four years apart are negative and statistically significant at the 10% level. The computed differences and the corresponding standard errors are presented in Table 8. This means that residences, which hold the energy star label, compared to residences that could be considered identical in terms of sale history pattern and building code requirements except for the label, are not re-selling for a premium. They are resold at a penalty of about 2%. This result is not too different from the result found in the second sale analysis in Table 5, were we found that the rate of depreciation is about 1.2%. To corroborate this finding in a way that is less taxing on the available data, we group sale patterns as before In this model, presented in column (2), we find that the proportionate difference between energy star and conventional residences that were built under the same building code and same transaction history is not statistically different.

5.5 Discussion of Results

Our results suggest that new Energy Star homes do in fact sell for more than conventional residences, but that the price premium for used Energy Star residences deteriorates over time.[27] Although we find that new Energy Star residences sell for a price premium and used residences sell for a similar price to used conventional residences, we are not able to completely pin down the mechanism through which this occurs. We can think of a few possibilities for the disappearance of the Energy Star resale premium. These include 1) an overstatement of technical efficiency of Energy Star residences, 2) the continuously-stricter Florida building codes, 3)

[27] Although our building code robustness checks also suggest that the first sale premium might decrease over time, we do not think we have sufficiently detailed data to completely understand this phenomenon.

physical depreciation of Energy Star capital, 4) difficulty of marketing a used Energy Star residence, and 5) sorting of different types of buyers between new and used residences. To the extent that the Energy Star label is tied to nicer appliances and other factors that increase the price of the residence, we might be picking up the deterioration of the premium for these items along with the disappearance of the Energy Star premium over time.

First, the first Energy Star residences built before 2002 were required to be 20 percent more efficient than conventional Florida residences; there is some reason to believe that the technical estimates of a 20 percent efficiency gain were slightly overstated. For example, Smith and Jones (2003) estimate that savings were more on the order of 15 percent. As homeowners realized that actual savings were smaller than predicted savings, the premium of Energy Star residences might have decreased. Even though technical estimates might have been slightly overstated, it would still be rational for buyers to pay a premium for Energy Star residences since they *do* in fact have lower operating costs. The overstatement of technical predictions of efficiency can therefore explain part, but likely not all of the decline in price premiums over time.

Although our results corroborate the findings of other authors who examine the Energy Star program in Gainesville, the issue of external validity still needs to be addressed. Florida is primarily a cooling climate, meaning more energy is spent cooling the home in the summer than heating it in the winter. Since cooling is exclusively powered by electric air conditioners while heating is primarily done from natural gas, it would seem reasonable to conclude that energy efficient Florida homes would lead to greater electricity savings than gas savings. Smith and Jones (2003) find the opposite; Energy Star residences in Gainesville saved 10-15 percent more electricity than conventional residences, while achieving up to a 20 percent reduction in gas usage. Even if the magnitude of these percent changes are due to the initial level of gas consumption, the results suggest that potential gains from the Energy Star program might be even more pronounced in heating climates. Additionally, Florida has a stricter building code than the national average. When the Energy Star program was first introduced, qualifying residential homes were required to be 30 percent more efficient than the national baseline, corresponding to only a 20 percent improvement over the Florida baseline. Thus we think our estimates for the Energy Star premium in Florida may be lower than estimates for other parts of the country.

Second, a potential cause of the deterioration of the sale premium is Florida's building code. Over the past decade, Florida has updated its building code every three years, increasing the efficiency requirements by up to 10 percentage points per cycle. In 2009, for example, Energy Star residences were only required to be 13 percent more efficient than conventional Florida residences. This means that the first generation of Energy Star residences was more efficient relative to the baseline Florida residence than new generations of Energy Star residences. This suggests that the aggressive Florida building codes could also be eroding the Energy Star premium over time.

Since the building code might be partly confounded with macroeconomics trends, it is also helpful to consider the policy implications of this possibility. Perhaps homebuyers did not value "green" during the housing market crisis. This might even have been the result of rational, optimizing behavior since marginal utility of consumption is generally higher in periods of crisis, making it rational for households to increase consumption today at the expense of investment in more efficient residences for tomorrow. In this case, we are not seeing a failure of the Energy Star label, although we should expect the premium to rebound when the housing market improves. However, since we saw a decline in the Energy Star premium during both a strong housing market (pre-2007) and subsequent crisis (post-2007), these factors do not seem to be driving our results.

While we have found some evidence to support the hypothesis that the building code is driving some of the disappearance of the Energy Star premium, our robustness check that only included residences build before 2002 (Figure 2) suggest that there are also other factors at work. Sales of used Energy Star residences fell rapidly after the first two years in our sample. This would not have happened if only the building codes were driving the depreciation, since these houses were built according to the same building standards.

A third possibility for the initial decline in the second sale premium is physical depreciation of the Energy Star capital relative to conventional homebuilding materials. There has been some evidence to suggest that this may be true in certain instances, but this position is still rather tenuous. For example, Jones et al. (2008) and Jones et al. (2010) demonstrate that Energy Star residences used more and more energy over time relative to conventional residences of the same vintage. These reports seem to attribute the change in relative efficiency to depreciation of Energy Star building materials. This may be partly true, however, properly sized HVAC systems, for example, should last longer than their conventional counterparts since the system will have to work less to heat and cool the interior of the residence. We think that the Jones et al. (2008) findings are likely in part due to behavioral responses of the occupants rather than depreciation of the Energy Star features.

Fourth, the initial drop in second sale prices might be that sellers have difficulty effectively marketing the label. Since builders build and sell hundreds of Energy Star residences, their scale might permit them to hire marketing experts to make sure that the Energy Star label earns a high premium. An individual seller, even with the help of a realtor, might not be able to effectively market efficient features of Energy Star residence. The informational asymmetries in the housing market (i.e. the seller knows the residence is efficient, but the buyer does not) may make it difficult to market Energy Star residences, especially for individuals (e.g. Pope (2008)). This might explain some of the disappearance of the second sale premium.

Fifth, it is possible that the decline is related to the issue of sorting. Individuals who buy new residences are generally wealthier and might have a differing level of environmental consciousness than used home buyers, resulting in a higher marginal willingness to pay for green residences. This effect might explain the difference in Energy Star premium, but it would not change the policy implications of our findings. If the energy savings and environmental benefits (*e.g.* indoor air quality) are enjoyed by the homebuyer, then any utility-maximizing agent, wealthy or otherwise, should still place a higher value on the efficient Energy Star residences. Since our data seem to be inconsistent with this theory, it appears that the label is failing to provide informational benefits in the resale market. Demographic data on the buyers of the residences in our sample, if available, would permit us to explore this issue further. Pursuing data that includes these characteristics would be worthwhile endeavor.

6. Conclusion

Because of the rising amount of energy used in residential consumption and the growing concern about environmental externalities, the Energy Star and similar programs are an important part of an effort to encourage green construction. The price premium for Energy Star residences represents the extent to which homeowners value energy efficiency and have access to information about efficient features of residences in the market. If homeowners value the

Energy Star and similar labels, the Energy Star program might serve as an effective alternative to building codes.

Despite the popularity of the Energy Star program, our results suggest that the program has had mixed success at generating the price premiums necessary to encourage more investment in green housing. In general, homeowners are willing to pay more for new Energy Star residences, but they do not value used Energy Star residences more than they value used conventional residences. In Florida, it appears as if one of the program's major shortcomings is its failure to work in tandem with local building codes.

The slow adaptations of the Energy Star program in Florida relative to the local building codes seem to be responsible for part of the deterioration of the Energy Star premium over time. This could decrease the trustworthiness of the label and pose problems for its long-term success. Since the building code is changing relative to the Energy Star requirements, the label no longer means the same thing for residences of a different vintage. An Energy Star residence built in 1999 might be up to 20 percent more efficient than a conventional residence built at the same time, but an Energy Star residence built in 2009 will only be up to 13 percent more efficient than a conventional residence built in 2009. This ambiguity may have caused the Energy Star premium to decrease during this period. The Energy Star brand might be more meaningful if it moved in tandem with the building code, increasing its standard to always maintain the same improvement in efficiency relative to the baseline residence.

Another potential culprit for the disappearance of the Energy Star resale premium over time might be marketing. Since individual homeowners might not be as effective marketing the label as builders, the resale premium for Energy Star residences could be lower than the first sale premium, even adjusting for wear and tear on the residences. If this is the case, policy makers could look for ways to make it easier for individuals to market their energy efficient residences. It would make sense for homeowners who purchase Energy Star residences to save documents that demonstrate the efficiency of their residences to potential buyers or to have a centralized way for homebuyers to access utility bills of residences they are considering. Future research is needed to sort out the importance of these issues for the Energy Star program if it is to be effective in promoting green construction in future residential housing markets.

Figure 1: Map of the Five Subdivisions in the Study

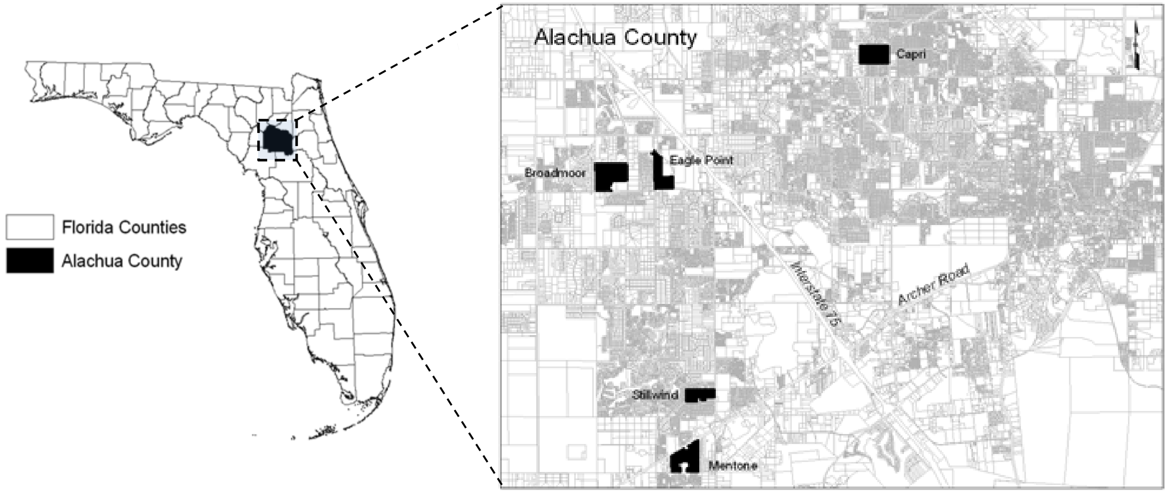
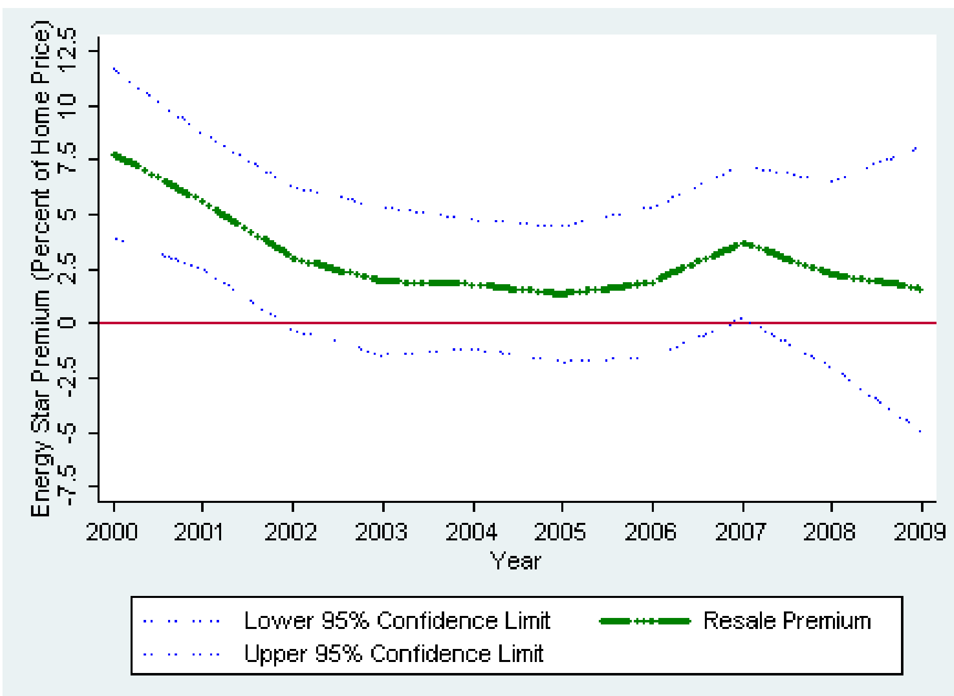


Figure 2: Energy Star Resale Premium for Residences Built before 2002



Notes: Coefficient and standard errors are obtained by repeated estimation of Equation 4 with two years of data at time.

Table 1: Energy Star Features and Estimated Savings

Feature	Est. Annual Savings	Upfront Cost	Maintenance Notes
Low-E Windows	$70-$80	$7,000-$20,000[28]	None
High R-Value Insulation	$100[29]	$1,500	None
Properly-sized HVAC[30]	$100-400	$2,000-$5,000	None
Tankless Water Heater[31]	$70-80	$800-$1,150	Frequent Service[32]

Notes: These are estimates are intended to give a rough approximation of the relative importance of each of these features. Although we have tried to provide references where possible, each of the estimates has a high variance and depends on idiosyncratic features of the residence and the occupants. For example, good attic insulation might help to protect ductwork from the summer heat, creating an interaction between the efficiency of the HVAC system and a residence's insulation. Also, the savings from insulation, low-e windows, and HVAC will vary dramatically in different climates. Several builders and energy auditors in the Gainesville area actually suggested that the low-e windows were the most important upgrade for Florida's climate.

[28] See http://www.consumerreports.org/cro/home-windows/buying-guide.htm for more details.

[29] The Energy Star website http://www.energystar.gov/index.cfm?c=home_sealing.hm_improvement_methodology has information that we used for this calculation.

[30] We used a calculator created by the DOE; this can be found online or by contacting us by e-mail.

[31] Consumer Reports has estimated cost and savings for various types of water hearters. Details can be found at http://www.consumerreports.org/cro/appliances/heating-cooling-and-air/water-heaters/tankless-water-heaters/overview/tankless-water-heaters-ov.htm.

[32] Although these Energy Star features can save money, it is possible that maintenance costs for some efficient appliances are higher than costs for similar conventional models. Consumer Reports suggests that tankless water heaters might require more frequent maintenance than tank-storage models, especially in areas with hard water. Increased calcium buildup on the inside of the units can decrease their efficiency, and many companies recommend yearly service by a qualified professional. This was the only such example that we were able to find, and we think that most efficient products have similar lifetimes to conventional counterparts.

Table 2: Summary Statistics

Variable Name	Variable Description	Mean	Std. Dev.	Min.	Max.
Price	Transaction Price	238,047	119,814	29,200	1,212,500
ln(Price)	Natural Logarithm of Transaction Price	12.26	0.49	10.28	14.01
Age	Age of House	5.23	9.93	0.00	54.00
Baths	Number of Bathrooms	2.32	0.61	1.00	5.50
Acres	Lot Size in Acres	0.13	0.31	0.00	5.20
Heated Sq. Feet	Square Feet of Heated Area in the House	2,066.02	615.07	728.00	5,570.00
Unheated Sq. Feet	Square Feet of Unheated Area in the House	743.79	246.17	0.00	2,521.00
Sale	Number of Times the Residence Sold	1.47	0.73	1.00	5.00
Poor Quality	Dummy Variable for One of Three Assessor Ratings of Quality	0.12	0.32	0.00	1.00
Better Quality	Dummy Variable for One of Three Assessor Ratings of Quality	0.81	0.40	0.00	1.00
Best Quality	Dummy Variable for One of Three Assessor Ratings of Quality	0.07	0.26	0.00	1.00
1^{st} Sale Energy Star	Dummy Variable for Energy Star Residence's First Sale	0.09	0.29	0.00	1.00
2^{nd} Sale Energy Star	Dummy Variable for Energy Star Residence's Second Sale	0.07	0.26	0.00	1.00

Notes: Other house attributes not included in summary table include dummy variables for method of heating, exterior wall materials, interior wall materials, flooring types, roof types, neighborhoods (refers to 50 small subdivision-level indicator variables), and 140 year-by-month variables.

Table 3: Energy Star Price Premium

Dependent Variable: ln(Price)	(1)	(2)	(3)	(4)
Energy Star Residence	**0.0494****	**0.0161***	**0.0177****	**0.0123****
	(0.008)	**(0.008)**	**(0.005)**	**(0.004)**
Better Quality	0.2125**	0.1481**	0.2043**	0.0925**
	(0.017)	(0.025)	(0.011)	(0.011)
Best Quality	0.2163**	0.1637**	0.2277**	0.1130**
	(0.025)	(0.032)	(0.017)	(0.018)
Age	0.0059**	0.0111**	-0.0065**	-0.0072**
	(0.001)	(0.001)	(0.001)	(0.000)
Num. Bathrooms	0.0830**	0.0546**	0.0515**	0.0210**
	(0.009)	(0.008)	(0.006)	(0.004)
Acres	0.0769**	0.0826**	-0.0020	0.0167
	(0.013)	(0.016)	(0.009)	(0.009)
Heated Sq. Feet	0.0004**	0.0003**	0.0004**	0.0003**
	(0.000)	(0.000)	(0.000)	(0.000)
Unheated Sq. Feet	0.0003**	0.0002**	0.0002**	0.0001**
	(0.000)	(0.000)	(0.000)	(0.000)
Constant	10.3664**	11.3377**	10.6091**	11.4392**
	(0.386)	(0.381)	(0.190)	(0.135)
Residence Attributes	X	X	X	X
Spatial Fixed Effects		X		X
Temporal Fixed Effects			X	X
Observations	5,528	5,528	5,528	5,528
R-squared	0.746	0.818	0.921	0.959

Notes: Residence attributes include dummy variables for method of heating, exterior wall materials, interior wall materials, flooring types, and roofing types. “Spatial” refers to 50 small subdivision-level indicator variables. There are 140 year-by-month indicator variables, indicated “Temporal.” Robust standard errors are shown in parenthesis. The * represents significance at the 10% level and the ** represents significance at the 5% level.

Table 4: Energy Star Resale Premium

Dependent Variable: ln(Price)	(1)	(2)	(3)	(4)
1st Sale Energy Star	**0.0127***	**0.0129***	**0.0131***	**0.0132***
	(0.005)	**(0.005)**	**(0.005)**	**(0.005)**
2nd Sale Energy Star	-0.0017	0.0160	-0.0007	0.0173
	(0.006)	(0.009)	(0.006)	(0.011)
2nd Sale Non-Energy Star	**-0.0133****	**-0.0144****	**-0.0131****	**-0.0138****
	(0.004)	**(0.004)**	**(0.004)**	**(0.004)**
Energy Star 2nd Sale * Age		**-0.0120****		**-0.0131****
		(0.002)		**(0.003)**
Non-Energy Star 2nd Sale * Age		**-0.0067****		**-0.0069****
		(0.000)		**(0.000)**
Better Quality	0.0925**	0.0921**	0.0936**	0.0931**
	(0.011)	(0.011)	(0.011)	(0.011)
Best Quality	0.1124**	0.1122**	0.1123**	0.1120**
	(0.018)	(0.018)	(0.019)	(0.019)
Num. Bathrooms	0.0212**	0.0213**	0.0212**	0.0213**
	(0.004)	(0.004)	(0.005)	(0.005)
Acres	0.0163	0.0162	0.0183	0.0183
	(0.009)	(0.009)	(0.010)	(0.010)
Heated Sq. Feet	0.0003**	0.0003**	0.0003**	0.0003**
	(0.000)	(0.000)	(0.000)	(0.000)
Unheated Sq. Feet	0.0001**	0.0001**	0.0001**	0.0001**
	(0.000)	(0.000)	(0.000)	(0.000)
Age	-0.0068**		-0.0070**	
	(0.000)		(0.000)	
Constant	11.4272**	11.4241**	11.4478**	11.4453**
	(0.133)	(0.133)	(0.135)	(0.135)
Residence Attributes	X	X	X	X
Spatial Fixed Effects	X	X	X	X
Temporal Fixed Effects	X	X	X	X
Sales < 3			X	X
Observations	5,528	5,528	5,031	5,031
R-squared	0.959	0.959	0.960	0.960

Notes: Notation in this table is consistent with Table 3. Robust standard errors are also used in these models, although statistical significant results remain significant when standard errors are cluster corrected at the neighborhood level. We did not try to cluster correct at the sub-division level since there are only five subdivisions and cluster correction is asymptotically consistent but biased with only a few clusters. The * represents significance at the 10% level and the ** represents significance at the 5% level.

Table 5: The Energy Star Premium and the Building Code

Dependent Variable: ln(Price)	(1)	(2)	(3)	(4)
Energy Star & 1997 Policy	**0.0282****			**0.0400****
	(0.006)			**(0.008)**
Energy Star & 2001 Policy	0.0084			0.0587
	(0.006)			(0.042)
Energy Star & 2004 Policy	**-0.0278***			
	(0.011)			
Non-Energy Star & 2001 Policy	-0.0073			-0.0133
	(0.005)			(0.026)
Non-Energy Star & 2004 Policy	-0.0121			
	(0.009)			
1st Sale ES & 1997 Policy		**0.0226****	**0.0226****	
		(0.008)	**(0.009)**	
1st Sale ES & 2001 Policy		-0.0039	-0.0033	
		(0.009)	(0.009)	
1st Sale ES & 2004 Policy		**-0.0588****	**-0.0593****	
		(0.013)	**(0.013)**	
2nd Sale ES & 1997 Policy		-0.0040	**0.0463****	
		(0.009)	**(0.014)**	
2nd Sale ES & 2001 Policy		**-0.0412****	-0.0089	
		(0.010)	(0.012)	
2nd Sale ES & 2004 Policy		**-0.0569****	**-0.0394***	
		(0.017)	**(0.017)**	
1st Sale Non-ES & 2001 Policy		**-0.0335****	**-0.0324****	
		(0.008)	**(0.008)**	
1st Sale Non-ES & 2004 Policy		**-0.0454****	**-0.0468****	
		(0.011)	**(0.011)**	
2nd Sale Non-ES & 1997 Policy		**-0.0325****	**-0.0337****	
		(0.006)	**(0.006)**	
2nd Sale Non-ES & 2001 Policy		**-0.0363****	**-0.0383****	
		(0.008)	**(0.008)**	
2nd Sale Non-ES & 2004 Policy		**-0.0479****	**-0.0513****	
		(0.012)	**(0.012)**	
2nd Sale ES * Age			**-0.0190****	
			(0.003)	
2nd Sale Non-ES * Age			**-0.0070****	
			(0.001)	
Better Quality	0.0951**	0.0946**	0.0940**	0.1043**

	(0.011)	(0.010)	(0.010)	(0.025)
Best Quality	0.1165**	0.1134**	0.1134**	0.1726**
	(0.018)	(0.018)	(0.018)	(0.031)
Age	-0.0075**	-0.0070**		-0.0059**
	(0.001)	(0.001)		(0.001)
Num. Bathrooms	0.0205**	0.0202**	0.0204**	0.0214**
	(0.004)	(0.005)	(0.005)	(0.007)
Acres	0.0194*	0.0195*	0.0199*	0.0216*
	(0.009)	(0.009)	(0.009)	(0.010)
Heated Sq. Feet	0.0003**	0.0003**	0.0003**	0.0003**
	(0.000)	(0.000)	(0.000)	(0.000)
Unheated Sq. Feet	0.0001**	0.0001**	0.0001**	0.0002**
	(0.000)	(0.000)	(0.000)	(0.000)
Constant	11.4683**	11.3450**	11.3432**	10.8902**
	(0.132)	(0.105)	(0.104)	(0.220)
Residence Attributes	X	X	X	X
Spatial Fixed Effects	X	X	X	X
Temporal Fixed Effects	X	X	X	X
Pre-2002 Residences Built				X
Observations	5,528	5,388	5,388	3,235
R-squared	0.959	0.960	0.960	0.961

Notes: Residence attributes as well as spatial and temporal fixed effects are included in all three models. Notation in this table consistent with Tables 3 and 4. Robust standard errors reported in parentheses.

Table 6: The Repeat Sales Regression

Dependent Variable: $\ln(Price_t/Price_{t-1})$	(1)	(2)	(3)
YSLS * Energy Star	**-0.0041***		
	(0.002)		
1-4YSLS * Energy Star		**-0.0271****	
		(0.010)	
5-10YSLS * Energy Star		**0.0294***	
		(0.014)	
5-10YSLS* Non Energy Star		**0.0263***	
		(0.011)	
1YSLS * Energy Star			0.0947
			(0.060)
2YSLS * Energy Star			-0.0205
			(0.021)
3YSLS * Energy Star			0.0097
			(0.022)
4YSLS * Energy Star			0.0568
			(0.031)
5YSLS * Energy Star			**0.1274****
			(0.042)
6YSLS * Energy Star			**0.1524****
			(0.052)
7YSLS * Energy Star			**0.1972****
			(0.061)
8YSLS * Energy Star			**0.2449****
			(0.078)
9YSLS * Energy Star			**0.2193****
			(0.076)
10YSLS * Energy Star			**0.2602***
			(0.103)
2YSLS * Non- Energy Star			0.0340
			(0.020)
3YSLS * Non- Energy Star			**0.0590***
			(0.024)
4YSLS * Non- Energy Star			**0.0853****
			(0.030)
5YSLS * Non- Energy Star			**0.1217****
			(0.039)
6YSLS * Non- Energy Star			**0.1517****
			(0.049)

7YSLS * Non- Energy Star			**0.1979****
			(0.057)
8YSLS * Non- Energy Star			**0.2065****
			(0.070)
9YSLS * Non- Energy Star			**0.2456****
			(0.083)
10YSLS * Non- Energy Star			**0.2345****
			(0.089)
11YSLS * Non- Energy Star			**0.3000****
			(0.110)
Constant			**-0.0382***
			(0.017)
Temporal Fixed Effects	X	X	X
Observations	1,895	1,895	1,895
R-squared	0.830	0.831	0.609

Notes: Notation in this table consistent with Table 3. Robust standard errors reported in parentheses.

Table 7: The Repeat Sales Regression and Building Code

Dependent Variable: log($Price_t$-$Price_{t-1}$)	(1)	(2)
1YSLS * Energy Star * Policy1997	**-0.2584*** **(0.113)**	
2YSLS * Energy Star * Policy1997	**-0.2917**** **(0.105)**	
3YSLS * Energy Star * Policy1997	**-0.2818**** **(0.096)**	
4YSLS * Energy Star * Policy1997	**-0.2475**** **(0.088)**	
5YSLS * Energy Star * Policy1997	**-0.1811*** **(0.081)**	
6YSLS * Energy Star * Policy1997	**-0.1640*** **(0.080)**	
7YSLS * Energy Star * Policy1997	-0.1151 (0.071)	
8YSLS * Energy Star * Policy1997	-0.0577 (0.072)	
9YSLS * Energy Star * Policy1997	-0.0906 (0.064)	
10YSLS * Energy Star * Policy1997	-0.0329 (0.071)	
1YSLS * Energy Star * Policy2001	**-0.3264**** **(0.119)**	
2YSLS * Energy Star * Policy2001	**-0.3438**** **(0.104)**	
3YSLS * Energy Star * Policy2001	**-0.3038**** **(0.096)**	
4YSLS * Energy Star * Policy2001	**-0.2666**** **(0.090)**	
5YSLS * Energy Star * Policy2001	**-0.1824*** **(0.082)**	
6YSLS * Energy Star * Policy2001	-0.1466 (0.077)	
1YSLS * Energy Star * Policy2004	-0.0994 (0.168)	
2YSLS * Energy Star * Policy2004	**-0.4003**** **(0.105)**	
3YSLS * Energy Star * Policy2004	**-0.3408**** **(0.121)**	
4YSLS * Energy Star * Policy2004	**-0.2168*** **(0.109)**	
2YSLS * Non- Energy Star * Policy1997	**-0.2857*** **(0.111)**	
3YSLS * Non- Energy Star * Policy1997	**-0.2647***	

	(0.103)	
4YSLS * Non- Energy Star * Policy1997	**-0.2501****	
	(0.095)	
5YSLS * Non- Energy Star * Policy1997	**-0.2223***	
	(0.088)	
6YSLS * Non- Energy Star * Policy1997	**-0.1906***	
	(0.080)	
7YSLS * Non- Energy Star * Policy1997	**-0.1613***	
	(0.073)	
8YSLS * Non- Energy Star * Policy1997	-0.1125	
	(0.068)	
9YSLS * Non- Energy Star * Policy1997	-0.1021	
	(0.064)	
10YSLS * Non- Energy Star * Policy1997	-0.0618	
	(0.063)	
11YSLS * Non- Energy Star * Policy1997	-0.0766	
	(0.097)	
1YSLS * Non- Energy Star * Policy2001	**-0.3153****	
	(0.112)	
2YSLS * Non- Energy Star * Policy2001	**-0.3010****	
	(0.104)	
3YSLS * Non- Energy Star * Policy2001	**-0.2564****	
	(0.096)	
4YSLS * Non- Energy Star * Policy2001	**-0.2301****	
	(0.088)	
5YSLS * Non- Energy Star * Policy2001	**-0.1729***	
	(0.088)	
6YSLS * Non- Energy Star * Policy2001	-0.1336	
	(0.083)	
7YSLS * Non- Energy Star * Policy2001	-0.1094	
	(0.100)	
1YSLS * Non- Energy Star * Policy2004	**-0.3923****	
	(0.115)	
2YSLS * Non- Energy Star * Policy2004	**-0.2987****	
	(0.095)	
3YSLS * Non- Energy Star * Policy2004	**-0.2440***	
	(0.099)	
4YSLS * Non- Energy Star * Policy2004	**-0.2385***	
	(0.105)	
5YSLS * Non- Energy Star * Policy2004	-0.1417	
	(0.093)	
1-4YSLS * Non- Energy Star * Policy1997		-0.0221
		-0.013
5-11YSLS * Non- Energy Star * Policy1997		0.0065
		(0.014)
1-4YSLS * Energy Star * Policy1997		**-0.0450****
		(0.015)
1-4YSLS * Energy Star * Policy2001		**-0.0765****
		(0.016)
5-10YSLS * Energy Star * Policy2001		-0.0030

		(0.019)
1-4YSLS * Non- Energy Star * Policy2001		**-0.0369***
		(0.014)
5-11YSLS * Non- Energy Star * Policy2001		0.0123
		(0.025)
1-4YSLS * Energy Star * Policy2004		-0.0326
		(0.048)
1-4YSLS * Non- Energy Star * Policy2004		**-0.0598***
		(0.030)
5-11YSLS * Non- Energy Star * Policy2004		0.0439
		(0.041)
Constant		-0.0224
		(0.015)
Observations	1,895	1,895
R-squared	0.839	0.602

Notes: Notation in this table consistent with Table 3. Robust standard errors reported in parentheses.

Table 8: Estimated proportionated differences

Dependent Variable: ln($Price_t$-$Price_{t-1}$)		
1YSLS * Energy Star - 1YSLS * Non-Energy Star	**0.0947**	***
	(0.0605)	
2YSLS * Energy Star - 2YSLS * Non-Energy Star	**-0.0492**	***
	(0.0159)	
3YSLS * Energy Star - 3YSLS * Non-Energy Star	**-0.0492**	**
	(0.0142)	
4YSLS * Energy Star - 4YSLS * Non-Energy Star	-0.0284	
	(0.0125)	
5YSLS * Energy Star - 5YSLS * Non-Energy Star	0.0056	
	(0.0171)	
6YSLS * Energy Star - 6YSLS * Non-Energy Star	0.0007	
	(0.0259)	
7YSLS * Energy Star - 7YSLS * Non-Energy Star	-0.0007	
	(0.0285)	
8YSLS * Energy Star - 8YSLS * Non-Energy Star	0.0383	
	(0.0418)	
9YSLS * Energy Star - 9YSLS * Non-Energy Star	-0.0262	
	(0.0345)	
10YSLS * Energy Star - 10YSLS * Non-Energy Star	0.0256	
	(0.0911)	

Notes: Notation in this table consistent with Table 3. Robust standard errors reported in parentheses.

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