Does the Housing Market Value Energy Efficient 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, and on average Americans devote 7.5 percent of their total spending to utility bills. Improving energy efficiency in the residential sector of the economy has been an important goal of energy policy in the United States over 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 energy efficiency through state-wide building codes. These building codes set minimum efficiency standards for all new residential construction, and in many states the requirements become more stringent over time. 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. In 1995 it was announced that homebuilders can certify new homes with the Energy Star label, indicating that these residences are 30% more efficient than the energy code

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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/csreport.htm#annual.
baseline home.\textsuperscript{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 housing.

A key marketing point of the Energy Star program, for homes, 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 higher values than less efficient residences.\textsuperscript{4} Nonetheless, this important claim that Energy Star residences 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 homes. To our knowledge, our study is the first in energy efficiency literature to attempt to control for unobserved heterogeneity in housing characteristics using repeated sales of the same homes, and we are also the first examine the resale price premium associated with the Energy Star label.

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. In addition, Nevin and Watson (1998) show that a $1 per year increase in savings from utility bills is associated with a

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

\textsuperscript{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
$25 increase in residence value. However, both studies have no information about construction characteristics (i.e. how efficient the residence is) and rely on self-reported utility bills, which might be measured with error. They also lack important neighborhood-level variables such as school quality and crime. Another study by Banfi et al. (2008) uses stated-preference methods, but 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. Although these early studies, on the price premiums for energy efficient construction, are qualitatively similar, their data make it difficult to convincingly estimate the magnitude of the willingness to pay for efficiency.

More recently, several studies have employed richer controls for building and neighborhood characteristics to estimate the price premium for the Energy Star label. 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 return of green buildings (Green Mark) in the residential sector for 250 projects in the city of Singapore. By using a two-stage regression, they showed that there is a 4% sale premium of green rated dwellings when compared to conventional buildings.
Our research has two main contributions to Energy efficiency literature. First, using repeat sales data, we are able to control for time-invariant home characteristics that could potentially bias cross-sectional estimates. Second, we study how the resale price premium changes over time for Energy Star houses. Although our empirical framework has limitations that we discuss below, we believe it provides the most credible estimate to date on how the Energy Star label is capitalized into housing prices.

Our study finds that new Energy Star residences sold for more than similar conventional residences during the first few years of the Energy Star program for homes, but that both the new and the resale price premiums disappeared after 2001. 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, suggest that the Energy Star program for new homes has had mixed success at increasing residential energy efficiency.

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 home resale data sample; 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). By that time, the label had already achieved a large market share in household appliances such as personal computers, printers, and monitors. The extension of the label to 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 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 so that 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 At 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 to 35 percent less because of the increasingly strict requirements of the state building code.

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. First, independent certification and the label’s dependable reputation could make it easier for owners to sell residences for a price that reflects the value of their energy-saving features. By potentially raising the sale and resale price of certified homes, the label makes it easier for builders and buyers to consider lifetime residential home costs rather than just upfront capital and purchase costs. Second, an effective label can make home energy efficiency characteristics salient to buyers. Since buyers deal with so many inputs in the home purchase decision, a model of limited attention would suggest that some buyers may not consider energy efficiency to be a priority. 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. This could reduce search and transaction costs for both buyers and sellers, making the market for homes more efficient (Gilman, 1989). By increasing the salience of energy efficiency, problems of asymmetric information in the housing market might also be alleviated.

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. Across the board, builders in our sample used low-e windows, high R-value insulation in the walls and attic, tankless water heaters, and properly sized heating, ventilation, and air.

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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.

11 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.

12 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
conditioning (HVAC) systems. Table 1 provides rough monetary estimates of the relative importance of each of these features.

Although all of the builders included the above upgrades in their Energy Star homes, it is possible that some builders also systematically bundled other attractive features with Energy Star homes. For example, one builder advertised native, low-maintenance trees and plants. Other amenities that might be bundled with the label could include higher-end appliances, better natural lighting, or higher ceilings.

Walls et al. (2013) suggest that the Energy Star label might be bundled with other features that would cause homeowners to pay more for a certified home than they would expect to save in energy costs. While we agree that bundling could be a problem, we think the Walls et al. estimates are overstated. The reason is that this study doesn’t observe actual energy consumption; it relies on a model that predicts the average energy use for a home with set of characteristics. The problem is that Energy Star homeowners are not likely to be similar to the average homeowner in terms of preferences for energy consumption. This underestimate of demand for energy services leads to an underestimate of the rational price premium for energy efficient homes. Although we can’t rule out the possibility that the Energy Star label is bundled with other amenities, we have data on an extensive set building quality features and materials that help us to control for bundling. If these controls for builder or neighborhood fixed effects don’t pick up whatever bundling is occurring, our estimates of the size of the Energy Star

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15 They divide the annualized Energy Star price premium by the average energy expenditures for homes with a given set of features; since for certain vintages of Energy Star homes this fraction is larger than 30 percent (the amount an Energy Star home is supposed to save), they conclude that either Energy Star homes are overpriced or that they are bundled with other amenities. The problem is that Energy Star homeowners might sort themselves into efficient homes precisely because they expect to consume more energy than the average homeowner. This suggest that Walls et al. should use a larger number for counterfactual energy expenditures in the denominator of their calculation, which would give them an annual premium relative to energy expenses closer to 30 percent.
premium will represent both the premium for efficiency as well as the premium for these other attributes.

2.2 Actual Savings from Energy Efficient Residential Homes

Although the technical predictions indicate that homes with the Energy Star features discussed in the previous section will save energy relative to homes without these features, *ceteris paribus*, ultimately the most important aspect of an energy efficient residence is the amount of energy that it *actually* saves.\(^\text{16}\) 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.

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. This translates 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.

\(^{16}\)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.
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 the deterioration of the Energy Star capital, it also seems possible that this phenomenon could be driven by a rebound effect. For example, studies such as Small and Van Dender (2007) 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.

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 complement the studies on energy usage and build upon the foundational work in capitalization of energy efficiency into sale price. Our estimates of the first price premium show the size of incentives for builders to supply more energy efficient homes. The estimates of the first sale also help to determine if the label is providing informational benefits and decreasing adverse selection or search cost problems. The estimates of the second sale indicate the extent to which buyers must recuperate the cost of their investment during their own
tenure in given home. Higher resale values will give builders and buyers stronger incentives to make the optimal lifetime choices of capital efficiency.

3. Study Area and Data

3.1 The Study Area: Gainesville, Florida

To estimate the price premium for Energy Star homes, our research uses data from Gainesville, Florida; this area is popular for studies on energy efficient homes because of a rich database 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 (See Figure 1). Its warm, humid climate places Gainesville in the 70th percentile of counties in terms of the total number of degree-days annually. 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. Another factor that might lead to lower 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.

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18 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.

19 In 2005, for example, residents of the Northeast spent on average $2,098 on energy, while those in the South spent $1,758. Average expenditures in the West and Midwest were $1,401 and $1,782 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. Price adjustments were made using data from the BLS, available at http://www.bls.gov/cpi/cpid05av.pdf.
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 the 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.

3.3 Energy Star Data

The second data set was graciously provided by Pierce Jones and was obtained from the Florida Solar Energy Center. 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 so that the HERS scores we observe corresponds to the actual energy efficiency at the time of the transaction. The residences in our dataset that scored above 86 on the HERS scale were all certified as Energy Star homes. The data are compiled so the unit of 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.

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

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20 This is the dataset used in Smith and Jones (2003).
21 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.
these subdivisions within the Gainesville area. 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)\textsuperscript{22}. We are also able to control for about 50 smaller neighborhoods within these five subdivisions, whose size varies from a dozen homes to over 500 homes. Figure 3 in the appendix shows the fraction of Energy Star homes in these smaller neighborhoods. Using neighborhood fixed effects allows us to control for unwanted between-community variation in quality of local amenities. In neighborhoods with only a few builders, it also allows us to remove idiosyncratic differences in building quality and technique.\textsuperscript{24} Because we don’t have enough data to include builder fixed effects, 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. We can’t directly verify this assumption, but Table 2b does provide evidence that Energy Star homes are comparable to conventional homes in their observable features such as size and quality. The biggest differences are that Energy Star homes are slightly newer. Finally, since we do not observe data on the buyers of these residences, we can’t examine if buyers who consume more energy than average sort themselves into efficient homes. If this were the case, we would still expect our estimates to be unbiased for the marginal willingness to pay for the Energy Star label, although the marginal buyer would be a higher use type than the average buyer.

\textsuperscript{22} Many of the Energy Star homes built in the Mentone subdivision were built by Atlantic Design Homes (ADH); in a conversation with the CEO of ADH, we were informed that buyers had the option of upgrading to an Energy Star home for $1,200, but in practice all buyers eventually made this upgrade whether or not they were originally interested in purchasing an Energy Star home. This is due to the fact that ADH worked with lenders who were willing to lower mortgage rates for efficient homes so that the $1,200 increase in price was offset by a lower mortgage payment each month, and in general a homebuyer’s monthly stream of payments didn’t change. The $1,200 upgrade was therefore more of an accounting object than a MWTP since it didn’t cost the buyer any more.

\textsuperscript{24} On average, the largest builder in each neighborhood had a 40\% market share of homes in the neighborhood. The 10\textsuperscript{th} percentile of this builder market share variable is 5.6\%, the median is 55\%, and the 90\textsuperscript{th} percentile is 69\%.
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.\(^\text{25}\)

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 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.\(^\text{25}\)

\(^{25}\) See Kuminoff and Pope (forthcoming) for an expanded discussion on these key assumptions in the hedonic model.
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

\[
\ln(\text{price}_i) = \beta \text{Energy Star}_i + \theta \text{HousingAttributes}_i + \alpha + \varepsilon_i
\]  

(1)

The dependent variable \(\ln(\text{price}_i)\) is the logarithm of the selling price of residence \(i\); \(\text{Energy Star}_i\) is an indicator variable for whether the residence is certified as an energy star house; \(\text{HousingAttributes}_i\) 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\(^{26}\), exterior material, roof type, floor type, and type of heating; \(\alpha\) is a constant; and \(\varepsilon_i\) is an error term. The key parameter of interest, \(\beta\), captures both a pure information effect of the energy star label and the effect of a more energy efficient residence (energy saving and comfort effect). An estimate of \(\beta\) greater than zero would be consistent with the idea that homeowners are willing to pay a higher price for an energy star certified residence.\(^{27}\)

A key assumption to obtain asymptotically consistent estimates from equation (1) is that the error term \(\varepsilon_i\) 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

\(^{26}\) Home quality is a standardized scale used to report the condition of the residence according to the assessor.
\(^{27}\) With our data we cannot disentangle if homeowners pay a higher price due to the pure information or the energy savings effect
\[
\ln(price_{ijt}) = \beta \text{Energy Star}_i + \theta \text{Housing Attributes}_i + \Gamma \text{Neighborhood}_j + \Psi YearMonth_t + \alpha + \epsilon_{ijt} \quad (2)
\]

where we include neighborhood fixed effects (\text{Neighborhood}_j), which are indicator variables for 50 small subdivisions in our sample, and year-by-month time fixed effects (\text{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.\(^{28}\) In order to analyze the depreciation of the Energy Star label, we create four additional energy star variables. The first variable (\text{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 (\text{1st Sale Non – Energy Star}_i) is an indicator variable that takes the value of one if the residence transaction occurs for a brand new conventional residence, and zero otherwise. Thus, \text{1st Sale Energy Star}_i indicates the sale premium for brand new Energy Star residences whereas \text{1st Sale Non – Energy Star}_i indicates the sale premium for new conventional residences. The third variable

\(^{28}\) 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.
(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. 2nd Sale Energy Star\_i indicates the resale premium for Energy Star residences. 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 2nd Sale Non – Energy Star\_i indicates the resale value of conventional residences. The model now takes the form:

\[
\ln(p\text{rice}_{ijt}) = \beta_1^{1st Sale Energy Star_i} + \beta_2^{2nd Sale Energy Star_i} + \beta_3^{2nd Sale NonEnergy Star_i} + \theta\text{HousingAttributes}_i + \Gamma\text{Neighborhood}_j + \Psi\text{YearMonth}_t + \alpha + \epsilon_{ijt} \tag{3}
\]

where the omitted category is 1st Sale Non – Energy Star\_i. Thus the coefficient $\beta_1$ is an indication of the price premium for new Energy Star residences compared to new conventional residences, $\beta_2$ is an estimate of the price premium for used Energy Star residences compared to new conventional residences, and $\beta_3$ is an estimate of the price premium for used conventional residences compared to new conventional residences.

To better understand the how the price premium for Energy Star homes changes after the first sale, we modify equation (3) to include two interaction terms between the 2nd sale of Energy Star houses and age of the house at the time of the transaction (2nd Sale Energy Star\_i * Age\_it ) and 2nd 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

\[
\ln(p\text{rice}_{ijt}) = \beta_1^{1st Sale Energy Star_i} + \beta_2^{2nd Sale Energy Star_i} + \beta_3^{2nd Sale NonEnergy Star_i} + \beta_4^{2nd Sale Energy Star_i * Age_i} + \beta_5^{2nd Sale NonEnergy Star_i * Age_i} + \theta\text{HousingAttributes}_i + \Gamma\text{Neighborhood}_j + \Psi\text{YearMonth}_t + \alpha + \epsilon_{ijt} \tag{4}
\]
where the coefficients $\beta_4$ and $\beta_5$ 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 understand how the price premium for new homes changes over time, we analyze sales of Energy Star homes 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.\textsuperscript{29} 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 regimes (1997, 2001 and 2004) and zero otherwise. For instance, $\text{Energy Star}_i \times \text{Policy}_{2001}$ takes the value of one if the residence is labeled as Energy Star and was built between 2001 and 2003, and zero otherwise. $\text{Energy Star}_i \times \text{Policy}_{2004}$ takes the value of one if the residence is labeled as Energy Star and

\textsuperscript{29} 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.
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:

\[
\ln(\text{price}_{ijt}) = B_1 \text{Energy Star}_i \times \text{Policy}_{t_i} + B_2 \text{Non Energy Star}_i \times \text{Policy}_{t_{97}} + \theta \text{HousingAttributes}_i + \gamma \text{Neighborhood}_j + \psi \text{YearMonth}_t + \alpha + \epsilon_{ijt}
\] (5)

The omitted category is conventional houses built under the 1997 Policy regime. \text{Policy}_{t_i} is a set of dummy variables for the 1997, 2001, and 2004 building codes and \text{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:

\[
\ln(\text{price}_{ijt}) = B_1 \text{1st Sale Energy Star}_i \times \text{Policy}_{t_i} + B_2 \text{2nd Sale Energy Star}_i \times \text{Policy}_{t_i} + B_3 \text{2nd Sale NonEnergy Star}_i \times \text{Policy}_{t_i} + B_4 \text{1st Sale NonEnergy Star}_i \times \text{Policy}_{t_{97}} + \theta \text{HousingAttributes}_i + \gamma \text{Neighborhood}_j + \psi \text{YearMonth}_t + \alpha + \epsilon_{ijt}
\] (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\textsubscript{i} * Age\textsubscript{it} and 2nd Sale Non – Energy Star\textsubscript{i} * Age\textsubscript{it}. The model takes the form:

\[\ln(\text{price}_{ijt}) = B_1 \text{1st Sale Energy Star}_i \times \text{Policy}_{t} + B_2 \text{2nd Sale Energy Star}_i \times \text{Policy}_{t} + B_3 \text{2nd Sale NonEnergy Star}_i \times \text{Policy}_{t_i} + B_4 \text{1st Sale NonEnergy Star}_i \times \text{Policy}_{t_{i7}} + \beta_4 \text{2nd Sale Energy Star}_i \times \text{Age}_{it} + \beta_5 \text{2nd Sale NonEnergy Star}_i \times \text{Age}_{it} + \theta \text{Housing Attributes}_i + \psi \text{Neighborhood}_j + \psi \text{YearMonth}_t + \alpha + \epsilon_{ijt} \tag{7}\]

### 4.4 Modified Repeat Sales Approach Model

The cross sectional models in the previous section attempt to control for unobservable factors that could affect price such as schools, parks, and other neighborhood amenities. They also control flexibly for omitted variables that vary temporally but not spatially, including energy prices, weather, macroeconomic changes, and supply-side cost changes in the construction industry. Despite the ability of these controls to absorb many important omitted variables, the validity of the cross sectional models still requires differences in neighborhood variables that affect price to be constant over time. This rules out changes in local public good provision at the neighborhood level, differential changes in school quality, changes in zoning laws, etc. Perhaps the biggest source of potential misspecification in the cross-sectional estimates is unobserved heterogeneity in the homes themselves that is correlated with both price and the right-hand side variables in the cross sectional models. We have already alluded to features of this sort, such as attractive landscaping or high-end appliances that are bundled with the Energy Star label and associated with higher prices. The repeat sales method allows us to control for some of these home characteristics that might be omitted from our cross section.

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.\textsuperscript{30} In our sample, we observe 1,895 residences that sold at least twice in our time period. Out of these, 316 residences were given the Energy Star label. This represents about 16 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 terms between \(\text{Energy Star}_t\) and indicators for the number of years since last sale \(\text{YSLS}\). 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:

\[
\ln\left(\frac{\text{price}_{it}}{\text{price}_{is}}\right) = \alpha_t - \alpha_s + \beta (\text{YSLS}_t \times \text{Energy Star}_i) + \Psi \text{YearMonth}_t - \Gamma \text{YearMonth}_s + \epsilon_{it} - \epsilon_{is}
\]

where the coefficients from these interactions will provide an index of energy star gradients (McMillen, 2003), \textit{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 also be affected by the change in building codes in Florida, we estimate the following equation:

\[
\ln\left(\frac{\text{price}_{it}}{\text{price}_{is}}\right) = \alpha_t - \alpha_s + \beta_1 (\text{YSLS}_t \times \text{Energy Star}_i \times \text{Policy}_t) + \beta_2 (\text{YSLS}_t \times \text{Non} - \text{Energy Star}_i \times \text{Policy}_{is}) + \Psi \text{YearMonth}_t - \Gamma \text{YearMonth}_s + \epsilon_{it} - \epsilon_{is}
\]

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.

It is important to note that we are making two implicit assumptions to recover the Energy Star price premium in these models. First, differences in amenities are allowed to have a cross-sectional effect on prices, but the properties of the amenities such as size, location, and quality must be fixed over time. This assumption could be relaxed in a more flexible version of the repeat sales model where home characteristics are included on the right hand side of the regression equation. The part of this assumption that is crucial to our identification strategy is that either omitted characteristics don’t appreciate or depreciate over time or that these characteristics are uncorrelated with the Energy Star label. We recognize that we don’t have strong evidence to support either of these claims, although the similarity of Energy Star and conventional homes along observable dimensions is suggestive that maybe unobserved features are also similar across the two groups (and thus uncorrelated with the label). The second important assumption rules out interactions between the Energy Star label and other hedonic characteristics; this is similar to the parallel trends assumption in a difference-in-differences framework.

If these two assumptions hold, then our repeat sales approach controls for the home and neighborhood attributes omitted from the cross section that don’t change in value over time. By looking at growth rates in prices rather than levels in prices, variables that only affect levels can be omitted without biasing the estimates. It is worthwhile to examine the plausibility of this assumption, which we have done by including interactions of observable characteristics and age in equation 2. T-tests for the quality, size, and bedroom interactions with the age variable were
not statistically significant. An F-test also failed to show evidence that these interactions were jointly non-zero, meaning we have no evidence that our observable characteristics appreciate or depreciate over time. Thus our biggest worry is unobserved features such as appliance that might depreciate more readily. If bundled features do appreciate or depreciate more in Energy Star homes, then part of the Energy Star gradient will be due to the change in price of the bundled features.

Finally, we note that since some types of houses may trade more frequently on the market than other types, another drawback of the repeat sales models might be sample selection bias. 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. It’s also worth pointing out that the repeat sales method does not solve the problem of bundling of other amenities with the Energy Star label if the bundled features change in price over time. If there is no bundling or the price of attributes bundled with the label is fixed over time, then the repeat sales can eliminate omitted variable bias that could bias our cross-sectional estimates.

Although both cross-sectional and repeat sales models have drawbacks, we view them as complementary methods to understand the price premium of the label. The cross sectional estimates included a richer set of controls for home quality, meaning they are more likely to pick up the value of the label itself rather than the label and the bundle of characteristics that could come in tandem with the label. The repeated-sales estimates can potentially solve omitted variables problems and even obviate the concern about bundling if hedonic attributes with the label if the assumptions discussed above are satisfied. To the extent that we have convincingly controlled for other features that might be associated with the label in our cross section, the
cross-sectional and repeat sales approaches are complimentary methods to study 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. 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)

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31 The qualitative results of alternative specifications are very similar to the estimates we present and they are available upon request.
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 the value of future energy savings that an Energy Star homeowner can expect to realize in the first 7 years of home ownership.\footnote{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.} 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 $1st \text{Sale Non} - Energy\ Star_i$. Thus, our parameter 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 $2^{nd} \text{Sale Energy Star}$ 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 $0.016 \times (0.0017 - (-0.0133))$, 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 $2nd \text{ Sale Energy Star}_t \times Age_{it}$ and $2nd \text{ Sale Non-Energy Star}_t \times Age_{it}$ 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. 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. This result is analogous to the Walls et al. (2013) result that shows that the price premium for Energy Star homes decreases with newer vintages.

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 $1st \text{Sale Energy Star}_i \times Policy_{1997}$. Once again, the original sale premium for new Energy Star houses compared to conventional houses built under the same 1997 building code is similar

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33 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 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.

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 $1.2 \left( -0.0190 - (-0.0070) \right)$ 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. In Figure 4 in the appendix we verify that we see a similar trend in transactions of Energy Star and conventional homes over time.
The building code estimates and the cross sectional estimates show two separate phenomena occurring in the Energy Star market. First, the premium for used homes seems to disappear over time, and second the premium for new homes erodes as the building codes become more stringent. While the disappearance of the resale premium could be due to the building codes, we plot in Figure 2 resale premium over time for houses built before the 2001 building code came into effect. This is to stress that resale effect is separate from the vintage effect, even if the causes might be similar.

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.\textsuperscript{34} 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 \((1 - 4)Y S L S_{t} \ast Star_{l}\) and \((1 - 4)Y S L S_{t} \ast Non - Energy Star_{l}\) and repeat sales that occurred 5 years or more of each other for Energy Star and conventional residences \((5 - 10)Y S L S_{t} \ast Star_{l}\) and \((5 - 11)Y S L S_{t} \ast Non - Energy Star_{l}\). The omitted category in this case is conventional residences that were sold twice within 4 years \((1 - 4)Y S L S_{t} \ast Non - Energy Star_{l}\). 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

\textsuperscript{34} 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.
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 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 $7YSLS_t \ast Energy Star_i$ 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 1.35 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 of Table 6 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

We have found two important features of the Energy Star market that have implications of the success of the policy. First, we find that the price premium associated with Energy Star
homes disappears over time in the resale market, and second we find that the first-sale premium disappears with newer vintages of Energy Star homes. These results are both related to the market failures that the program tries to address.

The disappearance of the resale premium suggests that builders and buyers of new homes won’t be able to consider lifetime home energy costs when deciding on energy efficiency. This disappearance is a consequence of signal failure. This will lead to less investment in Energy Star homes than the social-welfare maximizing level. More research is needed to understand why the Energy Star label price premium disappears in the resale market, but we have several possible channels in mind.

First, marketing a used Energy Star home might be more difficult than marketing a new Energy Star home. It is also likely that buyers with stronger preferences for energy efficiency systematically sort into new homes. 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.

It is also 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

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35 Other possibilities for the disappearance of the resale premium include overstatement of the efficiency of Energy Star capital or more rapid depreciation of this capital. Although there are proponents of these explanations, we tend to think that lower savings relative to engineering benchmarks are due to behavioral responses of the occupants rather than an inaccurate estimate of the efficiency difference.
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.

In the market for new homes, the disappearance of the price premium for Energy Star homes of new vintages suggests that the label isn’t alleviating the asymmetric information or search costs market frictions. A potential explanation for this effect 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.

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 foregoing the 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.

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 Florida.\textsuperscript{37} The disappearance of the resale premium suggests that homeowners might have trouble effectively marketing their used Energy Star homes. In other words, the label does not seem to be able to overcome the asymmetric information problem or making energy efficiency more salient in the resale housing market. Although early vintages of new Energy Star homes sold for more than conventional homes of the same vintage, labeled homes of later vintages did not sell for more than their conventional counterparts. It seems that

\textsuperscript{37} Walls et al. have a similar conclusion for three US cities outside of Florida.
perhaps conventional homes of new vintages are too similar in terms of efficiency for the label to be meaningful.

A 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.

The first-sale premium has probably been eroded by the Florida building code. 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. Hence the label doesn’t mean the same thing for residences of a different vintage. This ambiguity may have caused the Energy Star premium for new homes 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.
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.
Figure 3: Composition of the Housing Stock by Subdivision

Notes: Our sample has a total of 21.9% Energy Star Homes

Figure 4: Energy Star vs. Conventional Sales over Time
Table 1: Energy Star Features and Estimated Savings

<table>
<thead>
<tr>
<th>Feature</th>
<th>Est. Annual Savings</th>
<th>Upgrade Cost(^{38})</th>
<th>Maintenance Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-E Windows</td>
<td>$75(^{39})</td>
<td>$750(^{40})</td>
<td>None</td>
</tr>
<tr>
<td>High R-Value Insulation</td>
<td>$100(^{42})</td>
<td>$1,000(^{43})</td>
<td>None</td>
</tr>
<tr>
<td>Properly-sized HVAC</td>
<td>$250(^{45})</td>
<td>$0(^{46})</td>
<td>None</td>
</tr>
<tr>
<td>Tankless Water Heater</td>
<td>$75(^{48})</td>
<td>$350(^{49})</td>
<td>Frequent Service(^{50})</td>
</tr>
</tbody>
</table>

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.

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\(^{38}\) Upgrade cost represents a rough estimate of the price difference between the energy efficient feature and the standard feature.

\(^{39}\) Based on Consumer Reports at http://www.consumerreports.org/cro/home-windows/buying-guide.htm

\(^{40}\) We contacted a large window manufacturer who indicated that Low-E windows are about $50 more expensive than conventional windows. Based on internet searches, we assume the average house has 15 windows.

\(^{42}\) The Energy Star website http://www.energystar.gov/index.cfm?c=home_sealing.hm_improvement_methodology has information that we used for this calculation.

\(^{43}\) Based on difference in attic insulation costs between R30 and R60 attic insulation for a 2,000 square-foot attic using Lowe’s insulation calculator: http://www.lowes.com/cd_Blown+In+Insulation+Calculator_748453603_

\(^{45}\) We used a calculator created by the DOE; this can be found online at http://energy.gov/eere/femp/energy-and-cost-savings-calculators-energy-efficient-products.

\(^{46}\) Although many of our builders advertised this feature of their Energy Star homes, conventional new homes also have professionally sized HVAC systems.

\(^{48}\) Consumer Reports has estimated cost and savings for various types of water heaters. 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.

\(^{49}\) Based on costs at a major home improvement store

\(^{50}\) 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.