

## **The Intersection of Climate Beliefs and Sustainability: An empirical study of energy efficiency premiums in the residential real estate market**

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### **Abstract**

Building on the certification literature and previous work on the impact of climate change on real estate prices, this paper investigates how the prices of sustainable homes differ from conventional homes. This paper utilizes data from the Green Building Registry and the Yale Climate Opinion Maps, along with residential housing prices and uses the hedonic pricing model to estimate the economic impact of energy efficiency on housing prices. Using comprehensive sales transaction data merged with energy rating data of U.S. real estate properties, this paper finds that properties with better energy ratings are sold at a premium compared to those with poor energy performance. The results also suggest that the premium is more profound among neighbourhoods concerned about sustainability and environmental issues. The paper contributes meaningfully to the sustainable finance and energy ratings literature. It has the potential to further our understanding of the role of energy ratings on real estate pricing and how climate beliefs may impact this role.

**Keywords:** Energy Efficiency, Housing Market, Climate Belief, Sustainable Finance

**JEL Classification:** Q54, Q40, G41, D12

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### **I Introduction**

The real estate sector is tremendously important as it affects and is affected by climate change. It is an asset class that plays a substantial role in investors' portfolios. According to a recent survey by the global investment firm KKR, real estate investments account for about 22% of high-net-worth households' total assets (McVey, 2021). Buildings account for around one-third of global greenhouse gas emissions and consume 40% of the world's energy (Global Alliance for Buildings and Construction, 2018).

The previous work on real estate value, rising sea levels, and energy ratings helped form the foundation for the hypothesis that home energy ratings are capitalized in home prices. The hypothesis becomes readily testable through data collection from two primary sources. Information on energy ratings for residential dwellings is collected from greenbuildingregistry.com (GBR), and information on the characteristics of the homes and their sales price comes from Zillow.com. The dataset has broad coverage of observations across the U.S. and includes a more extended time series of energy efficiency and sales price. The Home Energy Rating System (HERS) ratings from the green building registry dataset allow us to draw more general implications across the United States. This paper focuses on exploring the link between housing prices, climate risks and efficiency scores of homes, thereby adding to both the asset pricing and socially responsible investing literature. The results of this paper show that

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differences in home energy ratings and beliefs on climate change are reflected in residential real estate prices. Specifically, homes with better energy efficiency ratings are sold at a higher price than otherwise comparable homes. This result is robust to various home price measures, such as tax assessment value and price per square foot, home characteristics controls and other regional controls. This study also finds that heterogeneity in beliefs about climate change significantly impacts the U.S. real estate market. All else being equal, the “green home premium” found in the study is more substantial in the region where more residents are aware of climate change risk than in a “non-believer” region.

This paper is inspired by previous work that has examined housing prices and other elements of climate risks, such as the risk of sea-level rise. A few studies have investigated the price impact of the risk of sea-level rise on property prices and documented the moderating influence of heterogeneity in beliefs about long-run climate change risks (Murfin & Spiegel, 2019; Bernstein, Gustafson, & Lewis, 2019; Baldauf, Garlappi, & Yannelis, 2020). The current work also contributes to the broader body of work that examines how energy ratings and metrics influence investors’ appetite to invest. For example, climate-focused labels for mutual funds have been shown to induce fund inflows (Ceccarelli, Ramelli, & Wagner, 2023). Kim and Yoon (2022) document a significant increase in fund flow in response to active managers’ commitment to ESG. In the context of real estate, we hypothesize that increased demand for more efficient homes translates to higher prices.

The rest of the paper proceeds as follows. Section II reviews the related literature on real estate prices, home efficiency ratings and climate beliefs and develops the main hypothesis. Section III describes the data and discusses the methodology. Section IV discusses the interpretation of the main results. Section V assesses the robustness of the findings, and Section VI concludes.

## **II Literature and Hypothesis**

This paper falls at the intersection of two kinds of literature: real estate asset markets, specifically the influence of energy efficiency on pricing, and climate beliefs. Concerning real estate and energy efficiency, Cajias and Piazzolo (2013) show that energy-efficient residential buildings have higher investment yields than inefficient buildings based on German evidence. Their results indicate that the total return on investments is positively related to the reduction in energy consumption. Cajias (2017) complements the previous study by providing strong evidence that the marketing process of real estate assets is influenced by their energy efficiencies. More specifically, energy-inefficient buildings are less welcome than efficient buildings (Cajias, 2017). From a cost-benefit perspective, a poor energy rating implies tenants are likely to pay more to cover the utility bills. Therefore, the low energy efficiency rating can be a “deal-breaker” for the tenant in the rental market.

In the broader European market, Cohen, Fedrigo-Fazio, Lyons, Lyons, and Mudgal (2013) provide a comprehensive analysis of E.U. country housing and rental markets to estimate the impact of energy performance certification with solid evidence of an energy efficiency premium, both in sales and lettings markets, in Europe. Other papers also find the existence of similar green home premiums in the U.K. and Southern Europe (Geske, 2022; Taltavull de La Paz, Perez-Sanchez, Mora-Garcia, & Perez-Sanchez, 2019). In the North American context, Walls, Palmer, Gerarden, and Bak (2016) document that Energy Star certification increases the sales prices of homes. The green home price premiums suggest that either green homes have valuable

characteristics or home buyers are "overpaying" for energy savings. However, their results are limited from 2005-2011 in the triangle region of North Carolina, Austin, Texas, and Portland, Oregon. Although it is rare to see studies that show contrary results to most of the findings discussed above, a few studies suggest more cautious reference and use of energy efficiency ratings—for example, Galvin (2023) raises the concern that energy rating may not reflect future energy savings accurately. As a result, home buyers can end up paying more than they should for energy-efficient homes.

Despite broad scientific consensus on climate change, the general public's opinion diverges substantially. A 2020 survey shows that about 51 percent of Americans surveyed are concerned with global warming, while the remaining 49 percent are not worried about global warming and believe the issue is unimportant (Gallup, 2020). It is interesting to investigate if such differences of opinion are reflected in how energy scores influence housing prices. Choi, Gao, and Jiang (2019) point to an essential aspect of the discussion that beliefs play a crucial role in pricing the risk of climate change and selecting strategies to mitigate climate change risks. Their paper sheds light on collective beliefs and actions about global warming, which can provide insights into the impact of collective and heterogeneous beliefs on real estate prices. Bakkensen and Barrage (2021) provide a theoretical framework and empirical evidence on how belief heterogeneity can reconcile the mixed empirical evidence on flood risk capitalization. Bernstein et al. (2019) also find that beliefs about climate change are essential in determining housing prices. They show homes exposed to sea level risks and located in counties where residents are worried about climate change to sell at a discount, which is consistent with the findings of this paper on climate belief and housing prices. This paper's primary hypothesis asks whether homes that receive better energy-efficient ratings are sold at a higher market price, all else equal. The main hypothesis is tested by a standard hedonic pricing method in pricing real estate assets. The secondary hypothesis explores whether the strength of the relationship between housing prices and energy efficiency ratings depends on the climate-related beliefs of individuals in the county where the home is located. The hypothesis is tested by partitioning the full sample into two sub-samples, believer and non-believer samples and adding interaction terms between climate belief and energy-efficiency ratings.

### **III Data and Methodology**

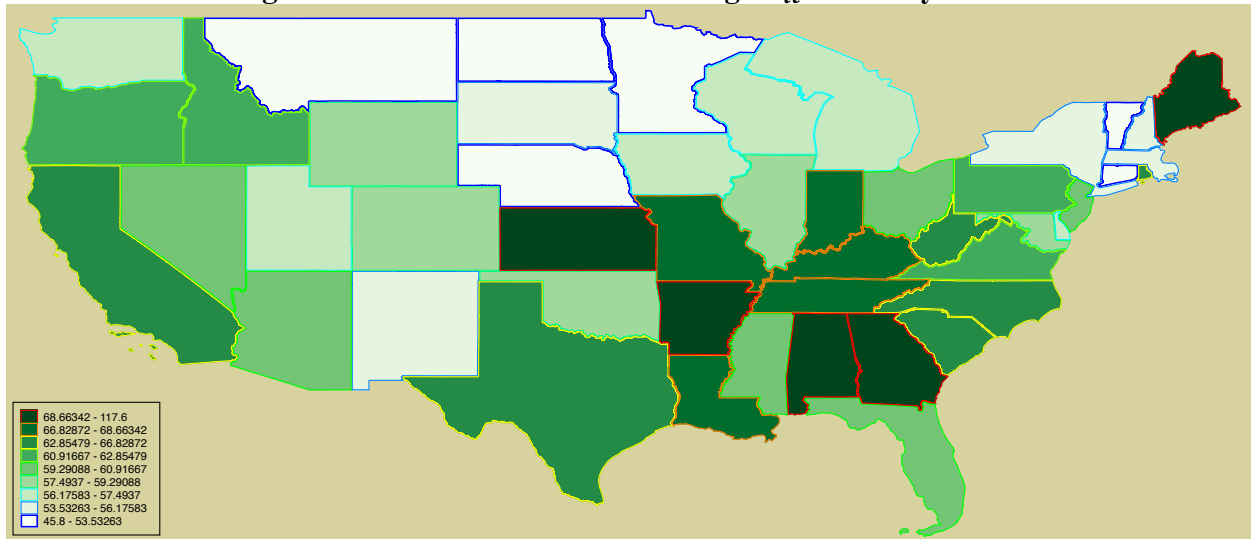
Home energy ratings are retrieved from [greenbuildingregistry.com](http://greenbuildingregistry.com) (GBR). The Green Building Registry (GBR) is a DaaS (data-as-a-service) platform that has provided green and energy-efficient home data to homeowners, real estate agents, appraisers, and lenders across the US. The application programming interface built by GBR allows access to consolidated data from multiple sources such as LEED, Earth Advantage, and NGBS GREEN. In this research, the Home Energy Rating System (HERS) is used to measure the energy performance of homes across the U.S.

The Home Energy Rating System assesses homes' energy performance on components such as exterior walls; floors over unconditioned spaces; ceilings and roofs; attics, foundations, and crawlspaces; windows and doors; vents and ductwork; HVAC systems, water heating systems, and thermostats. The Home Energy Rating System considers the performance of heating, cooling, water heating and lighting when deriving the final HERS index. The HERS Index equation compares the energy use of the assessed home to that of the HERS reference home, which has the same size and shape as the assessed home in a similar location and climate zone.

An index score of 100 means that the rated home has the same energy use as the HERS reference home, while a score of 0 means the home has net zero energy use. In other words, the

home produces as much energy as it uses. HERS rating scores can range from 0 to 150; the lower scores indicate less energy use and better energy performance. To have a more intuitive understanding of the correlation between housing price and energy efficiency, HERS rating scores are rescaled to the energy rating variable  $E_{it}$ , where  $E_{it}$  is defined as 150-HERS rating scores. Higher  $E_{it}$  values now indicate better energy performance. Figure 1 provides an overview of the average  $E_{it}$  values by states, where the deeper green colour represents a higher  $E_{it}$  values and better energy performance.

**Figure 1: An Overview of the Average  $E_{it}$  Values by States**



The Yale Climate Opinion Maps (Howe, Mildenerger, Marlon, & Leiserowitz, 2015) provide county-level evidence on whether respondents believe in climate change, whether there is scientific consensus, and whether they think their lives will be affected. According to researchers behind the project, this national survey has collected differences in opinions on climate change in all 50 states in the U.S. This dataset is merged with the Green Building Registry (GBR) and Zillow housing price to explore energy rating effects in housing prices among neighbourhoods with different climate change beliefs. With the help of the Yale Climate Opinion Map, we can provide more robust findings to investigate if the green home premium is equally profound among neighbourhoods with different beliefs on climate change. Other characteristics of neighbourhoods, such as political beliefs, can be possible sources of variation that link the effects of beliefs about climate change on home prices. This paper uses political belief as an instrumental variable to climate belief to test the robustness of the findings and explore more heterogeneities.

Table 1 lists all the variables used in this paper and describes the variables. Home transactional prices and other characteristics are available on Zillow.com. Variables that could be used to control for heterogeneity across homes include year built, lot size if the house has a garage, number of bathrooms, number of bedrooms and so on. In addition to features of the individual home, regional controls include county-level income data, population, the share of Republican voters, education level, county-level annual average temperature and beliefs about climate change to support future heterogeneity analysis.

Summary statistics for regional controls are presented in Table 2. The average house price ( $P_{it}$ ) in our sample is \$451,853.28 from 1962 to 2021. Homes have an average energy-efficient rating ( $E_{it}$ ) of 61.396, and an average of 61.93 percent ( $B_c$ ) of households are worried about climate

change. About 96% of our samples are single-family houses, and the rest are condos. The proportion of high-income households with an income of \$200,000 or more in the sample is about 27.1%, and the proportion of households that vote for the Republican Party is about 43.2%. Education is measured on a level of 1-10, with 10 being the highest education level in the sample and 1 being the lowest. The average education level of the full sample is 6.26.

**Table 1: Variable Descriptions**

Variables	Description	Source	Unit
$P_{it}$	Dollar transaction price of home $i$ at time $t$	Zillow	Numerical
$E_{it}$	Home Energy Rating System score of home $i$ at time $t$ rescaled as 150-HERS	GBR	Numerical
<b>Property-level Controls</b>			
Year	Year the property was built	Zillow	Years
Bedrooms	number of bedrooms of a property	Zillow	Numerical
Bathrooms	number of bathrooms of a property	Zillow	Numerical
Size	Total lot size of a property	Zillow	Numerical
Garage	Indicator if the property has a garage	Zillow	Dummy
HOA	HOA fees	Zillow	Numerical
Price per sqft	Price per sqft of a property	Zillow	Numerical
Tax value	Tax assessment value of a property	Zillow	Numerical
Single	Indicator for a single-family home	Zillow	Dummy
Family		Zillow	Dummy
Condo	Indicator for a condo	Zillow	Dummy
Pool	Indicator if the property has a pool		
<b>Regional Controls</b>			
Education	County average education level (rescaled)	ACS*	Scale of 1-10
Population	Population for each zip code	ACS	10
High Income	Indicator of high-income regions	IRS <sup>†</sup>	Thousands
GOP share	Percentage of individuals in a zip code voting for the Republican Party	HEDA	Dummy Percentage
$B_c$	Percentage of residents that believe that global warming is happening in county $c$	HMML <sup>‡</sup> NOAA <sup>§</sup>	Percentage
Temperature	Annual temperature means by county in Fahrenheit		Numerical

Table 3 presents some preliminary observations on the data by providing the correlation matrix among a portion of the variables listed in Table 2. A quick look at the table shows a positive correlation between the home price and energy-efficient rating  $E_{it}$ . In other words, the higher energy efficiency scores are correlated with higher prices. The correlation matrix also shows preliminary evidence of heterogeneous characteristics among different neighbours. The energy-

\* The American Community Survey

† Internal Revenue Service

‡ Howe, P.D., Mildenerger, M., Marlon, J.R., Leiserowitz, A. (2015). Geographic Variation in Opinions on Climate Change at State and Local Scales in the USA. *Nature Climate Change*, 2015, 5 (6), 596–603.

§ National Oceanic and Atmospheric Administration

efficient rating is positively correlated with regional characteristics such as higher income, better education level and more awareness of climate change issues. Moreover, households in regions with higher income, better education and higher housing prices are generally associated with more awareness of climate change issues.

**Table 2: Summary Statistics**

Variable	Observations	Mean	Std. Dev.	Min	Max
$P_{it}$	754,892	451,853.28	1,292,917	101	688,800,000
$E_{it}$	754,892	61.396	8.443	0	150
<b>Property-level Controls</b>					
Year	754,892	2016.482	3.447	1962	2021
Bedrooms	860,357	3.658	0.898	1	14
Bathrooms	931,773	3.024	1.036	0.5	15
Size	1,166,085	28,804.27	735,468.62	0	611,900,000
Garage	1,166,228	0.668	0.47	0	1
HOA	1,166,085	210.373	673.231	0	18,684
Price per sqft	17,874	191.657	117.88	19	3,221
Tax value	1,096,273	492,553.39	5,325,890.5	0	1,000,000,000
Single Family	1,166,085	0.959	0.198	0	1
Condo	1,166,085	0.041	0.198	0	1
Pools	1,166,085	0.07	0.255	0	1
<b>Regional Controls</b>					
Education	399,509	6.26	0.38	4.19	8.04
Population	1,166,085	9,701,180.2	6,910,484.3	444,117	30,075,104
High income	1,166,085	0.271	0.125	0	0.65
GOP Share	201,332	0.432	0.185	0	0.90
$B_c$	1,166,085	61.93	3.754	49.179	73.07
Temperature	631,353	59.84	9.16	34.59	78.82

The hedonic pricing method is used to estimate economic values for ecosystems or environmental services that directly affect market prices. In this case, the model is applied to estimate the economic impact of energy rating  $E_{it}$  on housing prices  $P_{it}$  and show how variations in housing prices can reflect the value of local environmental attributes. A hedonic model requires information on housing prices and locations of residential properties, property characteristics that affect selling prices, such as lot size, number and size of rooms, and the number of bathrooms, neighbourhood characteristics that affect selling prices, such as average household income and education level as well as environmental characteristics that affect prices such as HERS ratings. The key empirical challenge to identifying a green premium is that home valuations vary among dimensions other than their energy ratings. Homes with higher energy ratings are also more likely to have other excellent features that add to the home's value. For example, a new and better-insulated home may also have better interior features, a more solid foundation, and fewer issues

that need fixing. This concern can be addressed using a hedonic pricing model that controls for property-level characteristics and attributes of neighbourhoods.

**Table 3: Matrix of Correlations**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) $P_{it}$	1								
(2) $E_{it}$	0.0920	1							
(3) Bedrooms	0.026	0.1559	1						
(4) Lot size	0.0146	0.0036	0.2728	1					
(5) Education	-0.0432	0.0777	0.0139	-0.013	1				
(6) Population	0.2777	-0.0015	0.001	-0.1035	-0.2429	1			
(7) High income	0.0501	0.1840	0.1375	0.1369	0.2364	0.1171	1		
(8) GOP shares	0.0182	-0.1598	-0.0579	0.0475	-0.3735	-0.189	-0.0504	1	
(9) $B_c$	0.1396	0.1432	0.0332	-0.0336	0.2211	0.1533	0.1047	-0.3673	1

Our main dependent variable is the natural logarithm of the transaction price of home  $i$  at time  $t$ ,  $\ln P_{it}$ . The independent variables include covariates at the home level and county level. Home level covariates,  $X_i$ , include the natural logarithm of rescaled HERS rating, denoted as  $\ln E_{it}$  as well as other characteristics of homes mentioned in Table 1. County (regional) level controls,  $Z_i$ , include county-level income, population, the share of Republican voters, education level and beliefs about climate change. Year fixed effect  $\alpha_t$  is also included in the equation to control for general changes in housing prices over time. The main specification uses a standard real estate valuation framework similar to the model proposed by Bond and Devine (2016) to test the hypothesis that HERS is associated with home prices at a premium:

$$\ln P_{it} = \alpha_c + \alpha_t + \beta \ln E_{it} + \gamma X_i + \lambda Z_i + \varepsilon_{it} \quad (1)$$

As discussed previously, climate belief also plays a crucial role in the real estate market and energy-efficiency rating effects. To test the hypothesis of whether the strength of the relationship between housing prices and energy efficiency ratings is dependent on the climate-related beliefs of individuals, the full sample is partitioned into two sub-samples: believer and non-believer. A believer region has an above-median percentage of respondents believing in climate change. A non-believer region falls below the median percentage of respondents believing in climate change. Figure 2 provides an overview of the map of households' beliefs in climate change across the U.S. A deeper green colour represents that the residents in such states are more concerned with climate issues and environmental risks. The map of climate beliefs is consistent with the findings of Murfin et al. (2019) and Baldauf et al. (2020), that residents near coastal areas are more likely to worry about climate change and environmental issues.

Table 4 provides an indication of differences in believer vs non-believer regions of potential contrasting characteristics. It examines whether there are significant differences in average house prices, education, income, and political beliefs across regions with varying beliefs. Believer regions have, on average, higher housing prices, more efficient energy ratings, a larger population, a greater proportion of high-income households and higher education levels.

Figure 2. An Overview of Climate Belief by States

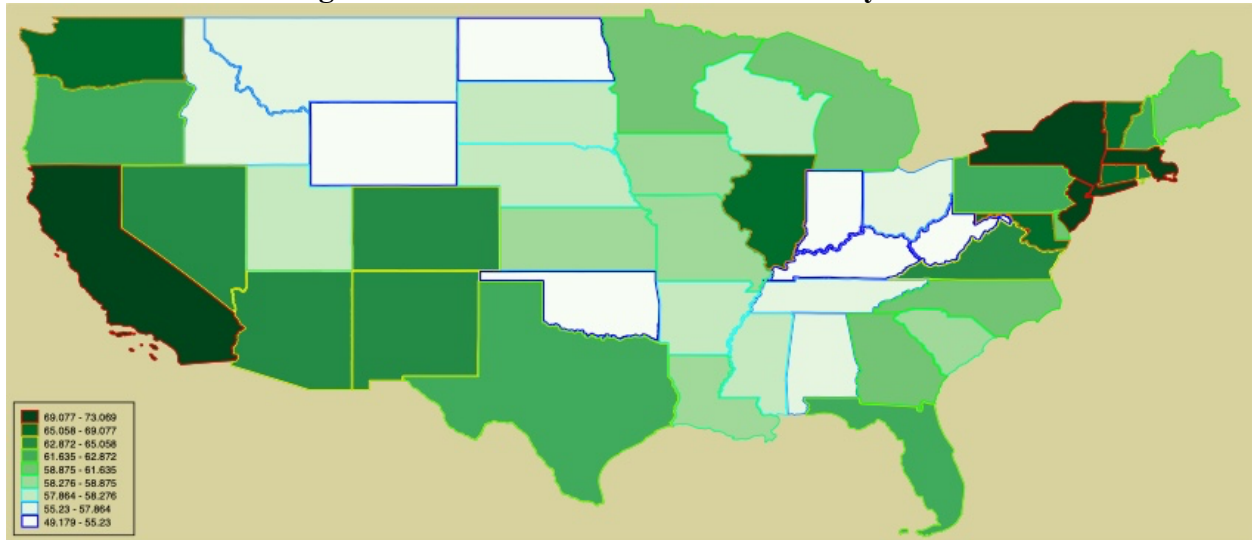


Table 4: Beliefs About Climate Change and House Prices

Variable	Observations	Believer		Non-Believer		
		Mean	Std. Dev.	Observations	Mean	Std. Dev.
$P_{it}$	350,596	564,575.80	1,714,489.00	404,298	354,050.50	742,324.20
$E_{it}$	350,596	89.73	7.84	404,298	87.62	8.82
Population	332,185	1,388,877	1,542,432	388,839	453,544.10	401,525.60
High Income	596,373	0.29	0.13	569,855	0.25	0.11
Education	181,025	6.29	0.40	218,484	6.22	0.37

Splitting the sample into believer and non-believer subsamples allows the coefficients on the regional and house-specific controls to influence price in different ways. While this may be useful in that different regions may show different associations among variables and home prices, it can confound the relation between our primary variable of interest, energy efficient rating, and prices by allowing this flexibility. An alternative specification is to allow the energy certification to interact with the belief variable. In other words, climate-related beliefs would be hypothesized to have a moderating or amplifying effect on how energy certification relates to housing prices. This specification is provided in equation (2):

$$\ln P_{it} = \alpha_c + \alpha_t + \beta_1 \ln E_{it} + \beta_2 \text{Belief} + \beta_3 \text{Belief} * \ln E_{it} + \gamma X_i + \lambda Z_i + \varepsilon_{it} \quad (2)$$

The main dependent variable is again the natural logarithm of the price of home  $i$  at time  $t$ ,  $\ln P_{it}$ . The independent variables include the natural logarithm of homes' energy rating score at time  $t$ ,  $\ln E_{it}$ , home-level characteristics  $X_i$ , regional level covariates  $Z_i$ , county-level fixed effect  $\alpha_c$ , year fixed effects  $\alpha_t$  and error term  $\varepsilon_{it}$ . Additional variables included here are the belief dummy variable, and the interaction between the belief dummy variable and  $\ln E_{it}$ . The belief dummy,  $\text{Belief}$ , takes a value of 1 for believer regions and 0 for non-believer regions.

The key identifying assumption is that unobserved determinants of home prices are uncorrelated with beliefs and  $\ln E_{it}$ , conditional on observables. To overcome the endogeneity

problems, Republican vote share has been included here as a source of instrument. It has been documented that Republicans are less likely to believe in climate change than Democrats. For example, a 2018 Gallup survey found that 89% of Democrats believe that global warming is caused by human activities, while only 42% of Republicans shared the same belief. In the instrumental variable regression, we choose the vote share of the Republican party as the instrument variable, which is believed to satisfy both inclusion restriction and exclusion restriction. The instrument is conditionally correlated with the endogenous variable (belief), and the share of Republican voters is assumed to be conditionally uncorrelated with unobserved determinants of home prices other than beliefs.

#### IV Results

Table 5 reports the effect of home energy rating score on house prices by estimating equation (1). The table illustrates that to correctly estimate the  $E_{it}$  coefficient, it is important to control for regional, year, and house characteristics. In the first column of the table, the regression model examines the relation between home energy efficiency certification and housing prices while controlling for year-fixed effects alone. The coefficient on the HERS rating is statistically significant at the one percent level. Since both housing price  $P_{it}$  and energy-efficient score  $E_{it}$  are in natural logarithm forms, each one unit increase in  $\ln E_{it}$  is associated with a 1.625 increase in  $\ln P_{it}$ . In other words, a 1% increase in the energy-efficient score  $E_{it}$  is associated with a  $e^{1.652 \cdot (\ln \ln 1.01)} - 1 = 1.657\%$  increase in housing price  $P_{it}$ .

**Table 5: Home Energy Score and House Prices**

	(1)	(2)	(3)
$\ln E_{it}$	1.652*** [0.031]	0.856*** [0.033]	0.306*** [0.031]
Population		0.059*** [0.002]	0.009*** [0.003]
High income		1.973*** [0.020]	1.477*** [0.024]
Education		0.147*** [0.006]	0.166*** [0.007]
$B_c$		0.054*** [0.001]	0.048*** [0.001]
Year fixed effects?	yes	yes	yes
Regional Controls?	no	yes	yes
House Controls?	no	no	yes
Observations	754,892	399,505	259,121
R-squared	0.033	0.089	0.157

In column two of the table, regional controls of population, the proportion of high-income households, education level and belief in climate change are added as additional covariates. It is observed that higher housing price is associated with a greater population, a higher proportion of high-income households, a higher education level and more awareness of climate change issues.

The regression results again confirm heterogeneity among different neighbourhoods and are consistent with the preliminary evidence we have seen from the summary statistics and correlation matrix. Although the economic value of  $E_{it}$  coefficient is slightly reduced after adding regional control variables, it remains statistically significant at the 0.01 level.

In column three of Table 5, we can see that the implications of this estimation are similar after adding home characteristic controls such as lot size, number of bedrooms, indicators of whether the home is a single-family unit or a condo, Homeowner association (HOA) fees and so on. Overall, the empirical results across all columns of Table 5 show a significant and positive relationship between energy-efficient ratings and home sales prices. On average, a 1% increase in the energy-efficient score  $E_{it}$  is associated with a 0.3049% to 1.657% increase in housing price  $P_{it}$ .

Having established a preliminary relation between energy efficiency certification and housing prices, we next move the analysis forward to ask whether beliefs about climate change influence the relation between HERS and home prices. The full sample is partitioned into two subsamples: believer and non-believer. A believer region has an above-median percentage of respondents believing in climate change. A non-believer region falls below the median percentage of respondents believing in climate change. The estimations for equation 1 are now truncated between believer and non-believer samples in Table 6. Again, the first column of the table controls for year-fixed effects alone, the second column adds regional controls and the third column adds home characteristic controls.

**Table 6: Beliefs About Climate Change and House Prices**

	Believer			Non-Believer		
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln E_{it}$	2.015*** [0.067]	1.833*** [0.109]	1.106*** [0.106]	1.011*** [0.029]	0.586*** [0.034]	0.078** [0.036]
Population		0.042*** [0.002]	-0.010*** [0.003]		0.206*** [0.006]	0.104*** [0.008]
High income		1.853*** [0.030]	1.211*** [0.036]		2.040*** [0.025]	1.299*** [0.035]
Education		0.258*** [0.010]	0.225*** [0.011]		0.180*** [0.008]	0.214*** [0.010]
Year fixed effects?	yes	yes	yes	yes	yes	yes
Regional Controls?	no	yes	yes	no	yes	yes
House Controls?	no	no	yes	no	no	yes
Observations	350,594	181,023	114,814	404,296	218,481	144,306
R-squared	0.05	0.099	0.201	0.038	0.082	0.159

The empirical results show that the “green home” premium is more significant in the believer regions. The table shows that the positive relationship between home prices and energy-efficient ratings is stronger in areas where more individuals believe in climate change. The results indicate that, in areas with stronger beliefs, the HERS rating has a much larger impact on house prices. This result is robust to a wide range of controls, including house characteristics and regional controls.

An alternative specification is to allow the energy certification to interact with the belief variable, as shown in equation (2). The empirical results from estimating equation (2) are shown

in Table 7. It again presents three columns allowing for various levels of control. However, from column 1 onwards, we include the energy-efficient rating variable, the belief dummy variable, and the interaction between the two. The coefficient of interest is  $\beta_3$  since the marginal effect of the home energy-efficient score on housing price is now  $(\beta_3 + \beta_1)$  for believer regions and  $\beta_1$  for non-believer regions.  $\beta_3$  is the additional marginal effect of the home energy-efficient score on housing price by believer regions over non-believer regions. As shown in Table 7, the coefficients of  $\beta_3$  and  $\beta_1$  are both positive, indicating that the additional marginal effect of the home energy-efficient score on housing price by believer regions over non-believer regions is positive. This result is consistent with our findings in Table 6, which also concludes that home prices are much more sensitive to energy-efficient ratings in areas where a higher fraction of individuals believe that climate change is happening. The combined marginal effect of the home energy-efficient score on housing prices for believer regions  $(\beta_3 + \beta_1)$  is also consistent with the coefficient reported in Table 6.

**Table 7: Beliefs and Energy-Efficient Rating Interactions**

	(1)	(2)	(3)
$\ln E_{it}$	1.031*** [0.030]	0.692*** [0.035]	0.133*** [0.035]
$B_c * \ln E_{it}$	1.005*** [0.074]	1.127*** [0.113]	0.998*** [0.111]
$B_c$	-4.114*** [0.332]	-4.805*** [0.505]	-4.236*** [0.499]
Population		0.042*** [0.002]	-0.010*** [0.003]
High income		1.853*** [0.030]	1.211*** [0.036]
Education		0.258*** [0.010]	0.225*** [0.011]
Year fixed effects?	yes	yes	yes
Regional Controls?	no	yes	yes
House Controls?	no	no	yes
Observations	754,890	399,504	259,120
R-squared	0.062	0.1	0.166

## V Alternative Specifications and Robustness Tests

In this section, we assess the robustness of the main findings by considering several variants of our main specification. Table 8 presents the instrumental variable regression results following the approach of Baldauf et al. (2020). It has been documented that Republicans are less likely to believe in climate change than Democrats. In the instrumental variable regression, we choose the vote share of the Republican party as the instrument variable, which is believed to satisfy both the inclusion and exclusion restrictions. The instrument is conditionally correlated with the endogenous variable (belief,  $B_c$ ), and the share of Republican voters is assumed to be conditionally uncorrelated with unobserved determinants of home prices other than beliefs.

All three columns of Table 8A confirm the inclusion restriction that geographic areas with more Republicans are less likely to believe climate change is happening. Column (1) shows that

**Table 8A: Inclusion Restriction**

	(1)	$B_c$ (2)	(3)
GOP share	-4.738*** [0.047]	-9.972*** [0.116]	-8.742*** [0.150]
Population		0.367*** [0.008]	0.447*** [0.011]
High income		2.407*** [0.112]	0.616*** [0.150]
Education		1.212*** [0.041]	1.438*** [0.053]
		0.027*** [0.000]	0.012*** [0.001]
Year fixed effects?	yes	yes	yes
Regional Controls?	no	yes	yes
House Controls?	no	no	yes
Observations	201,332	70,018	44,266
R-squared	0.055	0.186	0.208

**Table 8B: Instrumental Variables Estimates**

	(1)	$\ln P_{it}$ (2)	(3)
$B_c * \ln E_{it}$	0.204*** [0.009]	0.118*** [0.013]	0.187*** [0.019]
$\ln E_{it}$	1.046*** [0.049]	0.466*** [0.056]	0.058 [0.066]
Population		0.112*** [0.012]	0.018 [0.018]
High Income		1.681*** [0.049]	1.302*** [0.054]
Education		0.283*** [0.013]	0.372*** [0.015]
Year fixed effects?	yes	yes	yes
Regional Controls?	no	yes	yes
House Controls?	no	no	yes
Instruments?	yes	yes	yes
Observations	201,331	70,017	44,265
R-squared	0.007	0.145	0.221

precincts with a one percentage point higher level of Republican votes are associated with a 4.738 percentage point reduction in the fraction of individuals who believe climate change is happening. The effect is highly statistically significant at the 0.01 level. After adding regional controls in column 2 and house characteristics in column (3), the economic value of the GOP share coefficient is even more substantial and remains statistically significant at 0.01 level. Having verified the inclusion restriction in Table 8A, Table 8B reports results for an instrumental variable approach to estimating equation (3):

$$\ln P_{it} = \alpha_c + \alpha_t + \beta_1 \ln E_{it} + \beta_2 \text{Belief} * \ln E_{it} + \gamma X_i + \lambda Z_i + \varepsilon_{it} \quad (3)$$

As in Baldauf (2020), we use 2 instrument variables: GOP vote share and the interaction term  $\text{GOP vote share} * \ln E_{it}$  to instrument the endogenous  $B_c * \ln E_{it}$ . We find that our coefficient estimates of  $\ln E_{it}$  remain positive and significant, and the economic values are very close to the baseline results presented in Table 5. The estimate of the interaction term  $B_c * \ln E_{it}$  is also positive and significant, indicating that the additional marginal effect of home energy-efficient score on housing price by believer regions over non-believer regions is positive.

As an additional robustness test, Table 9 replaces the dependent variable of housing sales prices from Zillow with tax assessment value and price per square feet. Equation (1) is re-estimated here with three specifications, including various levels of controls. The coefficients mostly remain significant and positive at the one percent level with some exceptions in columns (3) and (5) mainly due to the substantial reduction in sample size. Moreover, the economic value of the coefficients is similar to what we presented in Table 5.

**Table 9: Alternative Specifications**

	Tax assessment value			Price per sq.ft.		
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln E_{it}$	0.832*** [0.018]	0.142*** [0.015]	0.04 [0.025]	0.620*** [0.082]	0.134 [0.088]	0.195** [0.091]
Population		0.041*** [0.001]	0.010*** [0.002]		0.054*** [0.004]	0.038*** [0.004]
High income		1.910*** [0.012]	1.242*** [0.025]		0.605*** [0.046]	0.430*** [0.059]
Education		0.146*** [0.004]	0.104*** [0.004]		0.189*** [0.016]	0.153*** [0.015]
$B_c$		0.027*** [0.000]	0.012*** [0.001]		0.023*** [0.002]	0.016*** [0.002]
Year fixed effects?	yes	yes	yes	yes	yes	yes
Regional Controls?	no	yes	yes	no	yes	yes
House Controls?	no	no	yes	no	no	yes
Observations	350,594	181,023	114,814	14,047	3,700	3,191
R-squared	0.05	0.099	0.201	0.049	0.254	0.503

Table 10 presents the effect of energy ratings with temperature heterogeneity and shows the robustness of the results in warm and cool temperature areas. In other words, do energy efficient homes perform equally well in hot and cold areas? Are the price effects well observed in both hot and cold areas? Equation (1) is estimated with the full sample partitioned into upper 50 percentile, lower 50 percentile, upper 25 percentile and lower 25 percentile. The results are consistent with the previous discussion on the HERS index score that it is a relative measure of the home being assessed to the energy use of the HERS reference home with the same size and shape in the same location and climate zone. The results are also consistent with the findings in Table 5, where we have county-level temperature as a control variable instead of partitioning the full sample into cool and warm areas.

**Table 10: Effect of Energy Ratings With Temperature Heterogeneity**

<b>Panel A</b>						
	Lower 50 percentile sample			Upper 50 percentile sample		
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln E_{it}$	1.378*** [0.045]	0.546*** [0.047]	0.053 [0.040]	1.933*** [0.042]	1.452*** [0.051]	0.748*** [0.047]
Population		-0.002 [0.009]	0.048*** [0.008]		0.026*** [0.002]	-0.013*** [0.003]
High income		2.476*** [0.029]	2.009*** [0.042]		1.771*** [0.026]	1.090*** [0.032]
Education		0.226*** [0.010]	0.210*** [0.011]		0.186*** [0.009]	0.139*** [0.011]
Year fixed effects?	yes	yes	yes	yes	yes	yes
Regional Controls?	no	yes	yes	no	yes	yes
House Controls?	no	no	yes	no	no	yes
Observations	315,615	170,161	114,524	439,275	229,343	144,596
R-square	0.042	0.157	0.043	0.112	0.202	0.159
<b>Panel B</b>						
	Lower 25 percentile sample			Upper 25 percentile sample		
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln E_{it}$	1.002*** [0.061]	0.399*** [0.072]	0.052 [0.063]	2.114*** [0.064]	1.105*** [0.071]	0.703*** [0.097]
Population		-0.035** [0.014]	0.039*** [0.011]		0.078*** [0.003]	-0.046*** [0.013]
High income		3.072*** [0.052]	2.569*** [0.070]		1.545*** [0.037]	0.673*** [0.096]
Education		0.263*** [0.014]	0.179*** [0.017]		0.017 [0.016]	0.074** [0.030]
Year fixed effects?	yes	yes	yes	yes	yes	yes
Regional Controls?	no	yes	yes	no	yes	yes
House Controls?	no	no	yes	no	no	yes
Observations	157,805	64,026	47,800	186,908	55,568	22,960
R-squared	0.054	0.162	0.216	0.101	0.177	0.159

## VI Conclusion

This paper studies the influence of home energy-efficient ratings on the valuation of real estate properties in the U.S. While other studies have examined energy efficiency and various aspects of real estate pricing, this study is the first to make use of a broad dataset of real estate prices spanning the entire US between 1962 and 2021. This sample allows us to explore heterogeneity among geographic regions at the county level in the US and comment on how local beliefs may moderate the relation between climate change, energy efficiency, and real estate pricing.

In the empirical analysis, a comprehensive dataset is constructed on home transaction prices in the U.S. and their corresponding energy-efficient ratings. This paper finds support for the

hypothesis that differences in home energy ratings and beliefs on climate change are reflected in residential real estate prices. Specifically, homes with better energy efficiency ratings are sold at a higher price than otherwise identical homes. This result is robust to various measures of home price, such as tax assessment value and price per square feet as well as home characteristics controls and other regional controls. This study also finds that heterogeneity in beliefs about climate change significantly impacts the U.S. real estate market. All else being equal, the “green home premium” found in the study is more substantial in the region where more residents are aware of climate change risk than in a “non-believer” region.

The paper contributes meaningfully to the sustainable finance and energy ratings literature. It has the potential to further our understanding of the role of energy ratings on real estate pricing and how climate beliefs may impact this role. Future extension of this research can investigate different types of properties, including commercial and rental and various energy efficiency ratings such as Energy Star and LEEDs.

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