Does Climate Change Affect Real Estate Prices? Only If You Believe In It

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This paper studies whether house prices reflect belief differences about climate change. We show that in an equilibrium model of housing choice in which agents derive utility from ownership in a neighborhood of similar agents, prices exhibit different elasticities to climate risk. We use comprehensive transaction data to relate prices to inundation projections of individual homes and measures of beliefs about climate change. We find that houses projected to be underwater in believer neighborhoods sell at a discount compared to houses in denier neighborhoods. Our results suggest that house prices reflect heterogeneity in beliefs about long-run climate change risks. (*JEL* R31, R32)

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Introduction

Despite broad scientific consensus on the occurrence of climate change, there is substantial disagreement among policy makers and the general public.

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In March 2017, 42% of Americans surveyed agreed that global warming will pose a serious threat to their way of life, whereas 57% disagreed (Gallup 2017).[1] Are such differences of opinion reflected in the prices of assets exposed to the consequences of long-run variability of climatic patterns?

In this paper we study whether residential real estate prices are affected by differences in beliefs about the occurrence and effects of climate change. Real estate is arguably the ideal asset class to address this question. First, its long-duration nature exposes it to the type of long-run risks that emanate from climate change. Second, real estate is by far the most important asset for the majority of households: the current homeownership rate is 63.6% (U.S. Census Bureau 2017), and the average household holds 40% of its assets in residential property, in contrast to 30.5% invested in financial assets (SCF 2013). Third, real estate is also an important source of household debt, adding to its relevance in the overall economy.

One source of risk in the valuation of real estate stems from natural disasters, such as floods, fires, and earthquakes. Such *current risks* are accounted for in the form of lower real estate valuations or higher insurance premiums, and are already documented in the literature. A largely ignored issue, however, is whether *changes in future risks* are reflected in real estate valuations. Climate change—that is, the change in the statistical distribution in future weather patterns—falls into this second category of "long-run" risks. In our paper, we investigate the link between differences in expectations about future risks and real estate prices by focusing on changes in flood risk associated with rising sea levels due to climate change. Scientific projections indicate that climate change will lead to a rise in the global sea level and that this will affect the coastal regions in the United States over the coming decades.[2] Approximately 2% of U.S. homes—worth a combined $882 billion—are at risk of being inundated by 2100. In some coastal areas, such as Hawaii and Florida, between 10% and 12% of all homes are expected to be underwater if sea levels rise by 6 feet (Rao 2017).

To understand the effect of heterogeneous beliefs on real estate prices and guide our empirical investigation, we build a simple frictionless model of the housing market. Agents differ in their beliefs about the occurrence of climate change and their preferences exhibit *homophily*, that is, they derive utility from owning a house in a neighborhood populated by like-minded owners. This tie to the community in which agents live acts as a friction for households who plan to leave a homogeneous neighborhood in response to lower home prices elsewhere. If the homophily effect is strong enough, then an equilibrium exists

[1] The media also has highlighted this polarization. A *Wall Street Journal* article by Newmann (2018) starkly epitomizes this polarization of opinion. The article documents that California localities warn of climate-change-related disaster when suing oil companies, while excluding such risks from the prospectuses of their municipal bonds. Such inconsistencies have led Exxon Mobil to a countersuit.

[2] See, for example, the Digital Coast Data project (National Oceanic and Atmospheric Administration 2018).

in which "believers" and "deniers" sort into different neighborhoods. In this "segmented" equilibrium, house prices in different neighborhoods may exhibit different sensitivities to climate change.

In our empirical analysis we employ three data sources. First, we obtain scientific forecast data on sea levels from the National Oceanic and Atmospheric Administration (NOAA). Second, we obtain data on beliefs about climate change risks from the Yale Program on Climate Change. Third, we employ proprietary data from *Zillow* on repeated home transactions for more than ten million homes, matched to sea-level rise projections.

We employ a hedonic model for house prices that we augment with measures of climate risks and households' beliefs about climate change. Our analysis shows that differences in beliefs about climate change significantly affect house prices. Specifically, a 1-standard-deviation increase above the national mean in the percentage of climate change "believers" is associated with an approximate 7% decrease in house prices for homes projected to be underwater. This finding quantifies the valuation *gap* between homes in believer and denier counties. However, it does not speak to the determinants of that difference. The effects we find may be due to overreaction by believers, underreaction by deniers, or a combination of both. This result is robust to a wide range of controls including house characteristics, zoning restrictions, amenities, variation in climate-change awareness overtime, salience of flood risk, and house supply effects.

Our work is related to the large literature on heterogeneous beliefs and asset markets.[3] Prompted by the inherent difficulties of homogeneous expectation models in explaining house price variations through changes in income, amenity, or interest rates (Glaeser and Gyourko 2006), recent work in real estate pricing has focused on the role of differences in beliefs (e.g., Burnside, Eichenbaum, and Rebelo 2016; Piazzesi and Schneider 2009; Favara and Song 2014; Bakkensen and Barrage 2017). Our model builds on the frictionless competitive equilibrium considered in Burnside, Eichenbaum, and Rebelo (2016) and introduces agents with a preference for owning in a neighborhood that is populated by like-minded owners, a property often referred to as "homophily."[4] Unlike Burnside, Eichenbaum, and Rebelo (2016), who are

[3] This literature is too vast to be reviewed here. A common theme emerging from this large body of work is that in a market-mediated environment, differences in beliefs can lead to speculative trading, bubbles, and excess volatility (e.g., Miller 1977; Harrison and Kreps 1978; Morris 1996; Scheinkman and Xiong 2003; Kuchler and Zafar 2017; Bailey et al. 2017, 2018), whereas at the firm level it can lead to overinvestment (e.g., Shleifer and Vishny 1990; Blanchard, Rhee, and Summers 1993; Stein 1996; Gilchrist, Himmelberg, and Huberman 2005; Bolton, Scheinkman, and Xiong 2006).

[4] The term "homophily" encapsulates the old idea that "birds of a feather flock together." Lazarsfeld and Merton (1954) coined the term in the sociological literature to explain a phenomenon that has been found to be a pervasive and important force in social networks (e.g., McPherson, Smith-Lovin, and Cook 2001; Currarini, Jackson, and Pin 2009). Favilukis and Van Nieuwerburgh (2017) use a similar mechanism and refer to it as a "consumption externality." A subtle difference between our approach and theirs is that in our setting the characteristic that makes a neighborhood attractive to an agent emerges endogenously, whereas in their setting it is an exogenous attribute of a location.

interested in the formation and dynamics of housing pricing bubbles, we focus on the cross-sectional properties of house prices and establish the existence of equilibria in which market segmentation by beliefs can arise endogenously. This spatial feature of our equilibrium also distinguishes our work from the literature of search frictions in the housing market, such as Piazzesi and Schneider (2009), Favara and Song (2014), and Piazzesi and Stroebel (2015).[5] Models of search frictions can rationalize the empirical fact that transaction volumes and time to sell are correlated with average house prices. We abstract away from this generalization which is tangential to the focus of our study. Unlike our model, which features two marginal agents in two different neighborhoods, both Piazzesi and Schneider (2009) and Favara and Song (2014) feature search models with optimistic marginal buyers only. As in our model, in Piazzesi and Stroebel (2015) house prices are determined in equilibrium by different marginal buyers. However, while Piazzesi and Stroebel (2015) use a search model to study the equilibrium effect of buyers with different search "breadth," we rely on a competitive equilibrium model to obtain endogenous valuations of neighborhoods when agents have heterogeneous beliefs.

Our work is also related to the nascent and growing literature concerned with the effects of climate change and asset markets. Relevant contributions to this literature include Giglio et al. (2015), Gibson, Mullins, and Hill (2017), Lemoine (2017), and Hong, Li, and Xu (2019). Giglio et al. (2015) study discount rates for valuing investments in climate change abatement. They find low discount rates to be appropriate at all horizons. They also use Zillow data and NOAA maps, and identify properties that will be flooded with a 6-foot rise in sea levels. They construct a climate attention index using textual analysis and find that when the fraction of listings that mention climate change doubles, properties projected to be flooded relative to other properties decrease by 2% to 3%. Gibson, Mullins, and Hill (2017) make explicit the link between new flood maps and the beliefs of agents and connect this to regular price signals, such as the cost of insurance. Lemoine (2017) distinguishes between direct "weather" (current risks) and "climate" (long-run distribution of weather) channels to study their implications for economic outcomes in a dynamic setting with rational expectations. Our study builds on this literature by not only focusing on the relationship of home prices and current risks but also expected future changes in flood risk. Variation in our data allows us to test the link between current market prices and belief heterogeneity controlling for current risks, as well as projections about future risks.

A closely related paper is Bakkensen and Barrage (2017), who study the effect of difference in beliefs about climate *risk* on the selection choice between coastal and noncoastal homes. Using a similar model as Burnside, Eichenbaum, and Rebelo (2016) with Bayesian learning, they show that

[5] Burnside, Eichenbaum, and Rebelo (2016) also analyze a search and matching model along the lines of Piazzesi and Schneider (2009).

heterogeneity in beliefs dramatically increases the projected housing market impact of future flood risk. In particular, if a fraction of agents are misinformed about sea-level rise and learn about it by observing current storms, then these agents can lead to overvaluations, excess volatility and sharp price decline as flood risk rises. Based on survey evidence from Rhode Island, Bakkensen and Barrage (2017) show that coastal residents attach higher amenity values to coastal living and lower flood risk perceptions, relative to inland owners. Our work differs from theirs along several dimensions. First, we focus on the price differences within otherwise identical coastal properties and do not consider the location choice between coastal and noncoastal regions. Second, their agents differ in their individual-specific amenity value that they derive from coastal owning. In contrast, our agents, have a "network-specific" amenity value (homophily). This allows us to construct an equilibrium in which two otherwise identical coastal neighborhoods have marginal buyers with different beliefs about climate change (i.e., we do not rely on exogenous variation of characteristics). Third, our empirical analysis focuses on a much larger sample of transaction-level real estate prices, which we combine with NOAA projections on sea-level rise and national-level survey data from the Yale Climate opinion project. Finally, the findings in Bakkensen and Barrage (2017) are primarily about the salience of *current* extreme weather events, while our focus is on the effect of difference in beliefs about *future* events resulting from long-run changes in climate patterns.

Our work is also related to contemporaneous work by Bernstein, Gustafson, and Lewis (2018), who estimate a discount in home prices of 7% due to exposure to sea-level rise. They find that this difference is more pronounced for non-owner-occupied properties, which they interpret as a reflection of increased sophistication of their owners. While their focus is mainly on estimating the price effect of sea-level rise, Bernstein, Gustafson, and Lewis (2018) also use data from the Yale Climate opinion survey to find that belief differences only affect the price of sea-level rise exposure in the owner-occupied segment of the market. We differ from this study along two dimensions. First, the main analysis of Bernstein, Gustafson, and Lewis (2018) focuses on assessing the effect of sea-level rise on house prices. In contrast, our focus is on the effect of *differences in beliefs* about sea-level rise on house prices. Second, we provide a theoretical framework that helps shape our empirical analysis on the effect of beliefs about climate change on house prices. Consistent with our results, Bernstein, Gustafson, and Lewis (2018) find that beliefs about climate change are important in the pricing of owner-occupied coastal properties. They show that exposed homes located in counties where agents are most worried about climate change sell at a 8.5% discount. This estimate is comparable to the 7% discount in our analysis. Furthermore, their interpretation—that beliefs about climate change matter most when owners themselves occupy the home—is consistent with our mechanism based on homophily in homeownership.

Finally, our work also relates to contemporaneous work by Murfin and Spiegel (2018). They focus on estimating the effect of sea-level rise on house prices, rather than heterogeneity in beliefs. Murfin and Spiegel (2018) use comprehensive data on coastal home sales and data on elevation relative to local high tides, whose variation they leverage in their estimation. In contrast to our findings, Murfin and Spiegel (2018) find an upper bound for the projected effects of sea-level rise on real estate prices that is quite small. The difference relative to our results is likely due to two factors. First, Murfin and Spiegel (2018) focus on an average effect while in our analysis we focus on how this effect varies with beliefs. Second, they exploit a different source of variation of sea-level rise resulting from vertical land motion. Areas with vertical land motion leading to higher projected sea-level rise tend to be in areas with more climate change deniers, such as Texas and Louisiana, where our model would suggest smaller effects of projected sea-level rise. Thus, we do not view their results as being inconsistent with belief heterogeneity affecting the impact of projected sea-level rise on real estate prices.

1. Model

We consider a simple frictionless model of the housing market in which agents may differ in their beliefs about the occurrence of climate change. We assume that agents have preferences that exhibit "homophily," that is, they derive utility from owning houses in a neighborhood populated by like-minded owners. Because of homophily, agents have strong ties to the community in which they live, and this acts as a friction for households who plan to leave a homogeneous neighborhood in response to lower home prices elsewhere. Under the conditions we specify below, we show the existence of equilibria in which "believers" and "deniers" sort themselves into geographically identical neighborhoods. Furthermore, we show that equilibrium house prices may differ in their sensitivity to climate change risk.

1.1 Setup

We consider a discrete-time, infinite-horizon, model economy populated by a continuum of agents with measure one divided into a mass $\mu^b \in [0,1]$ of climate change "believers," and a mass $\mu^d = 1-\mu^b$ of climate change "deniers." Believers and deniers disagree on the likelihood of climate-related events, for example, sea-level rise. We refer to believers as agents who attach a larger probability to climate-related events than deniers. All agents have linear utility with constant discount rates β^h, $h \in \{b,d\}$. Agents can either own a house or rent.

There is a fixed stock of houses, $k<1$, split in two geographically identical neighborhoods.[6] The rental market is composed of $1-k$ units produced by

[6] The fixed supply assumption is common in the literature, and it has been justified by the presence of zoning laws, land scarcity, or infrastructure constraints (e.g., Burnside, Eichenbaum, and Rebelo 2016).

competitive firms at a cost, the rental rate, that, without loss of generality, we normalize to zero.

Agents' utility from owning in a neighborhood increases in the number of similar types that own in the same neighborhood. We refer to the positive effect of owning in like-minded neighborhoods as homophily. The expected utility of an agent of type $h \in \{b,d\}$ in neighborhood $n \in \{1,2\}$ is

$$\mathcal{U}_n^h = \varepsilon^h + \phi(\mu_n^h), \tag{1}$$

where ε^h is agent h's per-period expected utility from owning, μ_n^h is the mass of type-h agents owning in neighborhood n, and $\phi(\cdot)$ is a weakly increasing function representing homophily. The larger the mass μ_n^h of type-h agents in neighborhood n, the larger agent h's utility from owning a house in n. We normalize the homophily function to $\phi(0)=0$.

1.2 Equilibrium

Let $\mu_n^h \leq \mu^h$ be the mass of h-owners, $h \in \{b,d\}$, in neighborhood $n \in \{1,2\}$, and let $\mu_R^h = \mu^h - \sum_n \mu_n^h$ be the mass of h-renters. We define a pair $(\boldsymbol{\mu}^b, \boldsymbol{\mu}^d)$ as an *allocation* of b- and d-homeowners, where the triplet $\boldsymbol{\mu}^h = (\mu_1^h, \mu_2^h, \mu_R^h)$ contains the mass of type-h agents in neighborhoods 1, 2, and rental housing. An allocation is *feasible* if, for $h \in \{b,d\}$ and $n \in \{1,2\}$, $\mu_n^h \geq 0$ and $\mu_R^h \geq 0$.

Equilibrium house prices in neighborhood n are determined by the marginal buyer h in that neighborhood. Such a buyer will be indifferent between buying a home in neighborhood n and renting. The price $P_{n,t}^h$ that makes agent h indifferent between owning in area n and renting is given by

$$-P_{n,t}^h + \beta^h(\varepsilon^h + \phi(\mu_n^h) + \mathbb{E}^h[P_{n,t+1}]) = 0, \quad h \in \{b,d\}, \quad n \in \{1,2\}, \tag{2}$$

where $P_{n,t+1}$ denotes the prevailing price at time $t+1$. If h is the marginal buyer in neighborhood n, the indifference price P_n^h in a stationary equilibrium is given by the nonexplosive solution of (2), that is,

$$P_n^h = \frac{\beta^h}{1-\beta^h}(\varepsilon^h + \phi(\mu_n^h)), \quad h \in \{b,d\}, \quad n \in \{1,2\}. \tag{3}$$

A *competitive equilibrium* in the housing market is represented by a set of house prices in the two neighborhoods, (P_1, P_2), and a set of allocations $(\boldsymbol{\mu}^b, \boldsymbol{\mu}^d)$ such that the house market clears. In a *segmented equilibrium*, the marginal buyer in neighborhood n is different from the marginal buyer in the other neighborhood.

Because deniers attach a smaller probability to climate-related events than believers, deniers' per-period expected utility from owning, ε^d, is larger than believers', ε^b. We assume that the same valuation hierarchy holds for the perpetuity value of owning a home. Specifically,

Assumption 1 (Valuation hierarchy). In the absence of homophily, deniers value houses more than believers

$$\frac{\beta^d}{1-\beta^d}\varepsilon^d > \frac{\beta^b}{1-\beta^b}\varepsilon^b. \tag{4}$$

One way to interpret Assumption 1 is that agents may disagree about the random time $\mathcal{T}$ after which homes will be permanently flooded, but that they are otherwise identical, that is, $\varepsilon^d=\varepsilon^b$, $\beta^d=\beta^b$, and $\varepsilon_t^h=0$ for all $t\geq\mathcal{T}$. If $\mathcal{T}$ is geometrically distributed, then Assumption 1 implies that the distribution of the flood arrival time $\mathcal{T}$ of believers dominates that of deniers in a first-order sense. To see this, suppose that ρ denotes the common discount rate, ε the common expected utility from owning, and that $\mathbb{P}^h[\mathcal{T}\leq t]=1-\gamma_h^{t+1}$, $t\in\{0,1,2\ldots\}$, where $\gamma_h\in(0,1]$ denotes the agent-specific survival probability. Then, in the absence of homophily, agent's h's valuation is

$$\mathbb{E}^h\left[\sum_{t=1}^{\mathcal{T}}\rho^t\varepsilon\right]=\sum_{t=1}^{\infty}\mathbb{P}^h[\mathcal{T}\geq t]\rho^t\varepsilon$$

$$=\sum_{t=1}^{\infty}\mathbb{P}^h[\mathcal{T}>t-1]\rho^t\varepsilon=\frac{\rho\gamma_h}{1-\rho\gamma_h}\varepsilon \tag{5}$$

The above expression illustrates that the discount factor β^h in Assumption 1 can be thought of as the product of a common time-preference parameter ρ and a survival probability parameter γ_h. Assumption 1 implies that $\gamma_b<\gamma_d$, that is, believers attach a lower probability of survival than deniers.

We further assume that the homophily effect from owning a house is sufficiently strong, specifically,

Assumption 2 (Homophily). The homophily benefit perceived by agent $h\in\{b,d\}$ when the entire neighborhood is composed of type-h agents is such that

$$\phi(k/2)\geq\Lambda\varepsilon^d-\varepsilon^b,\quad \Lambda\equiv\frac{\beta^d}{1-\beta^d}\frac{1-\beta^b}{\beta^b}. \tag{6}$$

Note that if $\beta^b=\beta^d$, then Assumption 2 requires that the homophily benefit from owning in a homogeneous neighborhood exceeds the difference $\varepsilon^d-\varepsilon^b$ in the per-period expected utility of owning between the two types of agents.[7] The following proposition establishes the existence of a segmented equilibrium in the housing market.

Proposition 1 (Segmented Equilibrium). If Assumptions 1 and 2 hold and $\mu^b\in[k/2,1-k/2]$, then there exists a stationary segmented equilibrium in which house prices are given by

$$P_1 = \frac{\beta^b}{1-\beta^b}\left(\varepsilon^b+\phi(k/2)\right) \tag{7}$$

$$P_2 = \frac{\beta^d}{1-\beta^d}\left(\varepsilon^d+\phi(k/2)\right) \tag{8}$$

7 If $\beta^b\leq\beta^d$, $\Lambda\geq1$. Therefore, when believers discount the future more heavily, Assumption 2 imposes a more stringent requirement on the homophily function ϕ.

and allocations $\boldsymbol{\mu}^h = (\mu_1^h, \mu_2^h, \mu_R^h)$ are

$$\boldsymbol{\mu}^b = (k/2, 0, \mu^b - k/2), \quad \boldsymbol{\mu}^d = (0, k/2, 1 - \mu^b - k/2). \tag{9}$$

Proposition 1 establishes the existence of an equilibrium in which housing markets are segmented by type. The result arises because the marginal home buyer in the two neighborhoods is of a different type. Believers are indifferent between owning in the believers neighborhood and renting, and deniers are indifferent between owning in the deniers neighborhood and renting.

1.3 Comparative statics

To analyze the effect of differences in beliefs on the equilibrium prices of Proposition 1, we need to put some structure on the beliefs of agents. We denote by s a random variable representing the sea-level rise in a neighborhood whose distribution is given by $\mathbb{P}$.[8] Believers and deniers differ in their assessment of their subjective distribution $\mathbb{P}^h$ of sea-level rise. Specifically, we assume that agent h's expected utility from owning depends on the expected sea-level rise as follows:

$$\varepsilon^h = \overline{\varepsilon} - \mathbb{E}^h[s] = \overline{\varepsilon} - \xi^h \mathbb{E}^{\mathbb{P}}[s], \quad h \in \{b, d\} \tag{10}$$

where $\mathbb{E}^h$ denotes the expectation under belief $\mathbb{P}^h$, $\overline{\varepsilon}$ represents the utility from owning regardless of expected sea-level rise, and constant ξ^h denotes the *sensitivity* of agent h's expected utility to sea-level rise.[9] Believers differ from deniers in that they attach higher probability to higher values of sea-level rise s. The following assumption formalizes the condition on the differences in beliefs.

Assumption 3 (Difference in Beliefs). The sensitivities ξ^b and ξ^d of agents' expected utilities to changes in sea level rise satisfy:

$$\xi^b \geq \Lambda \xi^d. \tag{12}$$

When $\beta^b < \beta^d$, $\Lambda \geq 1$ (see footnote 7), the above assumption requires that believers have to be sufficiently more sensitive than deniers to changes in sea-level rise. The following proposition characterizes the sensitivity of equilibrium prices from Proposition 1 to expected sea-level rise.

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8 One possible interpretation is to think of $\mathbb{P}$ as the "objective" distribution, based on climate science models.

9 In general, one can think of the sensitivity ξ^h in (10) as a random variable representing a change of measure $d\mathbb{P}^h/d\mathbb{P} > 0$. In this case, ξ^h can be used to define agent h's expectation as follows

$$\mathbb{E}^{\mathbb{P}^h}[s] = \mathbb{E}^{\mathbb{P}}[\xi^h s], \quad h \in \{b, d\}. \tag{11}$$

In this setting, the analog to Assumption 3 would be to require that the ratio $\xi^b(s)/\xi^d(s)$ is increasing in s (that is, it satisfies the monotone likelihood ratio property, MLRP). By MLRP, ξ^b first-order stochastically dominates ξ^d and therefore $\mathbb{E}^{\mathbb{P}^b}[s] \geq \mathbb{E}^{\mathbb{P}^d}[s]$. From the definition of agents' expected utility (10) we deduce that this condition is conceptually equivalent to Assumption 3.

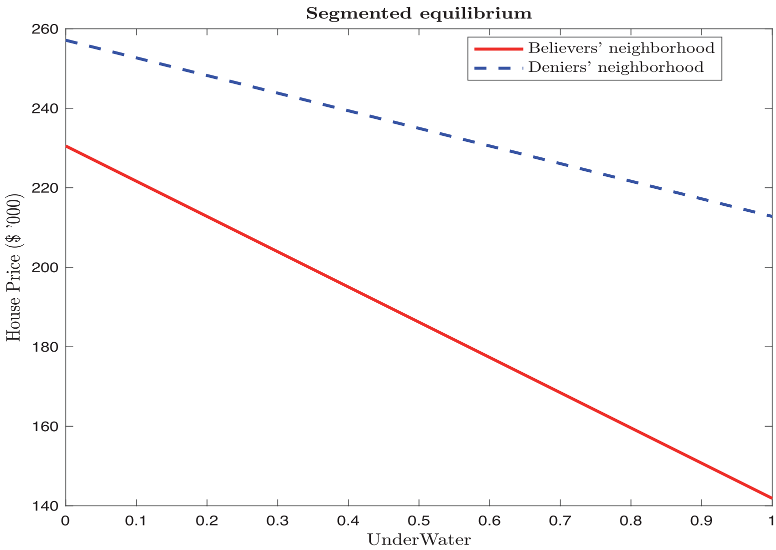

Figure 1
Model's prediction
This figure plots house prices of Proposition 1 against expected sea-level rise. Because the conditions of Proposition 2 are satisfied, home prices in the believer neighborhoods are more sensitive to changes in the expected sea-level rise than are home prices in denier neighborhoods. We use the following parameters: $\beta^b = \beta^d = 0.993$, $\xi^b = 1$, $\xi^d = \xi^b/2$, $\bar{\varepsilon} = 1$, and $\phi(k/2) = 1$.

Proposition 2 (Comparative Statics). Let $S \equiv \mathbb{E}^{\mathbb{P}}[s]$ denote the expected sea-level rise under measure $\mathbb{P}$. Under assumptions 1, 2, and 3, the equilibrium prices of Proposition 1 have weakly increasing differences in S, that is,

$$P_1(S) - P_1(S') \geq P_2(S) - P_2(S'), \quad \text{for} \quad S' > S. \tag{13}$$

Figure 1 illustrates the comparative statics result of Proposition 2. The main empirical prediction of the model is that if (a) deniers value houses more than believers (Assumption 1), (b) homophily is sufficiently strong (Assumption 2) and (c) believers are more sensitive to news about sea-level rise (Assumption 3), then, in equilibrium, the elasticity of house prices to sea-level rise is higher in believers' neighborhood than in deniers' neighborhood. In the analysis of Section 3 we assess the validity of the comparative statics described in Proposition 2 by empirically analyzing the effect of belief heterogeneity about climate change on real estate prices in the United States.

2. Data

In this section we describe the data sources and the construction of our main analytic data set. Table 1 contains a summary description of the variables we use in our analysis. We rely on three main data sources: (a) transacted home values

Table 1
Variable descriptions

Name	Description	Source
P_{it}	Dollar transaction price of home i at time t	Zillow
UnderWater$_i$	Indicator of whether home i is located in an area that is projected to be affected by sea level inundation of 6 ft. above current Mean Higher High Water (MHHW) by 2100, based on NOAA projections	Zillow
H_c	Percentage of residents in county c who answered "Yes" to the Yale Climate Survey question: "Do you think that global warming is happening?"	HMML[a]
Regional controls		
Income	Adjusted gross income (AGI) at zip code level (in 1,000 USD) for 2014	IRS[b]
Temperature	Daily Air Temperatures and Heat Index (1979–2011)	NLDAS[c]
Flood 10 y	Height of a flood (in cm) that has a ten percent chance of occurring in a given year, for each NOAA station (https://water.usgs.gov/edu/100yearflood.html)	CC/NOAA[d]
Population	Population count (in thousands) for each zip code	ACS[e]
Elevation	Elevation (in meters) at the centroid of each zip code	Google (2018)
GOP share	Percentage of individuals in a zip code voting for the Republican Party	HEDA[f]
House controls		
Age	Age of the property (in years)	ZTRAX
Year built	Year the property was built	ZTRAX
Size	Area of the building (in sq.ft.)	ZTRAX
Number of bedrooms	Count of the number of bedrooms of a property	ZTRAX
Number of bathrooms	Count of the number of bathrooms of a property	ZTRAX
Garage	Indicator for whether a property has a garage	ZTRAX
Agricultural	Zoning indicator: Agricultural use	ZTRAX
Communication	Zoning indicator: Communication use	ZTRAX
Commercial	Zoning indicator: Commercial use	ZTRAX
Exempt & institutional	Zoning indicator: Public use	ZTRAX
Governmental	Zoning indicator: Governmental use	ZTRAX
Industrial	Zoning indicator: Industrial use	ZTRAX
Industrial-heavy	Zoning indicator: Industrial-heavy use	ZTRAX
Historical & cultural	Zoning indicator: Historical and cultural use	ZTRAX
Miscellaneous	Zoning indicator: Miscellaneous use	ZTRAX
Personal	Zoning indicator: Personal use	ZTRAX
Recreational	Zoning indicator: Recreational use	ZTRAX
Multifamily	Zoning indicator: Multifamily use	ZTRAX
Residential	Zoning indicator: Residential use	ZTRAX
Transportation	Zoning indicator: Transportation use	ZTRAX
Vacant	Indicator for whether land is vacant	ZTRAX
Distance	Distance of a property to the closest coast line	Authors' calculations
Neighborhood density	Number of properties within a 0.5-km radius	Authors' calculations
Amenity controls		
Income	Adjusted gross income (AGI) at the ZIP code level (in 1,000 USD) for 2014	IRS[b]
Temperature	Daily Air Temperatures and Heat Index (1979–2011)	NLDAS[c]
Population	Population count (in thousands) for each ZIP code	ACS[e]
Latitude/longitude	Geographical coordinates of a property	ZTRAX
Education	Share of individuals with a bachelor's degree in 2015	ACS[e]

[a] Howe et al. (2015)
[b] Internal Revenue Service
[c] North America Land Data Assimilation System (NLDAS), https://wonder.cdc.gov/nasa-nldas.html
[d] Climate Central (CC) and National Oceanic and Atmospheric Administration (NOAA)
[e] American Community Survey (ACS)
[f] Harvard Election Data Archive (HEDA), https://projects.iq.harvard.edu/eda/data

and characteristics; (b) measures of the projected effects of climate change; and (c) measures of beliefs about climate change. In what follows we briefly describe the data used in our analysis. Table 1 lists all of the variables used, and Appendix B contains a detailed description of the data and various steps taken to transform the raw data into an analytic data set.

2.1 Real estate

Our main sources of real estate data are transactions data and proprietary supplemental data from Zillow Inc. Specifically, we use the Zillow Transaction and Assessment Data Set ("ZTRAX"), which Zillow provides to qualifying academic and institutional researchers. The Zillow transaction data has a 20-year history of property transactions from 1997 to 2017, as well as detailed home characteristics from more than 374 million public records across over 2,750 counties. Furthermore, Zillow provides us with a proprietary data set that contains home valuations based on their Zestimate algorithm as well as proprietary geographic information that can be used to match individual homes to future flood zones.

These data sets contain information about the geographic location for each home as well as a host of house-specific characteristics, such as size, availability of parking, number of rooms and bathrooms, that we use both as controls and as determinants of the amenity value of a property. We use the geographic location to match each home to a ZIP code, census tract, or county and to compute the distance of each home from the coast. Table 1 describes the main housing variables that we employ.

2.2 Climate

We use two types of climate change variables: (1) variables that describe the current climate and (2) variables pertaining to the change in climate. We start from publicly available maps by NOAA, which show the mean higher high water (MHHW) tidal datum, using a 6-foot sea-level rise above the current level. NOAA defines the tidal datum MHHW as the best possible approximation of the threshold at which inundation can begin to occur.[10] Therefore, coastal homes located below the MHHW level are either permanently submerged under water or in the intertidal zone, which is typically uninhabited. Zillow constructs an indicator variable for every home, $UnderWater_i$, that evaluates to unity if the home falls in a future flood zone.

Variables pertaining to the current state of climate include (a) a measure of the distance to the coast; and (b) a measure of the current risk of an extreme flood that has a 10% probability of occurring (*Flood 10 y*).

[10] The mean higher high water is the average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch (National Oceanic and Atmospheric 2013).

2.3 Beliefs about climate change

The main data source to measure beliefs about climate change is the Yale Climate Opinion Maps 2016 (Howe et al. 2015). This study provides, at the county level, survey evidence of how respondents answer questions, including (a) whether they believe that climate change is happening; (b) whether they believe that climate change is human caused; (c) whether they believe that there is scientific consensus on whether climate change is happening; and (d) whether they will be personally affected by climate change. Our main measure of beliefs in climate change is the percentage H_c of people who answered "Yes" to survey question (a).

2.4 Control variables

We employ a number of variables to control for local conditions in our analysis. Specifically, control variables at the ZIP code level include demographic variables, such as population, income, and political voting measures, that relate to the geography of a ZIP code, such as elevation at the centroid, current flood risk, and weather. To control for the amenity value of a home, we follow the procedure of Albouy (2016). We discuss the construction of the amenity measure in footnote 15. We also directly construct house-level measures of amenity and zoning variables from the Zillow data.

2.5 Data construction

We restrict attention to homes located within a distance of 50 km from the coast.[11] Across these homes there is considerable variation in (a) the impact of sea-level rise; and (b) the beliefs of residents about climate change. For example, Figure 2 shows the fraction of homes projected to be underwater given a 6-foot sea-level rise in Florida ZIP codes, and Figure 3 reports the fraction of people agreeing with the statement that climate change is happening in the Yale Climate Survey regarding climate change for Florida ZIP codes. Both figures show considerable variation along these two dimensions across ZIP codes.

Table 2 reports the summary statistics of the variables used in our regression analysis. The average house price in our sample is $286,130 (median $190,000). On average 8.5% of properties are located in a future flood zone and an average of 72.32% of households answered "Yes" to the Yale Climate Opinion Survey question: "Do you believe that climate change is happening?"

3. Empirical Analysis

3.1 Methodology

The key empirical challenge we face is that home valuations may vary along dimensions other than their projected exposure to sea-level rise and the degree

[11] The Online Appendix, Table OA.2, shows that these results are not sensitive to this restriction.

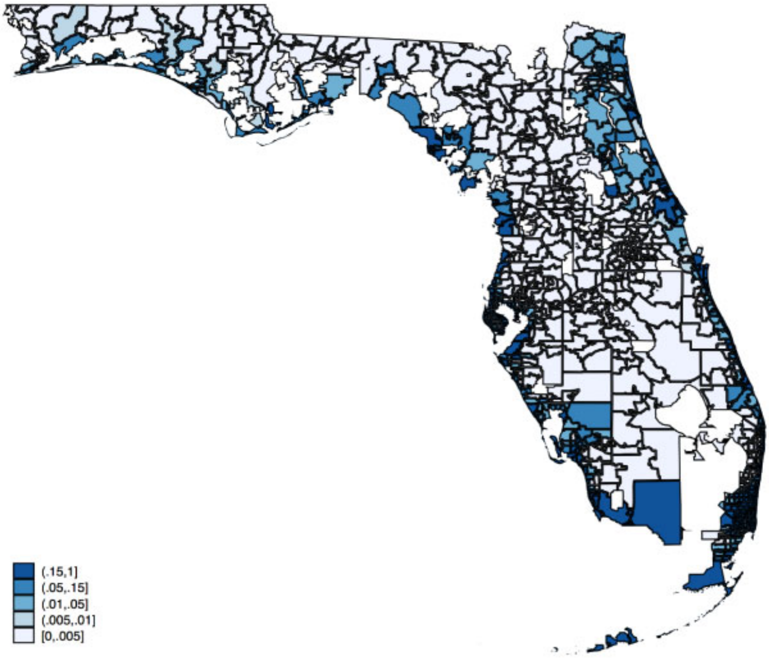

Figure 2
Underwater homes in Florida
This figure shows the fraction of homes projected to be underwater given 6 feet of sea-level rise in Floridan ZIP codes. National parks and lakes are excluded. *Source:* NOAA.

of belief in climate change of the neighborhood in which the property is located. For example, homes closer to the coast may be more likely to face damage in the event of sea-level rise, but at the same time they may be more valuable due to coastal views. We address this concern by specifying a hedonic pricing model that controls for individual building characteristics, such as distance from the coast, and attributes of neighborhoods, such as neighborhood density and average temperature.

Our main dependent variable is the natural logarithm of the transaction price of home i at time t, $\ln P_{it}$. The independent variables fall into the following categories: (a) covariates at the home level that encompass an indicator for whether home i is projected to be inundated in the future, UnderWater_i,[12] and other characteristics of homes, X_i; (b) covariates at the county level that include the logarithm of the percentage of residents in a given county c, who answered "Yes" to the Yale Climate Survey question: "Do you think that global warming is happening?", $\ln H_c$; and (c) covariates at the ZIP code

12 Formally, UnderWater_i is an indicator of whether property i is located in an area projected to be affected by sea-level inundation of 6 feet above current mean higher high water (MHHW) by the year 2100, based on publicly available NOAA projections.

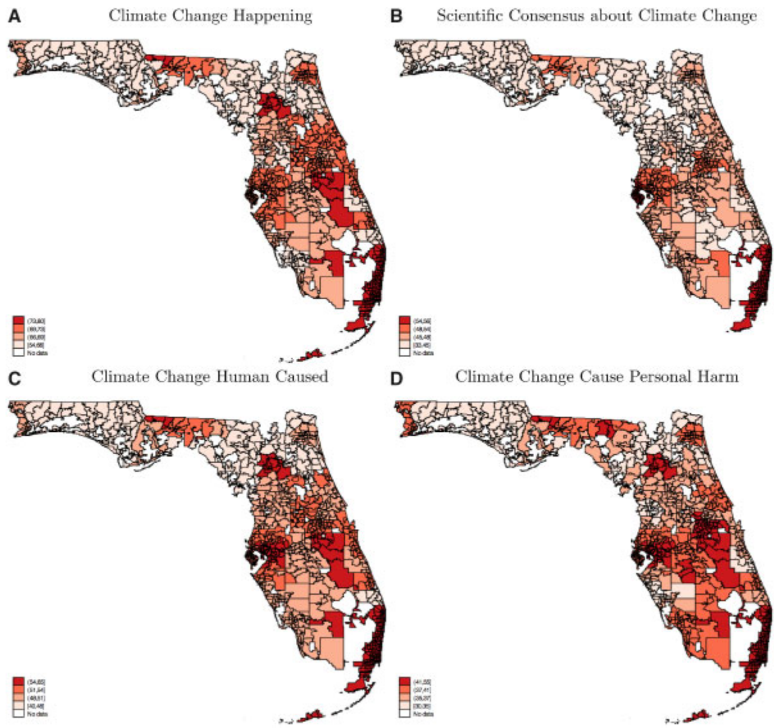

Figure 3
Beliefs about climate change in Florida
This figure shows the fraction of people agreeing with particular statements about climate change in Floridan ZIP codes. A statement is denoted above each panel. National parks and lakes are excluded. *Source*: Yale Climate Opinion Survey.

level, X_z. Our main specification consists of a rich hedonic model of house prices, which we augment with measures of climate risks and households' beliefs about climate change. The key identifying assumption is that unobserved determinants of home prices are uncorrelated with beliefs and whether a home is underwater, conditional on observables. The main challenge is that, all else being equal, coastal homes are more valuable than other homes. Thus, controlling for distance from the coast is particularly important. If, on the one hand, homes closer to the coast tend to have higher values, on the other hand, homes closer to the coast are also more likely to be flooded if sea levels rise. Additionally, if wealthy people live near the coast these homes may also have different characteristics. For example, these homes may be larger, or newer. This presents an omitted variable problem which is solved by controlling for distance from the coast.

We address this issue primarily by controlling for observables. To identify our effect we include in our hedonic regression (a) geography by distance from the coast fixed effects; (b) several characteristics that correlate with

Table 2
Summary statistics

	Mean	Median	SD	Min	Max
P_{it}	286,129.6	190,000	88,8762.5	1,000	4,750,000
UnderWater$_i$	.085	0	.279	0	1
H_c	.7232	.7231	.0502	.5609	.8404
Regional & Amenity controls					
Income	66,208.97	61,364	66,208.97	19,665	218,152
Temperature	54.554	51.83	9.928	33.95	70.9
Flood 10 y	.8395	.7925	1599	.4267	1.341
Population	52,941.61	52,941.61	248,686.8	0	6,557,746
Elevation	50.548	23	76.531	0	1917
GOP share	.475	.479	.178	0	1
Amenity	.1562	.1301	.2478	-.4039	.8088
Neighborhood density	627.3222	481.0000	612.0047	1	9,934
House controls					
Year built	1975	1981	27.412	1586	2017
Size	1,616.097	1427	774.368	1	4,680
Number of bedrooms	2.065	2	1.465	0	5
Number of bathrooms	1.761	2	1.117	0	5
Garage	.856	1	.3510	0	1
Observations					11,538,986

This table presents summary statistics for the main analysis variables. Table 1 provides descriptions of the variables.

flood projections; and (c) interaction terms between flood projections and county-level characteristics that may correlate with beliefs in climate change. Specifically, our main regression specification, which we estimate on the full sample is

$$\ln P_{it} = \alpha_{zd} + \alpha_y + \zeta\, \text{UnderWater}_i \times \ln H_c + \gamma' X_i + \lambda'(\text{UnderWater}_i \times X_i) + \omega'(\text{UnderWater}_i \times X_z) + \varepsilon_{it}, \quad (14)$$

where α_{zd} denotes ZIP code×distance fixed effects, that vary by ZIP code, and distance of a home from the coast,[13] and α_y is a set of year fixed effects, which evaluate to unity if the transaction date t of home i is in year y.

In addition, we also consider the following specification

$$\ln P_{it} = \alpha_{ced} + \alpha_y + \beta \text{UnderWater}_i + \gamma' X_i + \xi' X_z + \epsilon_{it}, \quad (15)$$

where α_{ced} denotes county×elevation×distance fixed effects, that vary by county, elevation at the ZIP code's centroid, and distance of a home from the coast. We estimate (15) for believer counties (i.e., counties for which $H_c \geq$ median(H_c)) and denier counties (i.e., counties for which $H_c <$ median(H_c)) separately.

The main coefficient of interest is ζ in regression (14). This coefficient captures the elasticity of house prices with respect to beliefs about climate

13 In some specifications, we will instead include county×elevation×distance fixed effects, α_{ced}.

change for an underwater property. In some specifications, we also include interactions between UnderWater_i and hedonic home level controls X_i as well as geographic controls X_z. To address potential serial correlation, we cluster standard errors at the county level, which is the level of variation in beliefs. Using the logarithm variable $\ln H_c$, has the attractive property that, without additional interactions ($\lambda' \times X_i$ and $\omega' \times X_z$), when UnderWater_i evaluates to unity, the term $\zeta \times \text{UnderWater}_i$ can be interpreted as the elasticity of house price with respect to H_c.

The key identifying assumption is that the error terms ε_{it} and ϵ_{it} have zero conditional expectation. An empirical challenge is that the amenity value of a home may be correlated with H_c. For example, beachfront property may be more valuable in the South, where more climate change deniers live. Thus, along with controlling for distance from the coast, it is crucial to include hedonic controls, X_i and X_z, to explain variation in home prices. We now turn to the precise definition of these covariates.

3.1.1 Home-level covariates, X_i. We include the distance from the coast for each home. In addition, following Giglio, Maggiori, and Stroebel (2014), we include housing characteristics, such as the lot size, number of bedrooms and bathrooms, parking, age of the property, and distance to the coast.[14] Appendix B.3 details how we determined the closest distance of a property to the coastline. Depending on the specification, we include interaction terms between these control variables and the UnderWater_i indicator.

3.1.2 ZIP-code-level covariates, X_z. The purpose of ZIP-code-level controls is to account for variables that affect the amenity value of a house, such as the quality of a neighborhood or the distance from the coast. We include demographic variables, such as population, income, and political voting measures. Beliefs about climate change may be correlated with other determinants of housing prices. For example, Democrats may be more likely to believe in climate change, but a Democrat controlled area may be following different land use and zoning policies, which could affect home prices. Short-term flood risk also may be correlated with homes being projected to be underwater in the future and depress home prices.

Moreover, people in urban areas may be more likely to believe that climate change is happening, and home prices may be higher due to geographic constraints, lower housing supply or the amenity value of living in urban areas. We also include variables that relate to the geography of a ZIP code, such as elevation at the centroid, current flood risk, weather, as well as controls for the amenity value. Finally, we also apply the method described in Albouy (2016), which develops a measure for the amenity value based on an equilibrium model

14 Table 1 reports the precise list of housing characteristics.

Table 3
Sea-level rise and house prices

	(1)	(2)	(3)	(4)	(5)
UnderWater$_i$	0.0893	−0.0131	−0.00557	−0.00278	−0.00353
	(0.0807)	(0.0388)	(0.0356)	(0.0335)	(0.0348)
Regional controls	No	Yes	No	No	No
House controls	No	Yes	No	No	Yes
UnderWater$_i$ × Distance	No	No	No	No	Yes
Distance fixed effects	No	No	Yes	Yes	Yes
ZIP code × Distance fixed effects	No	No	No	Yes	Yes
Observations	11,538,986	11,538,986	11,538,986	11,538,986	11,538,986
R^2	.001	.485	.028	.457	.645

This table presents results on the relationship between projected sea-level rise and home prices. The dependent variable in each specification is the log transaction price. The main independent variable is the indicator $UnderWater_i$ which is equal to one if a home i is projected to be underwater by 2100 given a 6-foot rise in sea level (see the definition in Table 1). The inclusion of fixed effects is denoted beneath each specification. *Distance* is measured at the level of each home. Robust standard errors are in parentheses.

of land use and trade. In that framework, the amenity value of a neighborhood is decomposed into quality of life, trade productivity, and home productivity, using variation in housing costs and wages.[15]

3.2 Beliefs about climate change and house prices

We begin our analysis by estimating the effect of sea-level rise, captured by the variable UnderWater$_i$ on house prices, as illustrated in regression (15). Table 3 reports the results.[16] The table illustrates that to correctly interpret the UnderWater$_i$ coefficient it is important to control for ZIP code, time, house characteristics, and, in particular, age and distance to the coast. In the absence of flood risks and projected damage due to climate change, homes closer to the coast may be more valuable due to the amenity values of being close to the coast or having waterfront views. If one does not control for distance from the coast, this omitted variable bias may generate a spurious positive relationship between sales price and a home being projected to be underwater due to sea-level rise. If we do not control for distance (Column 1), the marginal effect of UnderWater$_i$ is positive, indicating that a house located in an area that is projected to be underwater would sell for a *higher* price than a house not projected to be underwater. This result is a consequence of the fact that houses in an underwater area are also more likely to be more valuable because they are, for example, closer to the coast.

15 Specifically, using the intercity framework based on Rosen (1979) and Roback (1982), Albouy (2016) proposes the following parameterization of the total amenity value Ω^z in a geographical area z (ZIP code) with homogeneous population:

$$\hat{\Omega}^z = 0.39\hat{p}^z + 0.01\hat{w}^z, \tag{16}$$

where $\hat{p}^z$ is an estimated price of the nontraded home good, measured by the flow cost of housing services, and $\hat{w}^z$ is an estimate of wages in area z. We estimate $\hat{\Omega}^z$ at the ZIP code level using the aggregated Zillow Home Price Index and mean ZIP-code-level income from the Internal Revenue Service (IRS) statistics on income.

16 In Table 3 we cluster standard errors conservatively at the county level. If we use a less-conservative method of clustering and report Huber-White robust standard errors, then the results are highly statistically significant.

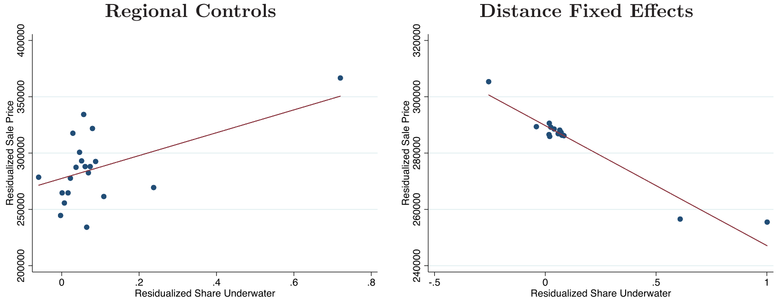

Figure 4
Home prices and projected flood risk
The dots in this figure represent mean home prices in twenty bins of the fraction of homes labeled as UnderWater, residualized using controls (see Table 1 for the definition of variables and controls). Each dot contains one-twentieth of the sample. The panel on the left residualizes both home prices and whether a home is underwater using regional controls. The panel on the right residualizes both home prices and whether a home is underwater using distance from the coast.

To illustrate the importance of controlling for distance from the coast, Figure 4 reports mean house price across twenty bins of the variable UnderWater_i residualized using the set regional controls in Table 1 (left panel) and distance fixed effect (right panel). As the left panel of the figure shows, without accounting for distance to the coast, one would infer that a higher likelihood of future flooding, as captured by the variable UnderWater_i, will be associated with a higher house price.

Column 2 of Table 3 adds in regional and house controls following Giglio, Maggiori, and Stroebel (2014), including lot size, the number of bedrooms, the number of bathrooms, parking, and property age. Regional controls include ZIP-code-level average income, population, elevation, the share of Republican voters, 10-year flood risk and average minimum daily air temperature. The UnderWater_i coefficient drops to -1.3% when we include regional and house controls. This suggests that many underwater homes near the coast are in cheaper localities, such as coastal Florida or southern Louisiana.[17] After controlling for time and ZIP code fixed effects, the UnderWater_i coefficient remains negative, although much smaller in magnitude and statistically insignificant.[18]

Table 4 presents our main findings regarding difference in beliefs about climate change and real estate prices. The first four columns report estimates of a variant of Equation (15), splitting the sample by above and below median belief that climate change is happening. Columns 1 and 2 include county$\times$distance$\times$elevation fixed effects, and Columns 3 and 4 include

[17] The mean sale prices are \$214,467 and \$210,747, respectively, in Florida and Louisiana, compared with \$304,655 in other states in the sample.

[18] Note that in Column 5, the marginal effect of UnderWater_i is not constant due to the inclusion of the interaction term Distance$\times\text{UnderWater}_i$.

Table 4
Beliefs about climate change and house prices

	(1) Below median	(2) Above median	(3) Below median	(4) Above median	(5) Full sample	(6) Full sample	(7) Full sample
UnderWater_i	0.0610*	−0.0499	0.0388	−0.0783*	−0.311**	−0.353**	0.260
	(0.0318)	(0.0519)	(0.0235)	(0.0457)	(0.130)	(0.154)	(0.264)
$\text{UnderWater}_i \times \ln H_c$					−0.966***	−0.993**	−1.181***
					(0.362)	(0.410)	(0.353)
Regional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
House controls	No	No	Yes	Yes	Yes	Yes	Yes
UnderWater_i × Regional controls	No	No	No	No	No	No	Yes
UnderWater_i × House controls	No	No	No	No	No	No	Yes
County × Distance × Elevation fixed effects	Yes	Yes	No	No	Yes	No	No
ZIP code × Distance fixed effects	No	No	Yes	Yes	No	Yes	Yes
Observations	5,879,841	5,659,145	5,879,841	5,659,145	11,538,986	11,538,986	11,538,986
R^2	.336	.498	.566	.692	.636	.645	.645

This table presents results on the relationship between beliefs about climate change and home prices. The dependent variable in each specification is the log transaction price. The main independent variable is the indicator $UnderWater_i$ which is equal to one if a home i is projected to be underwater by 2100 given a 6-foot rise in sea level (see the definition in Table 1). $\ln H_c$ is the log of the percentage of people who believe that climate change is happening. The columns labeled *Below (above) median* report the result from regression (15) for the subsample with the belief variable H_c below (above) its median value. The columns labeled *Full sample* report the result from regression (14) for the entire sample. The inclusion of fixed effects is denoted beneath each specification. *Elevation* is measured at the ZIP code level. *Distance* is measured at the level of each home. Transaction data come from *Zillow*. Belief data come from the Yale Climate Opinion Survey. Standard errors are clustered at the county level. * $p<.1$, ** $p<.05$, *** $p<.01$

ZIP code × distance fixed effects. The results indicate a negative and statistically significant relationship between home prices and homes being projected as underwater due to sea-level rise, but only in geographic areas with above median believers and after accounting for house controls and ZIP code × distance fixed effects (Column 4). In both pairs of columns, we can reject the hypothesis that the estimates on the interaction term are identical at the 1% and 5% level, respectively. The F-statistic for a test of equality on the interactions between Columns 1 and 2 is 10.02, and we thus reject the hypothesis of equality at the 1% level. The F-statistic for a test of equality on the interactions between Columns 3 and 4 is 6.57, and we thus reject the hypothesis of equality at the 5% level. Columns 5 and 6 estimate Equation (14), with county × distance × elevation and distance × ZIP code fixed effects, respectively.

Figure 5 graphically shows home prices in counties with above- and below-median beliefs that climate change is happening. The figure shows home prices in ventiles constructed from the share of homes projected to be underwater. Home prices and share of underwater homes are demeaned by the variable average in a ZIP code by mile distance from the coast. Consistent with the

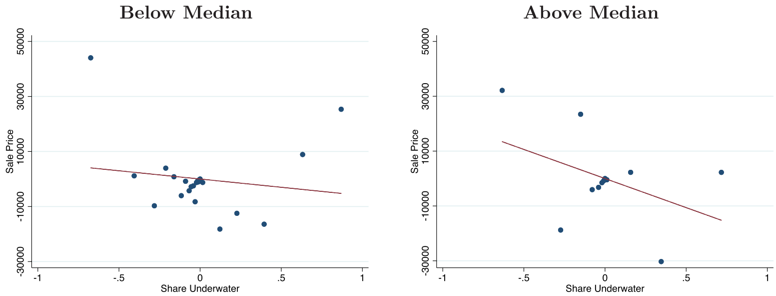

Figure 5
Home prices by flood measure and belief in climate change
The figure plots demeaned home prices in ventiles of demeaned share underwater. Each variable has been demeaned by the variable average in a ZIP code by mile distance from the coast. The left panel shows the data for homes in counties with below median belief that climate change is happening, and the right panel shows the data in counties with above median belief that climate change is happening. The flood projection variable UnderWater_i, the belief variable H_c, and the distance variables are defined in Section 2 and summarized in Table 1.

predictions of Proposition 2, we see a much flatter slope between home prices and a home projected as being underwater in geographic areas with more deniers.

Because of the finer granularity of the ZIP code fixed effects, we take Column 6 to be our main specification. This specification suggests that (a) a house located in a flood zone ($\text{UnderWater}_i = 1$) sells for 2.88% less than an identical house located outside a flood zone;[19] and (b) a house located in a flood zone ($\text{UnderWater}_i = 1$) sells for 0.993% less for a 1% increase in the fraction of households believing that climate change is happening. In Section 4.1 we discuss the economic magnitude of these estimates and argue that these magnitudes are plausible in light of available estimates of costs and forgone revenues following a flood. A negative coefficient on the interaction term $\text{UnderWater}_i \times \ln H_c$ supports the comparative statics of the model illustrated in Proposition 2, in that the valuation gap between believers and deniers is increasing in the probability of being flooded. A possible concern with the above findings is that UnderWater_i may be correlated with unobserved characteristics. To allay this concern, in Column 7 we interact UnderWater_i with regional and house controls. The estimated elasticity of interest in this specification is -1.181 and is statistically significant.

Figure 6 splits the sample into belief quartiles and reports the UnderWater_i coefficient obtained from estimating Equation (15) for each quartile. The figure shows coefficients equivalent to those reported in Columns 3 and 4 of Table 4, but in quartiles rather than above and below the median. The figure shows that the relationship between home prices and whether a home is projected to be

19 From Column (6), the marginal effect of UnderWater_i at the mean is $-0.353+(-0.993)\times(-0.3265)=-0.0288$, where -0.3265 is the mean of $\ln H_c$.

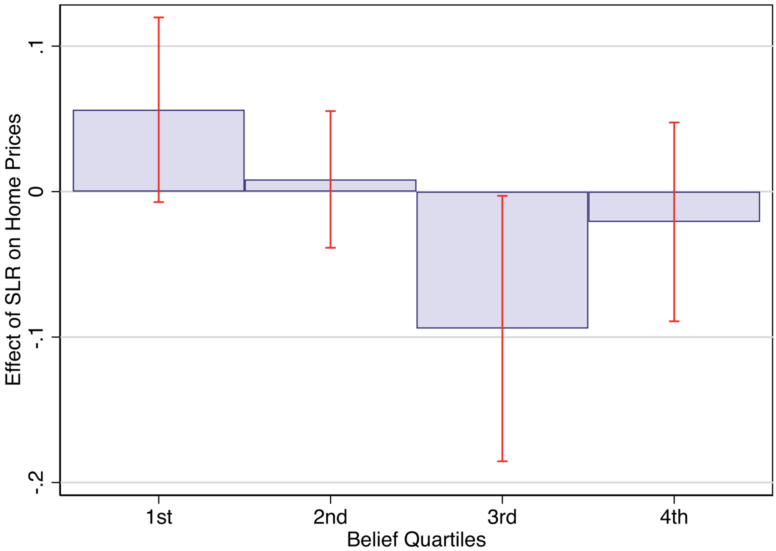

Figure 6
Home prices and sea-level rise by beliefs about climate change
This figure shows the relationship between home prices and sea-level rise, estimated from a regression of home prices on whether a home is projected to be underwater, broken down by quartiles of beliefs in climate changes. The thick bars represent regression coefficients, and the thin lines represent a 95% confidence interval. Standard errors are clustered at the county level. Belief data come from the Yale Climate Opinion Survey. Home price data were obtained from *Zillow*.

underwater due to sea-level rise is stronger in areas where more people believe in climate change. The results indicate that, in areas with more believers in climate change, the forecast of being inundated has a much larger negative impact on house prices. In contrast, the relationship between home prices and homes being underwater due to projected sea-level rise is close to zero and statistically indistinguishable from zero in areas where relatively fewer people believe that climate change is happening. Home prices are much more sensitive to projected sea-level rise in areas where a higher fraction of people believe that climate change is happening, with an estimated coefficient of between -0.02 and -0.1 in the regions with above median belief that climate change is happening.

3.3 Regional and income heterogeneity

In this subsection, we explore further heterogeneity by region, population density, and income level. Table 5 repeats the main analysis from Table 4 for subsets of our data for which variations in amenity are likely to be smaller. Specifically, we split the sample (a) by geography—North, South, and West; (b) by population density—Metropolitan Statistical Area (MSA) and non-MSA; and (c) by income—above and below $66,000, which is the rounded mean in our sample.

Table 5
Beliefs about climate change and house prices: Regional characteristics

	(1) North	(2) South	(3) West	(4) No MSA	(5) MSA	(6) Inc ≤ \$66,000	(7) Inc > \$66,000
UnderWater_i	−0.287	−0.282	2.353	−0.0309	0.246	0.0426	0.413
	(0.372)	(0.336)	(2.445)	(0.363)	(0.448)	(0.353)	(0.260)
$\text{UnderWater}_i \times \ln H_c$	−0.666***	−0.866*	−0.284	−0.725*	−0.980***	−0.792**	−0.893***
	(0.215)	(0.445)	(1.918)	(0.402)	(0.328)	(0.367)	(0.224)
Regional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
House controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
UnderWater_i × Regional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
UnderWater_i × House controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ZIP code × Distance fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,142,320	6,296,655	2,100,011	3,887,053	7,651,933	6,623,653	4,915,333
R^2	.661	.573	.637	.562	.680	.564	.620

This table presents results on the relationship between beliefs about climate change and home prices, broken down by regional characteristics. The dependent variable in each specification is the log transaction price. The main independent variable is the indicator $UnderWater_i$ which is equal to one if a home i is projected to be underwater by 2100 given a 6-foot rise in sea level (see the definition in Table 1). $\ln H_c$ is the log of the percentage of people who believe that climate change is happening. The inclusion of fixed effects is denoted beneath each specification. *Elevation* is measured at the ZIP code level. *Distance* is measured at the level of each home. Transaction data come from *Zillow*. Belief data come from the Yale Climate Opinion Survey. Standard errors are clustered at the county level. * $p<.1$, ** $p<.05$, *** $p<.01$

Columns 1 through 3 split the sample by regions: North, South, and West.[20] We find stronger effects in the North and South relative to the West Coast, with the interaction coefficients being negative and significant or marginally significant. We do not find a statistically significant effect on the West Coast, shown in Column 3, although the standard errors are quite large and the estimates are not precise enough to rule out the effects seen in Columns 1 and 2.

One potential hypothesis is that effects may be weaker in areas where we expect more climate change mitigation, such as levees in New Orleans. We hypothesize that climate change mitigating investments are more likely in urbanized and wealthy areas. Columns 4–7 of Table 5 explore heterogeneity across various attributes that may affect investments in climate change mitigation. We find that urbanization and income levels do not affect the main results.

Columns 4 and 5 split the sample by properties in an MSA and those not in an MSA. We find that the effect of the interaction between UnderWater_i and H_c is stronger in MSAs, although this difference is not statistically significant.[21]

20 We use the Mason-Dixon line to split North and South. The Midwest is not included as this landlocked region is not home to coastal properties.

21 The difference between the coefficients of the interaction term in Columns 4 and 5 is 0.2550, with a standard error of at least 0.3706.

Columns 6 and 7 split the sample by county income levels. Again, we find that the difference in effect of the interaction between UnderWater_i and H_c is not statistically different between the two columns, although effects are slightly stronger in higher income regions.

4. Amenity Values and Salience

In this section we provide some context for interpreting our empirical findings. First, we discuss the economic magnitudes implied by the estimates of the previous section, and relate the valuation gap between believers and deniers to the magnitude of expected cleanup costs after a flood. Second, we address the concern that belief about climate change may be correlated with the amenity value of coastal living. Third, we instrument for beliefs about climate change using political beliefs. Fourth, and finally, we discuss the tension between changes in climate risk and changes in policies designed to mitigate the effects of climate events.

4.1 Economic significance

To assess the economic significance of the empirical analysis, we provide two separate quantification exercises. In the first we relate our elasticity estimate to a measure of valuation gap between house prices in believers and deniers counties. In the second we use our estimates to infer the implied difference in flood probability, or, equivalently, expected life of a home, between believers and deniers.

Our analysis from the main specification in Column 6 of Table 4 indicates that conditional on being in a flood zone, the house price elasticity with respect to changes in beliefs about climate change is −0.993. To translate our elasticity estimate into an effect on house prices, we first note that from the summary statistics Table 2, a 1-standard-deviation increase in H_c, corresponds to a 6.94% (i.e., 0.05/0.72) change in H_c from its mean. Therefore, the unit elasticity estimated in Table 4 implies that a 1-standard-deviation increase in H_c is associated with a 6.90% decrease in the house price.

Let us consider the median home value of $190,000 in our sample, which is close to the average home price in Rao (2017). Our estimate suggests that moving this house from a neighborhood whose value of H_c is 1-standard-deviation below the mean to one that is 1-standard-deviation above, would decrease its value by approximately $26,220 (i.e., by 13.8% of $190,000). This can be thought of as the valuation gap between believers and deniers. To interpret the economic magnitude of this gap, we note that a portion of it can be attributed to costs associated with floods. According to Aon National Flood Services (2016), a 1-inch flooding of a 2,000 square foot house is expected to lead to cleanup costs of approximately $18,940, excluding damage to any personal property. The estimated valuation gap of $26,220 corresponds to the capitalized value of cleanup costs and forgone rent due to a flooding of around \$1,311 per year at an interest rate of 5%.

An alternative way to assess the economic magnitude of our estimates is to link price differences to differences in the perceived probability of a rare flood event between believers and deniers. Define the price ratio between deniers and believers as the ratio of predicted prices for 1 standard deviation above and below the mean of H_c, that is, $\overline{P} \times (1 \pm \zeta \frac{\sigma_H}{\mu_H})$. Using the estimates from Tables 2 and 4, we find that $P_d / P_b = 1.0690/0.9310 = 1.1482$. Assume that believers and deniers only differ in their assessment of the likelihood of the timing of when their home gets permanently flooded. If the arrival of that devastating flood is distributed geometrically as in the discussion following Assumption 1, the relative price between deniers and believers can be written as

$$\frac{P_d}{P_b} = \frac{\gamma_d}{1-\rho\gamma_d} \frac{1-\rho\gamma_b}{\gamma_b}, \tag{17}$$

where ρ is the common discount factor, which we set to 0.975 as suggested by Giglio et al. (2015). Equating (17) to 1.1482 and solving for γ_d yields $\gamma_d = \frac{1.1482\gamma_b}{1+0.1445\gamma_b}$. To interpret this relationship, we start with the definition of UnderWater$_i$ evaluating to unity: conditional on a 6-foot sea-level rise scenario, UnderWater$_i$ evaluates to unity for properties that are inside of an 80% confidence interval around NOAA's MHHW estimate for 2100 (National Oceanic and Atmospheric Administration 2017). Suppose a believer has γ_b to satisfy $\mathbb{P}[\mathcal{T} \leq (2100-2018)] = 1-\gamma_b^{82} = 0.8$, which implies that $\gamma_b = 0.9806$. In turn, this implies that $\gamma_d = 0.9862$. Using the property of the geometric distribution, we can translate these estimates to the expected lifespan of a property. Specifically, a believer expects a property to last for $\mathbb{E}^b[\mathcal{T}] = \frac{\gamma_b}{1-\gamma_b} =$ 50.5 years, while a denier expects a property to last for $\mathbb{E}^d[\mathcal{T}] = 71.5$ years.

In summary, both experiments suggest that the disagreement between believers and deniers is of economic significance. We emphasize, however, that our analysis does not speak to whether deniers or believers use correct projections about sea-level rise. It is possible that believers overreact or that deniers underreact, thus amplifying the discrepancy between their valuations. In other words, they may both be wrong, but they cannot both be right.

4.2 Amenity value of living near the coast

A potential concern in interpreting the estimates in Table 4 is that the amenity value of living by the coast may be correlated with belief about climate change. If this were the case, then our estimates of the difference in belief effect will be capturing the variation in amenity value of coastal living.[22] For example, the amenity value of living near the coast may be higher in warmer climates, such as the U.S. South, where belief that climate change is happening may be lower.

[22] We thank David Sraer for pointing this out.

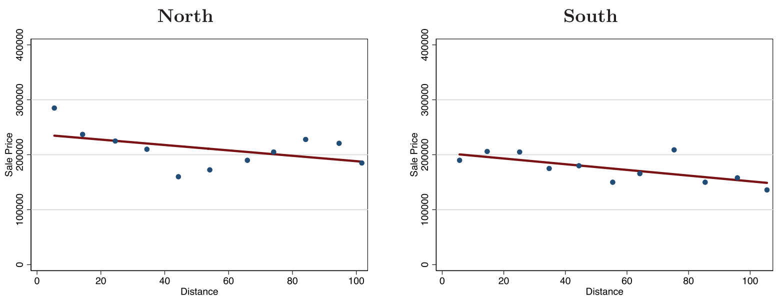

Figure 7
Home prices by distance from the coast
The dots in this figure represent mean home prices, by distance from the coast in 10-km bins, by region. The Mason-Dixon line (latitude 39°43′ N) divides the North and South. The solid line represents an estimated regression line between home prices and distance. The estimated coefficient (standard error) on distance is −490.9656 (312.9187) for the North and −518.4964 (184.7537) for the South.

Thus, the interaction between a home projected as being underwater and belief in climate change may be picking up the differential amenity value of living near the coast. Figure 7 plots median home prices against the distance from the coast, separately for the North and South. As the figure shows, the slope of the relationship between home prices and distance to the coast is quite similar in the North and South. Consistent with our results in the previous section, this suggests that the amenity value of living near the coast is not likely to vary substantially across U.S. regions.

To address this concern more formally, in Table 6 we extend the analysis of Table 4 by including measures of amenities in the regressions. We employ two types of such measures, which we label *Model-Based Amenity Controls* and *Direct Amenity Controls*. The former are based on the model of Albouy (2016), and the latter are variables such as income, temperature, population, latitude, education, and elevation taken from table IV of Albouy (2016). The results are quite similar to those in Table 4, and the coefficients are statistically indistinguishable. We conclude that our results are not driven by the variation in the amenity value of coastal living.

4.3 Instrumental variables estimates

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 our main specification, we control for political vote share, but this is another possible source of variation that can be used to identify the effects of beliefs about climate change on home prices.[23] In this section, we present results instrumenting for $\text{UnderWater}_i \times \ln H_c$ using Republican_z

[23] We are very grateful to the editors and Harrison Hong for suggesting this test.

Table 6
Beliefs about climate change and house prices: Controlling for amenities

	(1) Below median	(2) Above median	(3) Full sample	(4) Full sample	(5) Full sample	(6) Full Sample
UnderWater_i	0.0714***	−0.0652*	−0.324*	−0.289	−0.311**	−0.437
	(0.0244)	(0.0378)	(0.172)	(0.182)	(0.130)	(0.954)
$\text{UnderWater}_i \times \ln H_c$			−1.038**	−0.892*	−0.966***	−1.200***
			(0.440)	(0.456)	(0.362)	(0.418)
Regional controls	Yes	Yes	Yes	Yes	Yes	Yes
House controls	No	No	Yes	Yes	Yes	Yes
$\text{UnderWater}_i \times$ Regional controls	No	No	No	No	Yes	Yes
$\text{UnderWater}_i \times$ House controls	No	No	No	No	Yes	Yes
County × Distance fixed effects	Yes	Yes	Yes	No	Yes	No
ZIP code × Distance fixed effects	No	No	No	Yes	No	Yes
Model-based amenity controls	Yes	Yes	Yes	Yes	Yes	Yes
$\text{UnderWater}_i \times$ Model-based amenity controls	No	No	Yes	Yes	Yes	Yes
Direct amenity controls	Yes	Yes	No	No	Yes	Yes
$\text{UnderWater}_i \times$ Direct amenity controls	No	No	No	No	Yes	Yes
Observations	5,879,841	5,659,145	11,538,986	11,538,986	11,538,986	11,538,986
R^2	.556	.688	.638	.645	.636	.645

This table presents results on the relationship between beliefs about climate change and home prices. The dependent variable in each specification is the log transaction price. The main independent variable is the indicator $UnderWater_i$ which is equal to one if a home i is projected to be underwater by 2100 given a 6-foot rise in sea level (see the definition in Table 1). $\ln H_c$ is the log of the percentage of people who believe that climate change is happening. The column labeled *Below (above) median* reports the result from regression (15) for the subsample with the belief variable H_c below (above) its median value. The columns labeled *Full sample* report the result from regression (14) for the entire sample. The inclusion of fixed effects is denoted beneath each specification. *Elevation* is measured at the ZIP code level. *Distance* is measured at the level of each home. Transaction data come from *Zillow*. Belief data come from the Yale Climate Opinion Survey. Standard errors are clustered at the county level. * $p<.1$, ** $p<.05$, *** $p<.01$

and $\text{Republican}_z \times \text{UnderWater}_i$, where Republican_z denotes the percentage of people in a ZIP code voting for the Republican Party.

The instrumental variables (IV) estimate relies on two identifying assumptions. The first is the *inclusion restriction*, that the instrument is conditionally correlated with the endogenous variable. This assumption is testable, and we show that indeed the instrument is correlated with the endogenous regressor. The second is the *exclusion restriction*, that the share of Republican voters is conditionally uncorrelated with unobserved determinants of home prices other than beliefs. This assumption is untestable, but one has plausible reasons to worry that the political climate may affect home prices through other channels. For example, areas with more Republican voters may vote for politicians who promote different policies that affect the supply of housing. Additionally, Republicans and Democrats

Table 7
Sea-level rise and house prices: Instrumental variables estimates

	H_c	$\text{UnderWater}_i \times \ln H_c$		$\ln P_{it}$	
	(1)	(2)	(3)	(4)	(5)
Republican_p	$-.1332^{***}$	$.0743^{*}$			
	(.0218)	(.0415)			
$\text{Republican}_p \times \text{UnderWater}_i$		$-.6243^{***}$			
		(.0154)			
UnderWater_i			$-.2983^{**}$	$-.3773^{*}$	.1322
			(.1368)	(.1994)	(.2966)
$\text{UnderWater}_i \times \ln H_c$			-1.0793^{***}	-1.0618^{***}	-1.5998^{***}
			(.4078)	(.5391)	(.6420)
Regional controls	Yes	Yes	No	No	No
House controls	Yes	Yes	No	No	Yes
UnderWater_i × Distance × Distance	No	No	No	No	Yes
County × Distance fixed effects	No	Yes	Yes	No	No
ZIP code × Distance fixed effects	No	No	No	Yes	Yes
Instruments	No	No	Yes	Yes	Yes
Observations	11,538,986	11,538,986	11,538,986	11,538,986	11,538,986

The dependent variable in each specification is the log transaction price. The main independent variable is the indicator $UnderWater_i$ which is equal to one if a home i is projected to be underwater by 2100 given a 6-foot rise in sea level (see the definition in Table 1). Columns 1 and 2 present, respectively, the relationship between political beliefs and beliefs about climate change and the first stage. Columns 3–5 instrument $\text{UnderWater}_i \times \ln H_c$ using Republican_z and $\text{Republican}_z \times \text{UnderWater}_i$. The inclusion of fixed effects is denoted beneath each specification. *Distance* is measured at the level of each home. $^{*}p<.1$, $^{**}p<.05$, $^{***}p<.01$

may follow different schooling policies, which can affect home prices. We thus treat our IV estimates with caution.

Table 7 presents the IV results. The first column confirms that geographic areas with more Republicans are indeed less likely to believe that climate change is happening. Column 1 shows that precincts with a 10-percentage-point higher level of Republican votes are associated with a 1.3-percentage-point reduction in the fraction of people who believe that climate change is happening. The effect is highly statistically significant, at the 1% level. Column 2 presents the first stage estimation. The F-statistic is well above standard thresholds for weak instruments (Kang and Plfueger 2013).

In Columns 3–5, we instrument $\text{UnderWater}_i \times \ln H_c$ using Republican_z and $\text{Republican}_z \times \text{UnderWater}_i$. We find that our estimates are quite similar to those presented in earlier tables. The effect of $\text{UnderWater}_i \times \ln H_c$ is significant at the 1% level in all specifications, and, moreover, the point estimates are statistically indistinguishable from those reported in Table 4.

4.4 Variation in climate change awareness

Change over time in the population awareness about climate change, may raise additional concerns about the interpretation of our results. A first concern in attributing the results in Table 4 to belief heterogeneity about climate change is the possibility that buyers who believe in climate change might expect mitigation technology to affect the way individual new homes are built, for example, using pylons or stilts. In Section 3.3, Table 5, we show that the interacted effects of beliefs and sea-level rise are stronger in regions where we would expect more mitigation, such as urban areas and high-income areas. However, the difference is not statistically significant at conventional levels.

A second concern is that government intervention may affect mitigation policies at the neighborhood level. Therefore, heterogeneity in beliefs about *climate risk* and beliefs about *policies* to address climate risks may both affect equilibrium prices. The results in Table 5 concerning heterogeneity in population density and income are useful also to address the concern that improvement in flood protection technology at the neighborhood level (e.g., sea walls) might confound the effect of difference in beliefs. If government interventions are more likely in dense metropolitan areas, such as Manhattan, relative to less affluent rural areas, then we would expect prices in densely-populated areas to exhibit less price responsiveness with respect to sea-level rise.[24] Overall, from the results from Columns 4–7 of Table 5 we fail to reject that the coefficient for urban and nonurban areas or those for high and low income are equal. We conclude that although our estimated interaction coefficient is likely the manifestation of both difference in beliefs about climate risk and about government intervention, the latter effect does not seem to be dominant in our results.

A third concern is that new homes may be built on stilts. We deal with this concern in two ways. First, we control for the average age of local housing stock. Second, we split the sample into newer and older houses. Both approaches are designed to capture the fact that older houses are less likely to include stilts and other features that mitigate the impact of climate change risks. Figure OA.1 shows Google Trends for the term "stilt house" from 2006 to 2018. As the figure shows, searches for stilt homes have clearly increased, a finding consistent with an increase in media coverage around the same time.[25] To address the concern that adaptation technology at the property level may make the difference-in-beliefs interpretation of our results less persuasive, we repeat the analysis separately for old and new homes, based on whether a home was built before or after the year 2010, which corresponds to an uptick in interest in stilt homes.

Table 8 repeats the analysis of Columns 5 and 6 of Table 4, reproduced as Columns 1 and 2 of Table 8, and splits the sample by homes built before 2010 (Columns 3 and 4) and after 2010 (Columns 5 and 6). The first two columns add interactions for sea-level rise and the share of housing stock in the county built prior to 1980, obtained from the American Housing Survey. The last four columns repeat the analysis in Columns 5 and 6 of Table 4, by

[24] Walsh et al. (2015) use data for Anne Arundel County, Maryland, to document that the presence of adaptation structures, such as bulkheads or rip-raps, is associated with a 21% increase in property prices for homes located in zones threatened by sea-level rise.

[25] For example, in a *Wall Street Journal* article, Jackson (2013) reports that "[h]omeowners building in flood-prone and coastal areas are increasingly revisiting elevated stilt houses."

Table 8
Beliefs about climate change and house prices by time period

	(1)	(2)	(3)	(4)	(5)	(6)
	Full Sample		Pre-2010		Post-2010	
UnderWater$_i$	−0.599***	0.0737	−0.332**	0.251	0.193	0.450
	(0.163)	(0.273)	(0.132)	(0.267)	(0.119)	(0.388)
UnderWater$_i$ × lnH_c	−1.477***	−1.493***	−1.036***	−1.266***	0.494	0.372
	(0.368)	(0.383)	(0.371)	(0.367)	(0.316)	(0.315)
Regional controls	Yes	Yes	Yes	Yes	Yes	Yes
House controls	Yes	Yes	Yes	Yes	Yes	Yes
UnderWater$_i$ × Regional controls	Yes	Yes	Yes	Yes	Yes	Yes
UnderWater$_i$ × House controls	Yes	Yes	Yes	Yes	Yes	Yes
UnderWater$_i$ × Old housing stock	Yes	Yes	No	No	No	No
County × Distance × Elevation fixed effects	Yes	No	Yes	No	Yes	No
ZIP code × Distance fixed effects	No	Yes	No	Yes	No	Yes
Observations	11,538,986	11,538,986	11,276,845	11,276,845	262,141	262,141
R^2	.604	.649	.604	.648	.575	.631

This table presents results on the relationship between beliefs about climate change and home prices, split by time period. The dependent variable in each specification is the log transaction price. The main independent variable is the indicator $UnderWater_i$ which is equal to one if a home i is projected to be underwater by 2100 given a 6-foot rise in sea level (see the definition in Table 1). $\ln H_c$ is the log of the percentage of people who believe that climate change is happening. The inclusion of fixed effects is indicated beneath each specification. All specifications include controls for the interaction of county level pre-1980 housing stock and whether a house is projected to be underwater with 6 feet of sea-level rise. *Elevation* is measured at the ZIP code level. *Distance* is measured at the level of each home. Transaction data come from *Zillow*. Belief data come from the Yale Climate Opinion Survey. Standard errors are clustered at the county level. * $p < .1$, ** $p < .05$, *** $p < .01$

splitting the sample into homes built before and after 2010. Again we see that for homes built prior to 2010, the results are quite similar to those in Table 4. For homes built after 2010, we find no significant effect, which is consistent with an increase in climate change mitigation procedures, such as stilts and pylons, in the construction of new homes.

4.5 Beliefs and climate change salience

4.5.1 Repeated transactions. A potential drawback of the analysis in the previous section is that it leverages only cross-sectional variation in the belief and climate change variables. This raises identification concerns that unobservable, yet constant determinants of prices may be correlated with the interaction terms between climate change and beliefs about it. A challenge is the fact that we do not measure sea-level rise or beliefs about it over time. However, we exploit the fact that the overall salience of climate change in the public debate has increased in the two decades between 1997 and 2017.[26] Moreover, the projected risks of climate change are further into the future, and thus more heavily discounted in 1997 relative to 2017.

[26] For example, a Gallup poll indicates that in 2001, 57% of people believed that global warming is caused by human activities, compared to 68% in 2017 (Gallup 2017).

Table 9
Beliefs about climate change and house prices: Repeated transactions

	(1)	(2)	(3)	(4)	(5)	(6)
UnderWater_i	−0.0909	-0.146^{***}	−0.468	0.000136	−0.0230	0.395
	(0.0672)	(0.0391)	(0.419)	(0.444)	(0.311)	(0.331)
$\text{UnderWater}_i \times \ln H_c$			−0.547	−0.501	-0.587^{**}	-0.645^{**}
			(0.359)	(0.371)	(0.268)	(0.292)
Regional controls	Yes	Yes	Yes	Yes	Yes	Yes
UnderWater_i × Regional controls	Yes	Yes	Yes	Yes	Yes	Yes
House controls	Yes	Yes	No	No	Yes	Yes
UnderWater_i × House controls	Yes	Yes	No	No	Yes	Yes
County × Distance × Elevation fixed effects	No	No	Yes	No	No	Yes
ZIP code × Distance fixed effects	Yes	Yes	Yes	No	No	Yes
Observations	45,590	45,603	91,193	91,193	91,193	91,193
R^2	.613	.698	.568	.586	.658	.671

This table presents results on the relationship between beliefs about climate change and home prices, exploiting repeated transactions. The dependent variable in each specification is the log difference in transaction prices for the same home in 1997 and 2017. If a house was not transacted in 1997 or 2017, we use transaction prices from adjacent years. The main independent variable is an indicator equal to one if a home would be underwater given a 6-foot rise in sea level. $\ln H_c$ is the log of the percentage of people who believe that climate change is happening. All specifications include controls for ZIP-code-level income and short-term flood risk. Transaction data come from *Zillow*. Belief data come from the Yale Climate Opinion Survey. Standard errors are clustered at the county level. $^{*}p<.1$, $^{**}p<.05$, $^{***}p<.01$

We restrict the sample to homes for which we observe multiple transactions. We use the log price difference between 2017 and 1997, that is, $\ln P_{i,2017} - \ln P_{i,1997}$, as the dependent variable in place of $\ln P_{i,t}$.[27] We hypothesize that in 1997, climate change and its impact on coastal regions was less prevalent compared to 2017. This specification allows us to test whether homes that are projected to be underwater and are located in a denier neighborhood have experienced a muted price increase over the last decade.

The results based on transacted home prices are mixed and inconclusive. Table 9 reports the coefficients for the interaction term $\text{UnderWater}_i \times \ln H_c$ from regression (14). When we include ZIP code fixed effects and interactions, the coefficient is marginally significant at the 5% level. A negative coefficient of the interaction term in Columns 5 and 6 suggests that prices of homes projected to be underwater due to sea-level rise grew less in areas where a higher fraction of people believe that climate change is happening.

In other specifications the coefficient on the interaction has a similar magnitude, but is statistically insignificant. This is potentially due to the relatively small number of homes that were transacted in both the late 1990s and late 2010s, and a lack of statistical power to detect effects given the relatively small changes in beliefs during this time period.

27 If a house was not transacted in 1997 or 2017, we use transaction prices from adjacent years, that is, 1998 and 1999 or 2015 and 2016.

4.5.2 Salience of flood risk. We use the occurrence of hurricanes to measure salience of natural disasters. During time periods after a hurricane, homeowners are more aware of the consequences of flood risk because of news reports. Recent work by Choi, Gao, and Jiang (2018) shows that short-term climate events can affect beliefs about climate change. We consider such time periods but exclude areas that suffered consequences from hurricanes, which could directly affect home prices. Thus, we examine home prices following major hurricanes but *only in states that were unaffected by hurricanes*. We also restrict the sample to states on the East Coast, which are affected by severe hurricanes. Home transactions that occur during the time period when the devastating effects of hurricanes are present, make the effect of future sea-level rise more salient. The key prediction is that major hurricanes will affect the price of properties subject to being underwater due to climate change, even in areas that were not directly affected by the hurricane.

To isolate salient events, we obtain, for each of the top ten costliest hurricanes in the United States, according to the National Hurricane Center, the date and affected states which are listed in Table OA.1. We define an indicator $Hurricane_{st}$ that evaluates to unity for housing transactions that occurred within up to three months after a hurricane and in a state s that was not directly affected by the hurricane. We thus test for a differential effect around major hurricanes, in states unaffected by the hurricane.

Table 10 presents the results. Column 1 does not include any controls and importantly does not include time period fixed effects. An important source of bias here is the fact that home prices have risen over time, and hurricanes have become more frequent in recent years. When we add controls, Columns 5 and 6 indicate that for houses transacted shortly after a hurricane and in areas that were not directly affected by it, sales prices for homes projected to be underwater are lower. However, the effects are statistically insignificant or marginally significant at conventional levels.

5. Robustness and Placebo Results

In this section we assess the robustness of our main findings by considering several variants of our main specification. We also provide various placebo checks, and show the effects are smaller in areas with high housing supply elasticity, and in rental and commercial real estate markets. We provide further analysis to show that our main specification is robust to various alternatives.

5.1 Rental and commercial real estate markets

As a placebo test, we utilize residential rents and commercial real estate prices as outcome variables. While Proposition 2 does apply to residential or commercial real estate, we conjecture that differences in local beliefs are less important for these two types of transactions. For commercial real estate, differences in local

Table 10
Beliefs about climate change and transacted house prices during hurricanes

	(1)	(2)	(3)	(4)	(5)	(6)
UnderWater$_i$	−0.0277	−0.00809	0.0262	−0.0626	−0.00493	0.269
	(0.0394)	(0.0354)	(0.0313)	(0.304)	(0.0330)	(0.286)
Hurricane$_{st}$ × UnderWater$_i$	0.163***	−0.0233	−0.0247*	−0.0241*	−0.0232	−0.0255*
	(0.0328)	(0.0145)	(0.0149)	(0.0144)	(0.0145)	(0.0140)
Regional controls	No	No	Yes	Yes	Yes	Yes
House controls	No	Yes	Yes	Yes	Yes	Yes
UnderWater$_i$ × Regional controls	No	No	No	Yes	No	Yes
UnderWater$_i$ × House controls	No	No	No	Yes	No	Yes
County × Distance × Elevation fixed effects	No	No	Yes	Yes	No	No
ZIP code × Distance fixed effects	Yes	Yes	No	No	Yes	Yes
Observations	8,577,037	8,577,037	8,577,037	8,577,037	8,577,037	8,577,037
R^2	.413	.610	.599	.599	.610	.610

This table presents results on the relationship between beliefs about climate change and home prices, interacted with a sale 4 months after a major hurricane. The dependent variable in each specification is the log transaction price. The main independent variable is the indicator $UnderWater_i$ which is equal to one if a home i is projected to be underwater by 2100 given a 6-foot rise in sea level (see the definition in Table 1). $Hurricane_{st}$ is an indicator that equals to one for transactions that occurred within up to 3 months after a hurricane and in a state s that was not directly affected by it. The inclusion of fixed effects is denoted beneath each specification. *Elevation* is measured at the ZIP code level. *Distance* is measured at the level of each home. Transaction data come from *Zillow*. Belief data come from the Yale Climate Opinion Survey. Standard errors are clustered at the county level. $^{*}p<.1$, $^{**}p<.05$, $^{***}p<.01$

beliefs are likely less important because the participants in those transactions tend to be more sophisticated relative to residential real estate. Additionally, firm headquarters and thus decisions by corporations may be made in different geographies relative to real estate, where this is not the case in the residential housing market. For rental real estate, differences in local beliefs are likely less important because the homophily channel in our model is less important due to the shorter-term nature of the market.

We employ ZIP-code-level residential rent prices from Zillow and MSA level commercial real estate prices used in Chaney, Sraer, and Thesmar (2012).[28] Columns 3 and 4 of Table 11 show that the effect of differences in beliefs about climate change is not statistically significant when considering residential rents. This finding is consistent with the intuition that the rental market is subject to more turnover and less prone to the type of frictions highlighted in the theoretical model of Section 1—short-term renters are unlikely to consider long-term risk in decision-making. Columns 5 and 6 of Table 11 also indicate that differences in beliefs about climate change do not appear to affect the price of commercial real estate. This finding is consistent with the intuition that the commercial real estate market is predominantly characterized by sophisticated investors and therefore less prone to segmentation.

28 We thank David Sraer for kindly providing the commercial real estate data.

Table 11
Rent, office prices, and supply elasticity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Residential prices				Commercial prices		Supply elasticity	
	Buy		Rent				Below median	Above median
UnderWater	1.187**	0.0601	1.008***	0.120	0.425	−0.0147	−0.351**	0.0128
	(0.505)	(0.408)	(0.367)	(0.377)	(0.774)	(0.0247)	(0.165)	(0.0820)
UnderWater × $\ln H_c$	0.666	−1.854	1.502	−0.821	1.402	−0.0481	−0.884*	−0.0919
	(1.293)	(1.126)	(0.987)	(1.145)	(2.148)	(0.0673)	(0.495)	(0.223)
Regional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
House controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County fixed effects	No	Yes	No	Yes	No	Yes	Yes	Yes
Observations	33,638	33,638	10,778	10,778	9,828	9,828	4,231,352	4,179,793
R^2	.677	.822	.725	.862	.519	.969	.684	.612

This table presents results on the relationship between beliefs about climate change and real estate prices at the ZIP code level. The dependent variables are the log of the Zillow home prices at the ZIP code level for Columns 1 and 2, the log of the Zillow Rent Index at the ZIP code level in Columns 3 and 4, the log of the office price index at the MSA level based on Chaney, Sraer, and Thesmar (2012) in Columns 5 and 6, and house-level transacted prices in Columns 7 and 8. Columns 7 and 8 split the sample according to the Saiz (2010) measure of the elasticity of housing supply, into above and below median, respectively. The Saiz (2010) measure is available at the MSA level, for 269 MSAs. UnderWater is defined as the average of UnderWater_i across houses in our sample in a ZIP code in Columns 1–6. Standard errors are clustered at the county level. $^{*}p<.1$, $^{**}p<.05$, $^{***}p<.01$

5.2 Heterogeneity by housing stock supply

In our theoretical model, we assume that the housing stock in each neighborhood is fixed. However, if it were possible to expand the number of homes, then we conjecture that this would lead to additional housing units in the higher priced, relatively more profitable neighborhoods. We would expect differences in beliefs to matter more for price differences in areas with less elastic supply. We examine this possibility by taking into account the Saiz (2010) measure of local housing supply elasticity.[29]

To explore the effect of real estate supply elasticity and segmented real estate markets, in Table 11, Columns 7 and 8, we split the sample based on the Saiz (2010) measure of local housing supply elasticity. The table repeats the main analysis, splitting the sample above and below the median level of housing supply elasticity.[30] Consistent with the predictions of the model, the valuation gap between areas with different beliefs in climate change is greater in areas with lower supply elasticity. In fact, we only find statistically significant effects

[29] As above, we include a rich set of controls to address concerns that housing supply is correlated with demand. We also control for factors noted in Davidoff (2016) to assuage concerns that the measure of local housing supply is correlated with other demand factors. These include immigrant share, national changes to employment in local industries, a sand states indicator, high education share, and a coastal areas indicator.

[30] Note that the number of observations is lower than in the main sample. This is because not all homes in the data are located within an MSA, and the Saiz (2010) measure of housing supply elasticity is constructed at the MSA level.

of sea-level rise on home prices in areas with low housing supply elasticity, confirming the predictions of our model and the empirical analysis.

5.3 Alternative specifications

Table OA.2 varies our main specification to assess whether the results are robust to alternative specifications. Columns 1 and 2 use an alternative measure of beliefs. Instead of using answers to the survey question: "*Do you believe that climate change is happening?*" as our main measure of beliefs, we use answers to questions such as "*Do you believe that climate change will personally affect you*?" We find that the interactions are significant at the 5% level, indicating that the main results hold when we utilize an alternative measure.

The survey question about whether respondents are personally affected by climate change also allows us to address the issue of whether it is beliefs about climate change per se that influence home prices or beliefs about whether people will be harmed by climate changes. While we cannot directly disentangle beliefs and preferences in an empirical setting, we view answers to this question as pooling both preferences and beliefs. In fact, a negative answer could imply that either an individual does not believe that climate change is happening or an individual believes that climate change is happening, but is unconcerned about the personal impact of climate change.

Columns 3 and 4 replace the dependent variable with Zillow estimates of home prices rather than transaction prices. We use Zillow estimates for the same date that the home was transacted. The interaction between a home being underwater and beliefs about climate change remain significant. Columns 5 and 6 restrict the analysis to homes less than 40 km from the coast. The coefficients on the interactions are similar to those in the main results, and are significant at the 1% level. Columns 7–12 explore specifications showing the analysis for homes less than 60 Km from the coast, alternative clustering at the state level, as well as bootstrapping standard errors. The results remain significant at the 5% level or higher.

6. Conclusion

This paper studies the impact of belief heterogeneity about long-run climate change risks on the valuation of real estate in the United States. We develop a simple model of housing choice in which agents derive utility from owning in a neighborhood of similar agents to show the existence of equilibria in which agents endogenously sort by belief into geographically distinct neighborhoods. In our empirical analysis, we construct a comprehensive data set on home transaction prices in the United States that maps individual homes to future inundation projections, and to survey data on beliefs of U.S. population on climate change.

We find support for the hypothesis that differences in beliefs about climate change are reflected in residential real estate prices. Specifically, our main finding is that, all else being equal, homes located in climate change "denier" neighborhoods sell for about 7% more than homes in "believer" neighborhoods. This result is robust to a host of empirical specifications that account for change in climate change awareness over time, salience of flood risk, and house supply effects. We conclude that heterogeneity in beliefs about long-run climate change risks significantly affects the U.S. real estate market.

Our work shows that the effects of projected climate change may affect real estate prices decades before the projected damages are expected to occur. Although our estimated valuation gap between believers and deniers appears to be in line with available estimates of cleanup costs and forgone rent, our analysis is agnostic about whether it is believers who overreact or deniers who underreact to long-run risks of climate change. Further, our analysis does not distinguish between uncertainty about climate change and uncertainty about policy responses to climate change. Understanding the frictions that prevent real estate prices to be a fully disciplining device is an interesting and relevant endeavor that we leave to future research.

A. Proofs

A.1 Proof of Proposition 1

To show that the above set of prices and allocations is a segmented equilibrium, we need to show that at these prices, b-renters are indifferent between owning in the believers neighborhood 1 and renting while they weakly prefer renting than owning in the deniers neighborhood 2. Similarly, d-renters are indifferent between owning in the deniers neighborhood 2 and renting, while they weakly prefer renting than owning in the believers neighborhood 1.

By the definition in equation (2) of indifference prices, at price P_1 in equation (7), b are indifferent between owning and renting and, similarly, at price P_2 in equation (8) d are indifferent between owning and renting.

If an atomistic b-renter deviates and owns in the deniers neighborhood 2, his expected utility is

$$-P_2+\beta^b\left(\varepsilon^b+\phi(0)+P_2\right)=-(1-\beta^b)\frac{\beta^d}{1-\beta^d}\left(\varepsilon^d+\phi(k/2)\right)+\beta^b\varepsilon^b<0, \tag{A.1}$$

where the equality follows from equation (8) and the normalization $\phi(0)=0$, and the inequality follows from Assumption 1. Hence, from (A.1) it is not profitable for d-renters to deviate and own in the deniers neighborhood 2.

If an atomistic d-renter deviates and owns in the believers neighborhood 1, his expected utility is

$$-P_1+\beta^d\left(\varepsilon^d+\phi(0)+P_1\right)=-(1-\beta^d)\frac{\beta^b}{1-\beta^b}\left(\varepsilon^b+\phi(k/2)\right)+\beta^d\varepsilon^d<0, \tag{A.2}$$

where the equality follows from equation (7) and the normalization $\phi(0)=0$, and the inequality follows from Assumption 2. Hence, from (A.2) it is not profitable for b-renters to deviate and own in neighborhood 1. The allocation (9) is feasible and markets clear. ∎

A.2 Proof of Proposition 2

The claim in the proposition immediately follows by using (10) and Assumption 3 in the expression of equilibrium prices (7) and (8). ∎

B. Zillow Home Price Data

This appendix describes the data sets that we use to obtain home prices as well as characteristics of homes. We detail the steps necessary to construct an analytic data set, which we use in the main analysis. We first describe the raw data, and then we discuss the matching procedure.

B.1 Zillow Data

Zillow has provided us with two separate data sets that contain information about U.S. real estate. The database contains information on transaction and price estimates for more than 100 million properties.

Data Set 1 (D1). The first data set, the Zillow Transactions and Assessor Data Set ("ZTRAX"), is a national housing database composed of transaction and assessment records. The transactions data contain information from more than 374 million public records across over 2,750 counties. This encompasses approximately two decades of detailed information from sources such as deed transfers, mortgages, foreclosures, auctions, or property delinquencies. The assessments data contain property characteristics including detailed geographic information, as well as valuations for approximately 200 million parcels in over 3,100 counties. The ZTRAX data set contains approximately 800 variables.

Data Set 2 (D2). The second data set contains proprietary home valuations based on Zillow's Zestimate algorithm. This data set also contains an indicator of whether an individual property is located in an area that is projected to be affected by sea-level inundation of 6 feet above current mean higher high water (MHHW) by 2100, based on publicly available NOAA projections. This indicator uses Zillow's proprietary measure of property locations.

B.2 Data Set Construction

To obtain an analytic data set that can be used for the analysis, we perform a number of tasks that require high-performance computing capability.[31]

We start by extracting information from the assessments tables of D1 for each property that is located in one of 4,335 ZIP codes that will be affected by sea-level rise in 2100. This information includes variables such as geographical coordinates. We extract property characteristics including the number of rooms, number of bathrooms, and lot size. To match D1 and D2, we use fuzzy matching based on a property's address and ZIP code.

Finally, we limit attention only to properties for which we have a transaction price.

B.3 Computing Distance to the Coast

We use the longitude (`PropertyAddressLongitude`) and latitude (`PropertyAddressLatitude`) of a property to determine its shortest distance from the coast. We obtain the coordinates of the U.S. coastline using the Python package `Basemap`.

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