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The Impact of Waterfront Location on Residential Home Values Considering Flood Risks

Authors Norm G. Miller, Jeremy Gabe, and Michael Sklarz

Abstract We confirm existing findings of significant premiums for waterfront proximity, more so for oceans, bays, and large lakes than rivers. We then expand research on housing price trends immediately before and after major storms in directly affected markets. Our findings support a consensus view that single-family home prices rebound quickly to prior macro trends after major storms, with little persistent negative impact on value. In addition, using elevation as a proxy for flood risks associated with sea level rise, we find inconsistent evidence that the market perceives flood risk and discounts property prices accordingly. The absence of a permanent market reaction may change as the market is exposed to increases in insurance premiums or other direct pricing of the risks. Our results suggest either a short-term horizon for buyers of coastal properties at risk, or a moral hazard problem whereby residential owners are dependent upon and subsidized by government and mispriced flood risk insurance premiums.

Keywords Climate change; sea level rise; flood risks; housing prices

With growing certainty over climate change impacts in the absence of coordinated mitigation, we investigate whether housing markets are adapting to these likely impacts. In 2018, the Intergovernmental Panel on Climate Change (IPCC), which collates global research, released a special report on the expected impacts of climate change associated with a global 1.5°C temperature increase above pre-industrial levels, an outcome the panel describes with high confidence as ''likely'' (Masson-Delmotte et al., 2018). Relevant to this study, the report describes ''high confidence'' global impacts, which include sea level rise, increases in mean temperature, and increases in ocean temperature, as well as ''medium confidence'' regional impacts including increased precipitation (storms).

Additionally, the U.S. National Climate Assessment, released in November 2018 (U.S. Global Change Research Program, 2018), projects between $66 and $106 billion in losses directly related to flooding by 2050 and between $238 and $507 billion by 2100. These results will have a direct impact on the economy, with the report predicting a 10% decrease in GDP from climate change by 2100. The assessment suggests that actions being taken by cities, from installing pumps to preserving wetlands, are not expected to be nearly enough to counteract the potential impacts of climate change and that stronger, unprecedented action needs to be taken within the next 12 years.

In the context of increased certainty of sea level rise and disruptive regional weather events such as storms, do housing markets need to adjust for these negative expectations that are associated with proximity to water? In this paper, we examine the impact of water proximity on residential property values in three parts. In the first, we examine general premiums relative to the type of waterfront using a longitudinal and cross-sectional sample of property in markets across the United States, confirming and expanding the empirical evidence of water proximity on housing prices. This confirmation is useful to put the following case studies in context, and our large dataset offers a scale improvement on past market studies of waterfront value. In parts two and three, we focus specifically on known and future flood risk respectively to explore whether house prices reflect suggested negative effects of climate change. A growing literature describes these increased costs, notably damage caused by sea level rise and increased storm surge, directly affecting real estate markets (e.g., McAlpine and Porter, 2018).

Water frontage has a strong positive influence on location value, but with expectations of a global 1.5°C temperature increase, the question arises as to whether the negative influences of sea level rise and storm loss exposure offset the positive amenity value. Real estate markets characterized by long-lasting immobile assets are an excellent laboratory to explore whether markets are adapting to the increased certainty of climate change; prices today reflect long-term expectations of economic and consumption utility. Our findings reveal inconsistent evidence that housing markets are pricing climate change risk. Availability bias is prevalent; in markets hit by recent damage-causing storms, observed price discounts dissipate quickly. One potential reason discussed is whether insurance payouts mitigate the impact on value. We argue that federal flood insurance programs are underpriced and artificially prop up housing markets at higher risk of loss due to climate change. Only in extreme events large enough to displace employment, such as Hurricane Katrina in 2005, do we observe a longer-term depression of housing prices.

Literature Review

Our study contributes to two strands of research. First, it is well known that waterfront locations affect housing prices. We seek to ground our data in this literature and explore at greater scale whether the type of waterfront affects value since climate change is expected to affect ocean coastlines more than other types of waterfront. Second, exposure of housing markets to documented flood risk has been well studied and we use this literature to inform pricing models associated with climate change.

Waterfront Premiums

Real estate adjacent to water is widely known to trade at higher prices than non-adjacent properties, all else equal (Diamond, 1980). Recent studies have added nuance to this common wisdom. Dumm, Sirmans, and Smersh (2016) find that waterfront location premiums in Tampa, Florida persist through housing market slumps, thus the magnitude of such premiums is greatest during a slump. In a methodological critique, Rouwendal, van Marwijk, and Levkovich (2017) argue that waterfront locations correlate with high-quality home features and thus highly controlled experimental conditions are necessary to isolate quality and waterfront premiums if an exact magnitude is desired. They find that a development of identical houses offers a small waterfront premium for a single location in the Netherlands.[1]

Oceanfront, relative to rivers and lakes, has generally been demonstrated as having more impact on residential property value. Another contribution of Dumm, Sirmans, and Smersh (2016) is to reveal that type of waterfront is not equal in regards to consumer preferences; in Tampa, ''bayfront'' properties trade at over a 100% premium while ''lake'' (15%) and ''pond'' (3%) properties have much lower premiums. One reason for waterfront-type premium variance, aside from view and supply constraints, may be that there is dampening of temperature variation from ocean proximity. This makes summers mild and not too hot in locations like San Diego, where Conroy and Milosch (2011) find that the oceanfront premium for proximity is nonlinear in distance from the coast. While it may be quite large for homes that are very close to the coast—possibly increasing the value for homes within 500 feet of the coastline by over 100% (compared to all homes beyond six miles of the coast), and falling to 62.8% for homes between 500 and 1,000 feet of the coast, and so on. Their results suggest that ''the effect declines rapidly... and ultimately becomes negligible beyond six miles from the coast'' (Conroy and Milosch, 2011, p. 215)

Further demonstrating how a waterfront premium is a function of waterfront type, Benson, Hansen, Schwartz, and Smersh (1998) find that views generate an average 25% price premium; however, when views were classified into seven categories, the percentage increase in property value attributable to a view ranged from 8.2% for a poor partial ocean view, 18.1% for a lake view, 29.4% for a good partial ocean view, 30.8% for a superior partial ocean view, and 58.9% for an unobstructed ocean view. Lakefront property, which provides recreational access as well as view amenities, added 126.7% to value. When property was very close to the ocean, premiums also rose. For example, an unobstructed ocean view adds 68.3% to value if the property is located within 0.1 miles of the ocean, but only 44.7% if the property is located a mile away from the water and 30.6% if located two miles from the water. In summary, rivers and lakefronts are not as valuable as ocean fronts. However, there are exceptions for large lakes, such as the Great Lakes, which behave more like oceans with regard to temperature modulation, views, and recreational opportunities. Unobstructed views are more valuable and waterfront premiums decline exponentially, not linearly, as one travels away from the coast.

Known Flood Risks and Housing Markets

While climate change is expected to have effects on real estate markets beyond flooding and coastal storm surges, these two effects dominate the real estate literature in this area. One reason is that these effects are relatively certain to occur, albeit at a slow and uncertain pace. Another reason may be that it is expensive to manage the risk associated with sea level rise, floods, and storm damage; relocation is the most practical risk management strategy. On the other hand, landowners facing increased wildfire risks can clear fire-prone bush and specify fireproof building materials to manage these risks. Market pricing of the risk of damage associated with sea level rise and storm surge should thus be better reflected in real estate pricing, inverse to the cost of insuring against this risk.

A useful starting point is the literature on house prices associated with existing flood risks. Beltran, Maddison, and Elliott (2018) collate real estate studies on known flood plain risks, concluding there is a 4.6% discount on average for housing located in an officially designated flood plain. In regards to variance from that average, the authors study recent flooding events and describe a range of behavioral heuristics, including information asymmetry, perceptions of flood protection measures, and availability of experiences with flooding, that affect housing markets in flood prone areas. Bélanger, Bourdeau-Brien, and Dumestre (2018) show that discounts of around 4% for at-risk homes also exist in Canada, where flood insurance is essentially unavailable, suggesting that buyer awareness of risk, not capitalization of insurance costs, drives these flood-risk pricing discounts.

Recent work on known flood risk pricing expands the scope of market effects. Turnbull, Zahirovic-Herbert, and Mothorpe (2013) argue that liquidity is also affected by known flood risk; at-risk properties are likely to spend more time on the market. Atreya and Czajkowski (2019) find a spatial component to pricing discounts. Buyers are more willing to accept flood risk in neighborhoods nearest to coastlines, often paying a premium for at-risk properties, which suggests that demand for coastal amenities offset flood risk. Discounts are highest for at-risk properties located far from coasts, which are presumed to have less amenity benefit to offset the known risk.

Another research question is whether homeowners are aware of locations with a high risk of flooding. For example, much of the Sacramento-San Joaquin Delta of California is below sea level, but the area is not considered a floodplain because of an engineered levee system designed to withstand a 100-year flood. As a result, residents are not informed that they are at risk from floods or purchasing a home in a floodplain.[2] Ludy and Kondolf (2012) study this region and conclude that most residents did not understand the risks of being flooded. Another interpretation of their survey is that households rely on the government to restrict development in locations and that the government is a trustworthy source of information on flood risks. Additional research on risk awareness by Pilla, Gharbia, and Lyons (2018) in Ireland finds that past experience of flood events is more important than scientific assessments in determining whether a household is aware of flood risks.

Widely publicized storm events have pricing effects on markets, although most studies on housing prices suggest that pricing effects are short-lived. Murphy and Strobl (2010) examine home prices before and after several major hurricanes over the prior few decades and conclude that there were minor dips in real home prices for a few years after the events, followed by recovery with some minor residual effects when local economic bases were negatively affected. Home prices often increase more than they decrease a few years after the hurricanes. Ortega and Taspinar (2018) provide a case study of Hurricane Sandy, finding that increased media and social attention on a large event has lasting effects on housing prices. Bin and Landry (2012) study Pitt County, North Carolina. Prior to Hurricane Fran in 1996, they detect no market risk premium for a home being in a flood zone, but find significant price differentials after major flooding events, amounting to a 5.7% decrease after Hurricane Fran and an 8.8% decrease after Hurricane Floyd, but this negative effect on the premium diminished over time, essentially disappearing about five or six years after each event. They conclude the lack of a persistent effect suggests that buyers' and sellers' risk perceptions may change with the prevalence of hazard events and that homebuyers seem unaware of flood risks and insurance requirements.

Perceived risk after a major storm event is more important than whether a subject property was damaged in the event. Ortega and Taspinar (2018) find pricing discounts associated with houses that were not damaged during Hurricane Sandy but are now perceived to be at high risk of coastal flooding. The reductions in value could, as the authors note, alternatively have been caused by increases in flood insurance premiums. Insurance premiums, in effect, communicate flood risks to the market if correctly priced. However, it is often the case that households in locations at risk of flooding do not purchase flood insurance. Only 17% of homeowners in the eight counties most directly affected by another major storm, Hurricane Harvey in 2017, had flood insurance, according to Federal Emergency Management Agency (FEMA) data.[3] While homeowners with a mortgage are required to purchase separate flood insurance policies, the cost of the insurance may be prohibitive for low-income families.

House prices may rebound quickly after a major flood or storm, but the economic fortunes of those affected remain depressed. Bleemer and Van der Klaauw (2017) also study the 2005 Hurricane Katrina event and conclude that households affected by flooding are on average poorer, with higher rates of insolvency and less home ownership, ten years after the hurricane.

In summary, there is a reasonable consensus in the literature that designated flood risks are captured in market pricing, but strongly subject to an availability heuristic: prices dip when memories of an event are fresh or reconstruction is evident, but fade over time. Persistent house price discounts for flood risks appear most likely to exist where storms alter the economic base of an area or in response to insurance costs, although there appears to be little enforcement of federal flood insurance mandates and many households choose to face the risks uninsured.

Sea Level Rise Risk and Housing Markets

The question we address is whether households price the future risk of climate change, notably sea level rise and the expansion of coastal areas at risk of flooding and storm damage. There are no published maps or official government guidance to inform consumers of sea level change, but increased attention to climate change adaptation has seen interest in this question. Given the relative certainty of future long-term sea level rise in the scientific consensus (Masson-Delmotte et al., 2018), knowing whether markets are pricing these risks is an important research question to inform governments as to whether intervention is needed to better inform housing markets and other long-term investors.

Fuerst and Warren-Myers (2019) study a coastal suburban municipality adjacent to central Melbourne, Australia. They first replicate research on officially designated flood plain locations and prices, finding a consistently negative 2%–8% discount (though never statistically distinct from zero at the 90% confidence interval). In additional pricing models, they use elevation data to map a larger area at risk if sea level rise is 1.0 meter or 2.7 meters, finding no effect on prices in these expanded at-risk areas. Their early results suggest that consumers in this municipality are not discounting beyond officially designated flood risk areas.

Bernstein, Gustafson, and Lewis (2019) conduct the most exhaustive study to date on the potential effects of sea level rise, mapping sea level rise risks along the entire coast of the U.S. They conclude low-lying properties trade at a discount of approximately 7% compared to similar but less exposed properties located an equal distance from the coast. They further break affected properties into exposure buckets, with properties that will experience ocean encroachment after one foot (30 cm) of global average sea level rise trading at a 22% discount, two to three feet (60–90 cm) at a 17% discount, four to five feet (90 cm–1.5 m) at a 9% discount, and six feet (1.8 m) at a 6% discount. They find no rental pricing discounts, which makes sense given the shorter-term horizon and lower wealth exposure of renters. A potential limitation of this study is a pricing model relying on relatively few building attributes (number of bedrooms, square footage, and age of the building) with no additional measures of quality. We seek to improve on this approach using a physical condition measure, in addition to the typical physical attributes associated with pricing models.

Data

We start with a large database of waterfront properties to analyze the general empirical impact of waterfront location on value. We start with approximately 1.2 million waterfront house sales in the U.S. that are adjacent to waterfronts, as identified by geographic information systems (GIS) and selected from the database of Collateral Analytics.[4] We combine this identification of waterfront transactions with approximately 6.5 million non-waterfront transactions in the same ZIP Codes to estimate the net waterfront effects on value. We say ‘‘net’’ effect because there could be negative influences from flood risk perceptions and positive influences from proximity to water at the same time. The actual national sample of observations used in our models, after filtering for incomplete descriptive records, is 3,459,180.

This first step is important because the literature suggests that waterfront premiums in housing are highly contextual, depending on the amenity value of the water as well as supply elasticity within the market. Besides creating a comparison for our later research on flood and sea level rise risk, our purpose in estimating waterfront premiums in Part 1 is to confirm the general relationships present in the literature. Our longitudinal investigation in Part 2 and Part 3 examines whether significant storm events or expanded sea level rise impact flood-risk perceptions and lead to deviations from market trends.

Part 1: Waterfront Premium Benchmarks

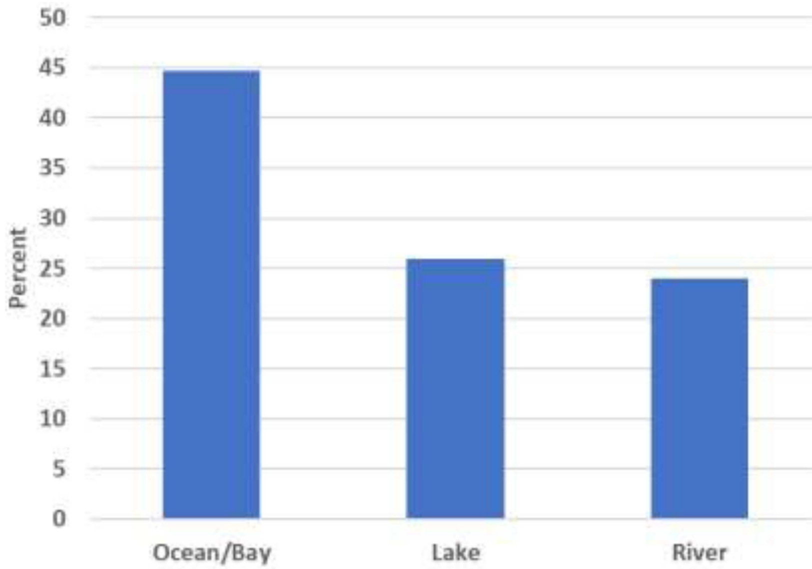
While waterfront and unspoiled views are undoubtedly a cherished attribute priced in the housing market, not all water is the same. For example, one of the attributes that makes waterfront valuable is the view. However, each parcel will have a different view and the quality of this view will vary even in close proximity to the water. Other examples where the utility of waterfront and its impact on value vary could be water depth (for recreational opportunities), water quality and purity, sound quality (such as the sound of breaking waves or the beating of pelican wings), the type of and color of water (lake, ocean, river, stream), fishing quality and access, and even the temperature of the water or air, as air temperature is stabilized by proximity to water.

Here we estimate the net effect of being on a waterfront lot for property sales since the year 2000. By including nearly 18 years of sales, and adjusting the sales to 2018 via a localized home price index, we are able to broaden the sample. This large sample size of nearly 3.5 million observations offers a unique perspective on waterfront premiums, as few studies have such large datasets and use scale to offset inefficient statistical estimations caused by factors such as housing quality endogenous to waterfront locations (Rouwendal, van Marwijk, and Levkovich, 2017). These waterfront properties sort into three types: ocean/bayfront,[5] lakefront, and riverfront, following similar classification techniques by Dumm, Sirmans, and Smersh (2016).

We use a standard hedonic housing model to control for the influences of physical attributes, including size, age, property condition, and a number of features such as bedrooms, baths, fireplaces, the time of the sale, and the general location. A binary variable equal to 1 is associated with transactions adjacent to a waterfront based on the waterfront classification above. These three variables are our variable of interest. We run hundreds of estimates—one model for each state and each ZIP Code—and summarize the results since the purpose is a foundation for flood and climate risk assessment.

In Exhibit 1, we show the overall average waterfront premiums in the U.S. that result from our hedonic models. Oceanfront properties exhibit the highest premiums, nearly 45% over homes within the same ZIP Code but are off-water, while lakefront homes have premiums of just over 25% and riverfront homes 24%. While different in magnitude due to the nationwide scope, the relative difference between oceans and lakes/rivers is similar to that reported for Tampa by Dumm, Sirmans, and Smersh (2016), who find (ocean) bayfront premiums of 107% and riverfront premiums of 61%.[6] In Exhibit 2, we show the same descriptive results

Exhibit 1 | Waterfront Residential Premiums by Type of Waterfront

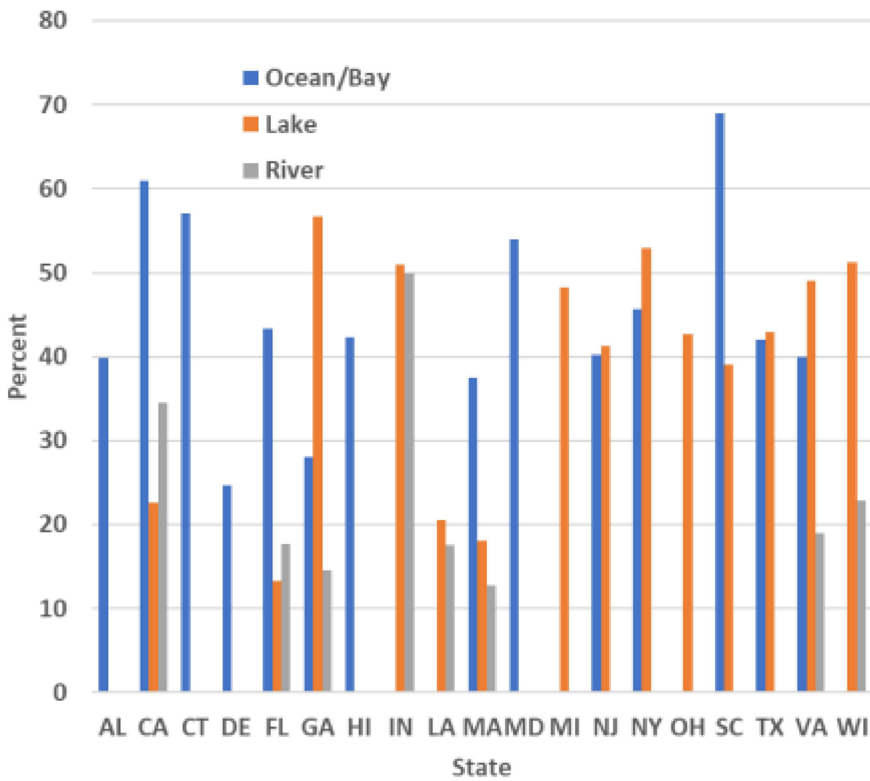


of average waterfront premiums by state; notable here is the geographical diversity of premiums for lake and riverfronts, again consistent with the literature.

Exhibits 3, 4, and 5 present residential single-family property transaction prices per square foot of living area for three different waterfront ZIP Codes over time since 2005. These markets were chosen due to a high volume of sales for the longitudinal period of 2005–2017, which is important to mitigate the correlation between waterfront and housing quality. Exhibit 3 shows Newport Beach, California, where oceanfront property trades at about a 40% premium as of 2016. Exhibit 4 shows Canyon Lake, California, with a lakefront premium of about 22% as of 2017, and Exhibit 5 shows Stockton, California, with a riverfront premium that has been declining for several years. Stockton is subject to flooding from the nearby San Joaquin River, which has been subject to increasing floods over the last decade.[7] These single markets demonstrate how market cycles and relative premiums can vary over time. The obvious point is that relative premiums do vary over time, and we should exercise caution when it comes to sweeping generalizations about water proximity and value. It also appears that perceptions and relative value of water proximity might change over time in those areas perceived to be in greater jeopardy of flood risk. This might be what we are observing in Stockton. The pricing gap from the waterfront to the non-waterfront areas has been shrinking but is still slightly positive.

In summary, waterfront or near waterfront properties continue to demand significant price premiums, even with the more nascent concerns over flood risks. These premiums on average are highest for oceanfront properties, followed by properties that front lakes and rivers. It is true that the homes near water tend to

Exhibit 2 | Waterfront Residential Premiums by Type of Waterfront by State



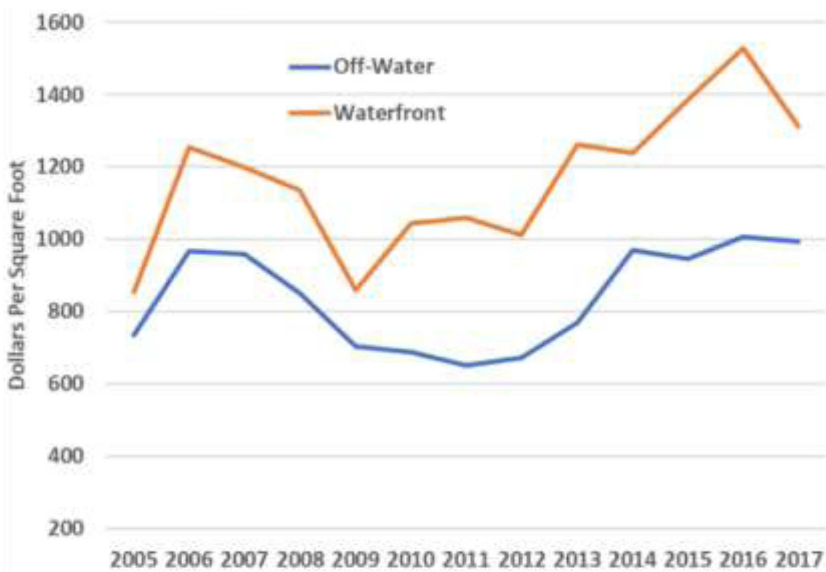
be higher quality, but teasing out the exact waterfront effect is not as interesting as documenting the longitudinal trend where quality and waterfront location can be assumed to be constant over time, leaving it to further research to investigate whether quality is responsible. For example, if quality is causing the tightening of the riverfront premium in Stockton, future research could investigate whether assets away from the water are disproportionally increasing in quality.

Part 2: Storm Pricing Effects

Literature resulting from Hurricane Fran in 1996 (Bin and Landry, 2012) and Hurricane Sandy in 2012 (Ortega and Taspinar, 2018) provides evidence that house prices react to major destructive events, but only for short periods of time. This suggests that the mechanism driving house price adjustments is an availability heuristic; once social and media attention wanes, past macro-trends in house prices resume. With our longitudinal data, we seek to explore waterfront premiums from two more recent events: Hurricane Harvey in 2017 and Hurricane Irma in 2017.

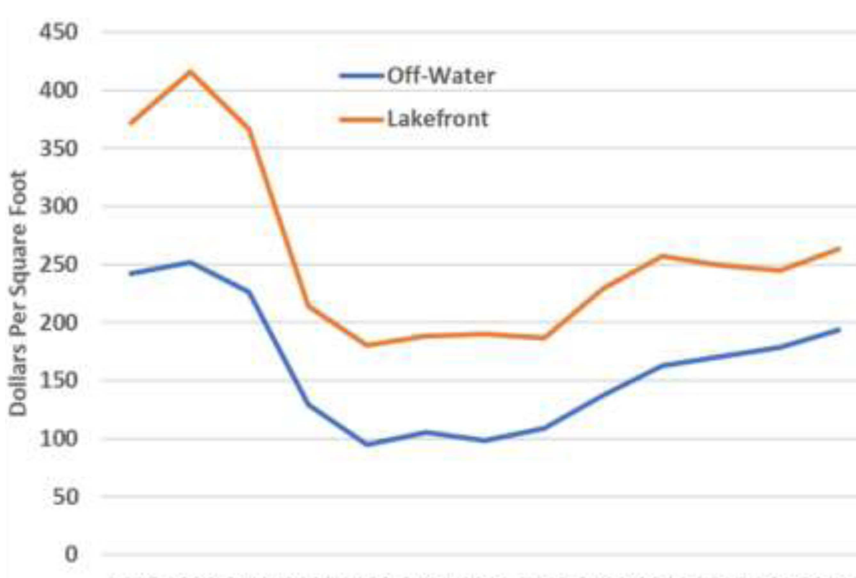
Category 4 Hurricane Harvey hit Texas on August 25, 2017 and affected Rockport, Texas directly, as well as the major metropolitan area of Houston. Harvey caused

Exhibit 3 | Sample Oceanfront Historical Premium



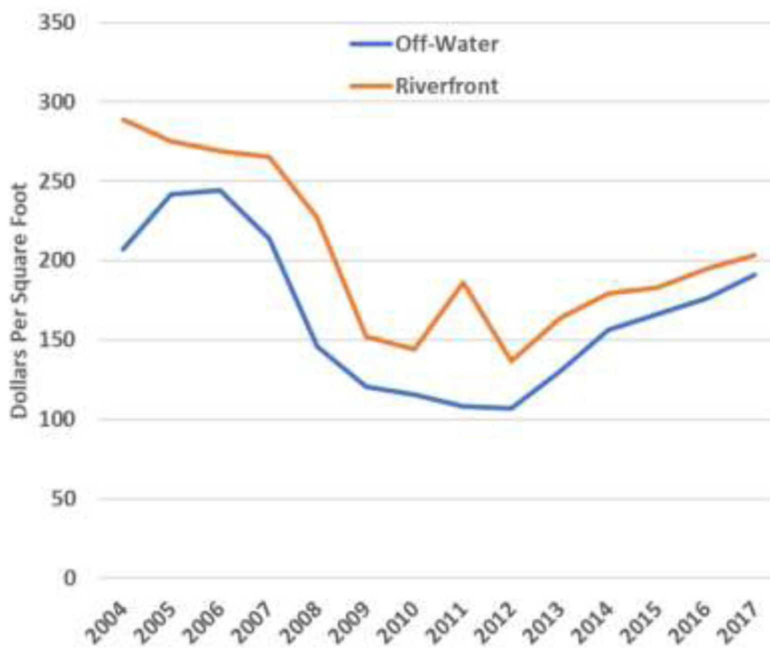
Note: Newport Beach, California ZIP Code 92663 single-family sold price per living area for oceanfront and off-water sales.

Exhibit 4 | Sample Lakefront Historical Premium



Note: Canyon Lake, California ZIP Code 95287 single-family sold price per living area for lakefront and off-water sales.

Exhibit 5 | Sample Riverfront Historical Premium



Note: Stockton, California ZIP Code 95219 single-family sold price per living area for riverfront and off-water sales.

$125 billion in property damage in Texas according to the National Hurricane Center. Significant federal relief, also in the range of $125 billion, was provided soon after the storm.

Hurricane Irma hit Florida a week later on August 30, 2017, costing some $70 billion in property damage, along with significant dampening of tourist visits for the following few months, although tourist demand was back to normal one year later. Among those markets hit hardest was tourism-dependent Key West, where there was no place to escape, aside from leaving the island entirely.

After Hurricane Harvey, we see the volume of sales in the ZIP Codes representing the hardest hit area (Rockport) drop to nearly zero in September, perhaps with some sales delayed. This is typical after a major natural disaster. The few transactions that do occur do so within the context of a lessened supply, as many residents sought temporary shelter. As seen in Exhibit 6, single-family sales volume in Rockport after Harvey remained below normal for several months. Exhibit 7 shows that prices dipped more than seasonally normal in early 2018, both on a sales price basis and on a price per square foot basis. While prices remain a little lower than before Harvey, they have rebounded, perhaps influenced by insurance rebuilding and funds brought into the market. There appears to be little permanent impact.

Exhibit 6 | Rockport, TX Sales Volume Over Time

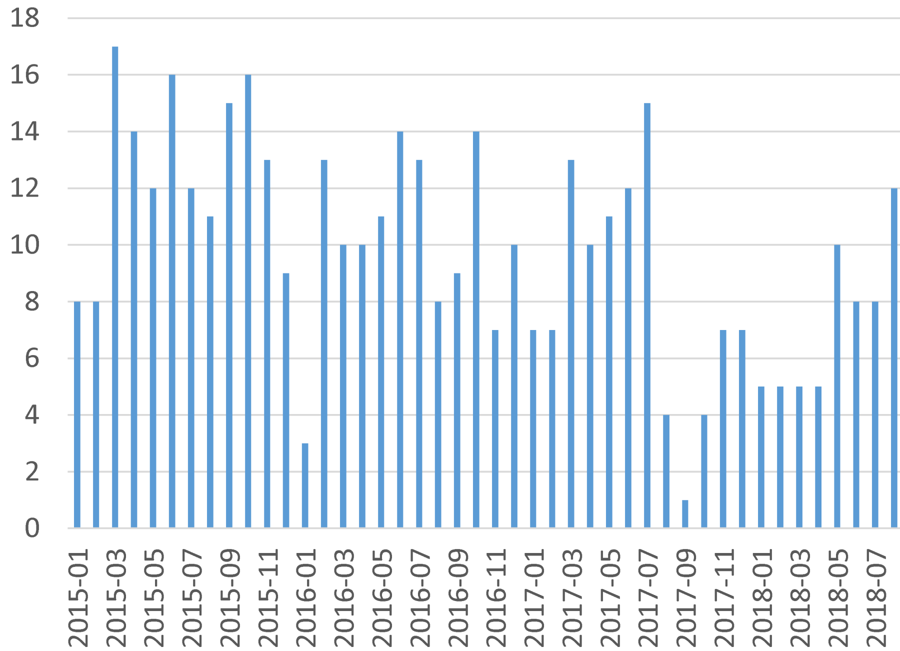


Exhibit 7 | Rockport, TX Sales Prices and Sales Price Per Square Foot Over Time

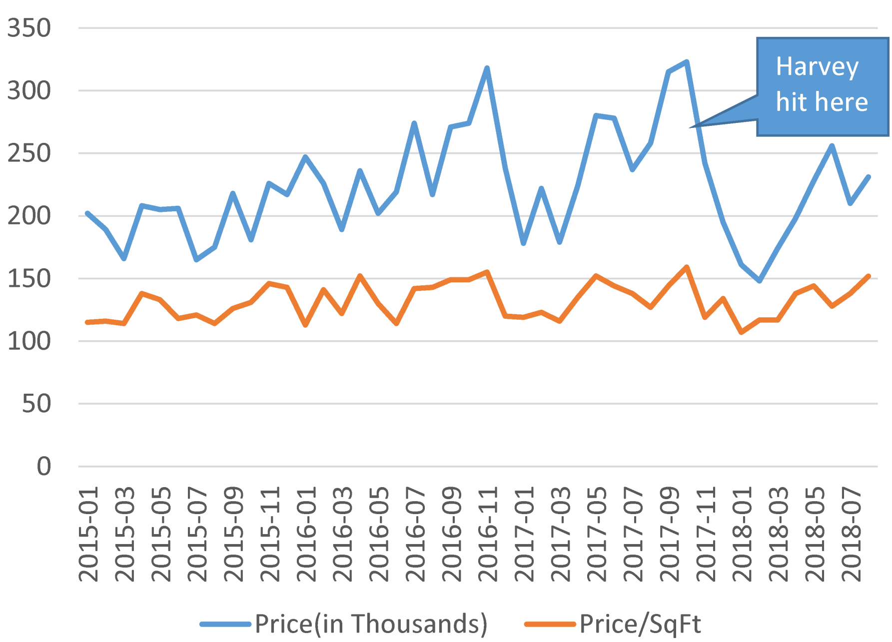
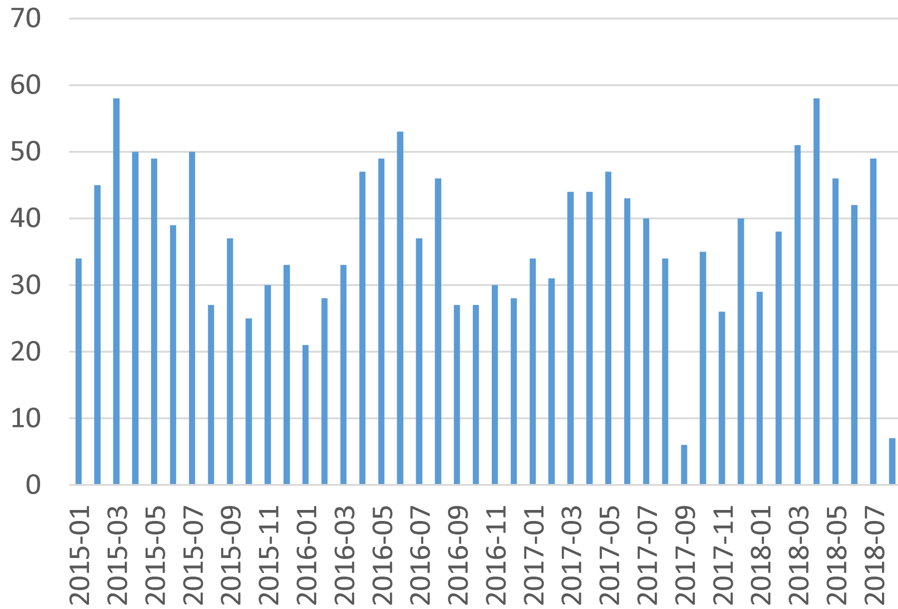


Exhibit 8 | Key West, FL Sales Volume Over Time



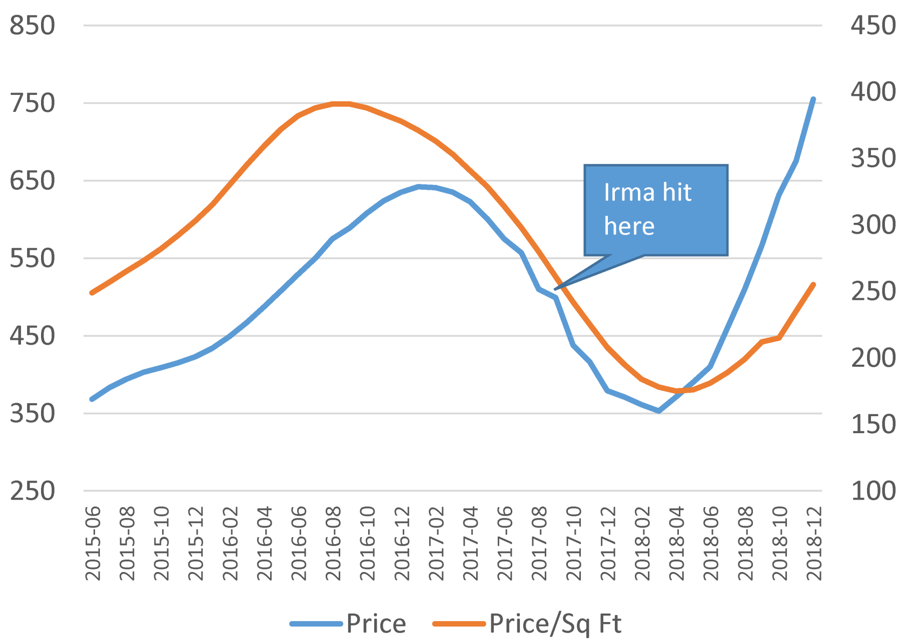
After Hurricane Irma, sales in the ZIP Codes representing Key West also saw few single-family home sales in September 2017, as shown in Exhibit 8; however, sales volume returned to nearly normal fairly quickly. Interestingly, it is difficult to see any effect on prices, which were already in decline (Exhibit 9) as part of a larger macro-cycle.

These Rockport and Key West comparisons are not markets deep enough to efficiently separate variations in the quality and features included in the mix of sales, so the above conclusions in regard to magnitude are limited. It does appear, though, that little permanent fears or price effects remain in these two markets directly impacted by major storms. Other markets that were examined include the coastal ZIP Codes of Marco Island, Naples, and Jacksonville, Florida, all areas hit hard by Irma according to news reports, but almost no market reaction can be detected there either aside from a very temporary dip.

Investors reaped the benefits of short-term distress from Hurricane Harvey, and possibly many other such storms, perhaps because these investors know how the system of federal support and insurance works. What these investors may also know is the cost to repair homes and how fast a well insured or protected market will rebound.

A deeper look into the role that insurance plays in house price recoveries is available from the "costliest" hurricane in U.S. history—Hurricane Katrina in 2005—which affected an area where many of the residents live at or below sea level (New Orleans). Exhibit 10 presents prices and employment in New Orleans from 1990 through 2018. Hurricane Katrina made landfall on August 29, 2005.

Exhibit 9 | Key West Sales Prices and Sales Price Per Square Foot Over Time



Note: Price in thousands and per square foot (right scale).

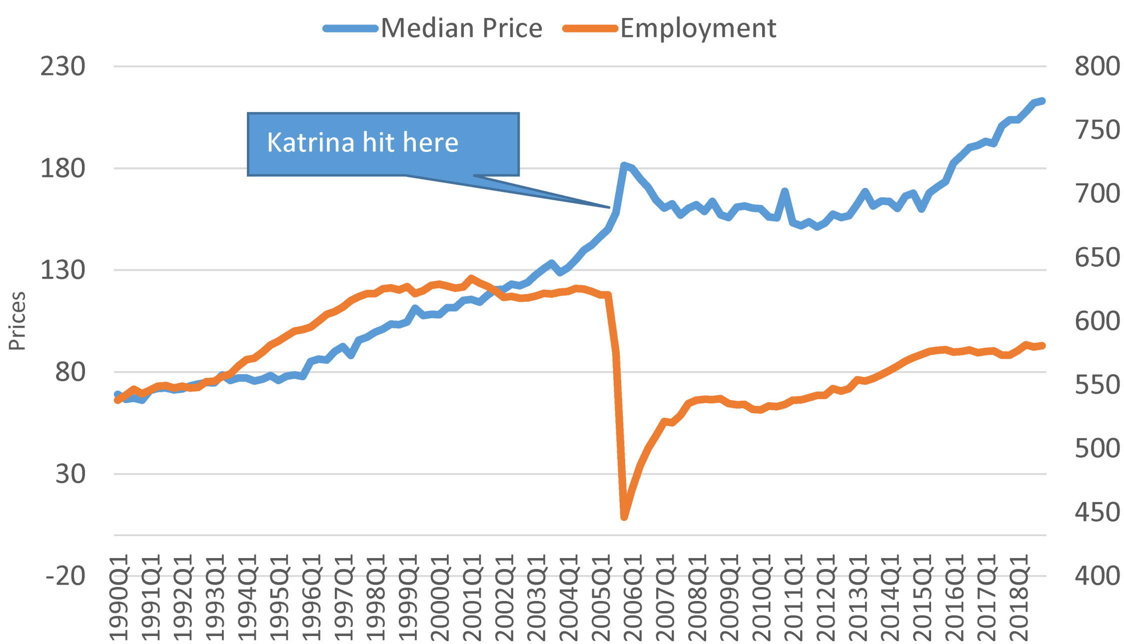
Private insurance companies paid out an estimated $41 billion in claims (in 2005 dollars), mostly in Louisiana, with an additional $16.1 billion paid out from the National Flood Insurance Program (Hartwig and Wilkinson, 2010). Over a quarter of a million residents were displaced and many could not return to their jobs for months. Employment losses seem to be an important reason for the slow recovery in home prices after 2006. Still, home prices did rebound about a decade later.

New Orleans has several coastal markets that are located below sea level, but prices do not seem to reflect the risk of repeated flooding. Notably, Hurricane Harvey also resulted in widespread flooding in New Orleans in 2017, but that event is not even visible in the pricing or employment trends in Exhibit 10.

Part 3: Sea Level Rise Effects

With existing trends in the literature confirmed in our data, are housing consumers considering climate change risks? Sea level rise and storm surges are expected to have the greatest impact on oceanfront properties, but the difference is most important for marginal properties that would not have been at risk except for an expected rise in sea level. Properties outside known flood-risk areas are not required to purchase flood insurance from the federal government. Bernstein, Gustafson, and Lewis (2019) suggest that U.S. home buyers price increased risks as a result of sea level rise, but further investigation is warranted for two reasons.

Exhibit 10 | New Orleans Home Prices from 1990 Through 2018



First, as pointed out earlier, their model omits direct measures of housing quality, relying on distance from the coast to proxy ‘‘equivalence’’ of quality, coastal amenities, and other unobserved housing characteristics. Second, their suggested magnitudes of pricing discounts, averaging 7%, is high compared to the general consensus that *known* flood risks attract a 4% discount; this suggests their variable of interest is instrumenting for effects beyond sea level rise risk.

As argued by Rouwendal, van Marwijk, and Levkovich (2017), the primary challenge for any pricing model associated with waterfront amenities is to remove unobserved selection or sorting by type of owners, property quality, or neighborhood quality that is correlated with location. For example, consider two buildings next to each other (same view and location qualities) in the same neighborhood on the waterfront. One building is 15 feet above current sea levels and the other is only one foot above sea level. The original buildings were constructed and sold in the 1970s in the same year and are otherwise identical. The building on the 15-foot above sea level lot has had interior renovations multiple times and the building on the one-foot lot has never been updated to current standards because of a fear of flooding. As a result, the building on the one-foot lot is much lower in quality. When this lower quality property sells, the econometrician will find a large discount for the one-foot elevation building. This ‘‘flooding discount’’ will reflect the role of the elevation (flooding risk) and the unobserved building quality deterioration. As a result, the capitalization of the flooding risk will be overestimated, as we suggest may have occurred in Bernstein, Gustafson, and Lewis’ (2019) study. Therefore, any estimate of waterfront premiums must control for the quality of the building, the attributes of the building, and the attributes of the location.

In three case study markets, we attempt to disentangle the discount associated with being at risk of flooding and sea level rises from the positive amenity of owning a waterfront lot in a large housing market. The data here includes three metro areas. First, we investigate 10,720 residential single-family home observations in ZIP Codes touching waterfront from the San Francisco metro area, where data on elevation and nearness to water are available, along with the variables required to control for other influences on value. Additional models investigate San Diego, with 91,166 observations, and Chicago, with 90,157. With a location on Lake Michigan, Chicago serves as a useful control market that is at risk of flooding, but not as a result of sea level rise. Each metro area is run as a separate model independent of observations in the other two.

All ZIP Codes touching waterfront locations are included in the samples for each metro area. These sales occurred from January 2012 through the end of third quarter 2017, with quarterly time dummies used to control for time fixed effects in each market. Waterfront is defined as properties touching the average high-tide water line. These markets were chosen based on availability of elevation data above high-tide water lines to the nearest meter. Approximately 20% of the waterfront sample lies at one meter or less of elevation, 20% is located between one and two meters, and 60% is above two meters.

Exhibit 11 | Table of Mixed Effect Panel Regression Results for Single-Family Home Sale Prices

	Waterfront Touching	Elevation 1 meter	Elevation 2 meters	Elevation 3 meters	Adj. R^2	*F*-Value	*N*
Chicago	31.98%***	5.38%	5.35%	5.69%	0.669	11.56	90,157
San Diego	35.33%***	11.66%*	13.53%	26.57%	0.655	13.78	91,166
San Fran.	8.65%***	−4.86%*	−13.97%*	4.30%	0.718	14.11	10,720

Notes: Each metro area is run as a separate regression. Not reported are control variables for fixed time dummies and control variables as described in the text.
*Significant at the 10% level.
***Significant at the 1% level.

Our model uses a mixed effects specification for each city, with random effects for each ZIP Code and fixed effects for time:

$$ln\ p = \alpha + \lambda t + ln(\beta_n X_n + \beta W + \beta E_1 + \beta E_2 + \beta E_3) + \varepsilon_{b,w}.$$

Here, p is the selling price, α is an intercept term, which includes a random effect based on the ZIP Code of observation, and λt are fixed time effects. The exogenous control variables (X_n) include living area, lot size, swimming pool, bedrooms, baths, age, age squared, garage units, and property condition. Waterfront location, W, is a binary variable equal to 1 for each parcel touching the high-tide mark. Three variables then predict pricing effects as a function of elevation above the high-tide line: E_1, E_2, and E_3 represent a parcel featuring land measured at an elevation of less than 1 meter, 1–2 meters, and 2–3 meters above the high-water line respectively. The error term ($\varepsilon_{b,w}$) contains residual errors between and within each ZIP Code random effect. All control variables are significant at the 10% level or better.

Key estimation results for these three models are shown in Exhibit 11. The waterfront premiums shown are only for single-family property touching the high-tide mark. The control sample includes all properties within the same ZIP Code, but not touching the waterfront. The elevation premiums are estimated independent of the waterfront premium, although additional specifications interacting elevation and waterfront were also investigated. Large samples allow us to rely on the models to dissociate quality and waterfront effects.

Two of our three case study markets reveal pricing in line with awareness of flood risks.[8] Chicago, the control market, is indifferent to elevation changes, which makes sense given that sea level rise is not a concern. In San Francisco, where the risks are ocean-based and subject to sea level rise risk, we do find a discount associated with low elevations near the waterfront compared to higher elevation property on a similarly large scale as observed by Bernstein, Gustafson, and Lewis

(2019). However, the discount does not appear to be consistently associated with flood risk as the highest discounts are not seen at the lowest (1 meter) elevations.

In San Diego, no flood risk discounts are observed, even at the lowest levels where high tides already flood the waterfront homes a few times a year. Instead, there are flood risk premiums; at-risk low elevation households pay more to live below one meter. The rest of the regression coefficients on elevation are not statistically different from zero. Further testing of alternate specifications not shown here reveal that relative elevation-price relationships do not materially change if interacted with the waterfront variable or tested alone in the absence of the waterfront variable.

Comparing the flood risk discounts observed in San Francisco and the flood risk premiums in San Diego suggests there may be important local market nuances on the value that waterfront location provides in regards to occupant amenity. Further study could investigate whether this difference is systematically related to the value that waterfront location provides in each metro area. For example, the relatively cold ocean temperature in San Francisco means waterfront amenities are likely valued for views rather than for recreation (direct access), meaning higher elevation properties (better views) could be in higher demand.

With the availability heuristic prominent in the flood-risk literature, our results could reflect a historical lack of recent storminess on the west coast of the U.S. During our sample period, the only major floods to affect California were at the end of the period in early 2017; the rest of the sample was a drought period. However, San Diego experiences modest floods during high tides every year, so many waterfront homes are subject to flooding during these periods, yet residents are willing to pay higher premiums for occasional flood incursions even when the waterfront amenity value and quality value are controlled in a large sample.

It is entirely possible that sea level rise risks from higher hurricane storm surges are reflected in Florida markets not studied here, although our storm case study results do not support that conclusion when examined a year or so after a major storm event, nor is there supportive evidence in the study by Murphy and Strobl (2010), who focus on hurricanes. On the west coast of the U.S., no systematic elevation discount fear is apparent; instead it varies from market-to-market.

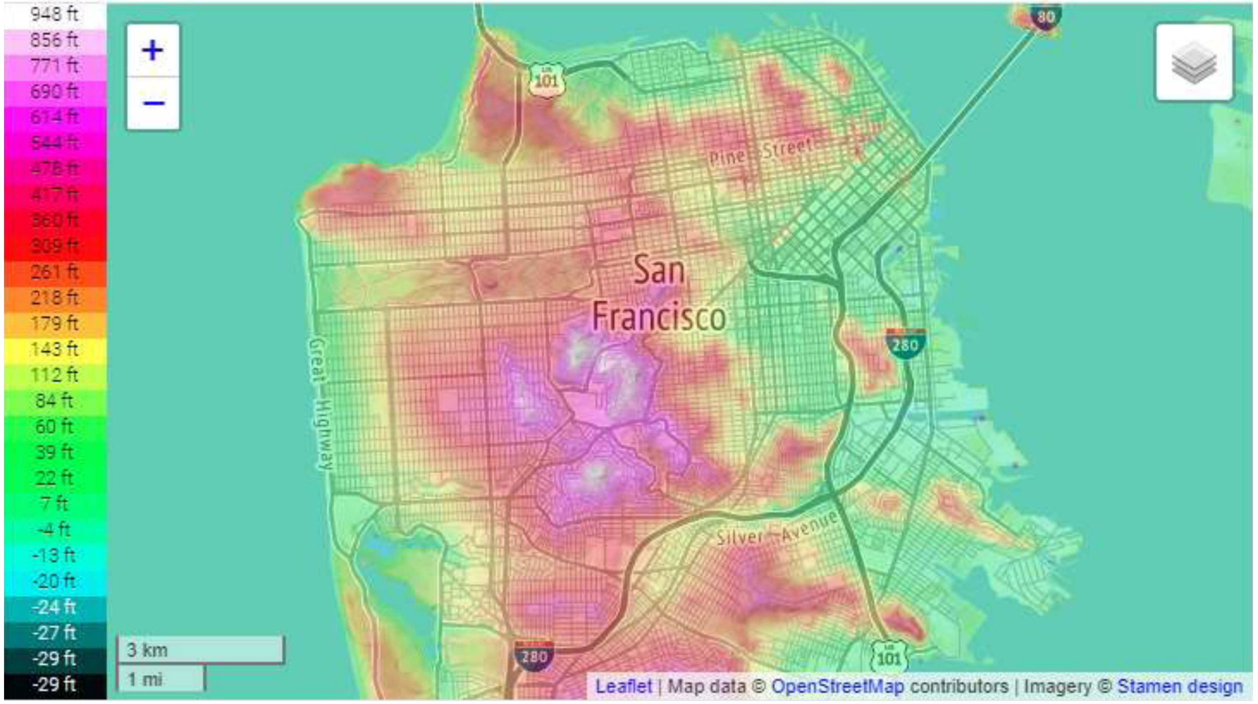
Exhibit 12 shows elevation data for the continental U.S., Mexico, Southern Canada, and part of the Caribbean and Central America. Most of the flood-prone zones are in Florida and the Southeast regions of Texas and Louisiana. The west coast of the U.S. has some low-lying inland areas just east and south of San Francisco, as well as some along the coast of Southern California. This map is not intended as showing detail for potential flood areas, but simply to note, via lighter colors, that most of these are on the east coast, Florida, and with some along every coast. Exhibit 13 shows a more detailed map of elevation data for San Francisco. Here, the green areas are at high risk of flooding from storms and high tides. These should be the areas where flood risk discounts will appear in our model, and indeed we do observe some minor, but inconsistent, pricing associated with elevation in San Francisco.

Exhibit 12 | Elevation Data for the U.S., Mexico, the Caribbean, and Southern Canada

Another consideration for the lack of a systematic price effect from known and expected flood risks is a moral hazard argument that federal insurance premiums subsidize high risk development. Baylis and Boomhower (2019) suggest this may be the case for wildfire risks. They conclude that a substantial portion of the total social costs of wildfires comes, historically, from federal firefighting efforts that prevent or reduce loss. This taxpayer-supported cost, in turn, results in higher property values for those properties most at risk relative to their values if the high-risk properties had to support the full costs of protection. We see the same type of moral hazard for owners of coastal properties at risk of flooding. Not only are the flood maps out of date in relation to current research on sea level rise, but the government through FEMA and NFIP has historically subsidized owners within flood zones, whether designated as such or not (Congressional Budget Office, 2017). This subsidy props up housing markets in flood zones and we expect that sea level rise risks will price into single-family residential markets when private and public insurance premiums increase to more accurately reflect the private risks of locating in at-risk areas. There exists a significant moral hazard from such subsidies that has resulted in minor if any capitalization of flood risks into property values.

A final theory for the lack of a significant price effect from known flood risks, such as in Florida from hurricanes, is that the more typical buyers of coastal single-family homes are older and wealthy enough not to care. That is, for those

Exhibit 13 | Elevations in San Francisco



whom waterfront property is purchased as a retirement residence, their risk horizon is short term; these residents will not care about sea levels in 2050 or 2100. While we do not have data on the age of buyers in our dataset, a spot check of some demographics does confirm the significantly higher average age for buyers along the east coast of Florida.[9]

Conclusions

The market should, in theory, recognize and discount property value in line with flood risks along the coasts. Regression results from our San Francisco case study (Exhibit 11) reveal possible but inconsistent evidence of price discounts for single-family homes in high-risk, low elevation locations not subject to recent storms that could indicate the pricing of sea level rise risk. On the other hand, San Diego home buyers continue to pay significant low elevation price premiums for homes most at risk of sea level rise that already experience regular tidal flooding.

In Florida and Texas markets recently hit by major storm events, price discounts dissipate quickly and either the new wave of buyers ignores or forgets the risks, or alternatively insurance proceeds mitigate the value impact. When employment displacement lingers, home prices are also slower to recover, as was shown in the case of New Orleans after Katrina in 2005.

In regards to why we observe high variance in pricing of sea level-rise risk, further research can follow up on three hypotheses developed from our case studies. First, the amenity values of waterfront location are an aggregated mix of view and access amenities. In markets where views are the dominant amenity value, such as San Francisco, prices increase with elevation and thus indirectly account for sea level-rise risk while waterfront access markets, such as San Diego, may be willing to trade off sea level rise risk with higher amenity values. Second, recent data from the Congressional Budget Office (2017) combined with our storm-event pricing data suggest that high federal debt resulting from insurance payouts after major storms provides a large subsidy to development in these regions and thus creates a moral hazard. Third, we also suggest that buyer profiles may be important to the pricing of long-term sea-level rise risk. Markets driven by wealthy, older-aged buyers may not price this risk due to the short-term nature of these buyer's consumption demand.

This analysis is important, not just to become better at valuing residential properties within waterfront proximity, but also because the massive amount of infrastructure construction necessary to mitigate billions of dollars of property damage and economic disruptions requires a better understanding of what is at risk. While there is no question about the potential for catastrophic property damage and the possibility of mass population relocation required with sea level rise and more frequent major storms, we cannot yet verify that insurance policies or society is pricing these risks.

Endnotes

[1] This study is of a single development near a Dutch lake and canal system. In the context of Dumm, Sirmans, and Smersh (2016), who attempt to disaggregate different types of waterfront (lake, ocean, river, etc.), small lakes have low premiums. And the only prior study on waterfront housing prices in the Netherlands (Luttik 2000) shows similarly low premiums. Rouwendal, van Marwijk, and Levkovich (2017) state that ''The Netherlands is also known as the lowlands and water—a canal, a river, a pond or a lake—is often not far away,'' so this study is not terribly representative of a market where waterfront land is supply limited. Thus, it is not surprising to find that waterfront premiums in the Netherlands can be difficult to distinguish from quality premiums.

[2] The National Flood Insurance Program (NFIP) requires owners of property with mortgages within the 100-year flood zones (1% chance of flooding) to purchase federal flood insurance. The federal protection against flood risks assists flooded owners in rebuilding homes that have sometimes been flooded before. The cost of the flood insurance is clearly below any market determined rates as evidenced by the increasing losses at the NFIP, which is now about $25 billion in debt (Congressional Budget Office, 2017).

[3] FEMA data on federal flood insurance coverage is collated by the Insurance Information Institute and is available at https://www.iii.org/fact-statistic/facts-statistics-flood-insurance. Viewed December 1, 2019.

[4] Our data on waterfront properties are limited to the following states: Alabama, California, Connecticut, Delaware, Florida, Georgia, Hawaii, Indiana, Louisiana, Massachusetts, Maryland, Michigan, New Jersey, New York, Ohio, South Carolina, Texas, Virginia, and Wisconsin.

[5] We also ran models with ''oceanfront'' separated from ''bayfront'' but the pricing effects are nearly identical for each. Because there is a subjective boundary issue associated with defining the point at which oceanfront becomes bayfront, we combine these two in the results presented here.

[6] For further comparison, our results for Florida as a whole (see Exhibit 2) show that oceanfront/bayfront properties receive a 42% waterfront premium, lakefront 14%, and riverfront 16%.

[7] While not discussed here, inland river flooding risk is increasing because of precipitation trend changes associated with climate change, but also because of increased urbanization associated with higher runoff (less infiltration). So our results in Stockton also speak to the positive feedbacks created between climate change and urbanization with regard to flood risks.

[8] We indirectly assume no significant mitigation of flood risks is provided by sea walls or other infrastructure not considered in the elevation measure. To our knowledge, none of our three markets are planning major infrastructure projects to mitigate flood risk increases associated with climate change.

[9] Using ESRI data, the percentage of those aged 65 and above was significantly higher on the Southeast Florida coast than the nation as a whole for data from 2017.

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