(2020) 49, 43–52

The Review of Regional Studies

The Official Journal of the Southern Regional Science Association

Impacts of Sea Level Rise on Real Estate Prices in Coastal Georgia*

Jason Beck[a] and Meimei Lin[b]

[a] *Department of Economics, Georgia Southern University, USA*

[b] *Department of Geology and Geography, Georgia Southern University, USA*

Abstract: This paper adopts a hedonic pricing model to study the impact of vulnerability to inundation from sea level rise on home prices in Savannah, Georgia. We find that homes most at risk from sea level rise are associated with an approximate 3.1 percent price discount. The results are consistent with prior studies, which uses data from different locations in U.S. coastal areas. We also find that the discount is more significant in our later sample period, indicating that house buyers may be becoming more aware of the climate risk. This paper contributes to the understanding of house pricing factors in the study area regarding the sea level rise effects.
Keywords: coastal Georgia, house prices, hedonic model, sea level rise
JEL Codes: R30, R31, R11

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1. INTRODUCTION

It is widely accepted that human beings have altered our natural environments in ways that could trigger irreversible consequences for global climate systems. Since the mid 20$^{\text{th}}$ century, global average temperatures have risen and the resultant retreat of land ice and thermal expansion of water molecules has caused sea level rise (SLR) worldwide. While the exact rate at which temperature and sea level will continue to rise is unknown, SLR is projected to be in the range of one to six feet by the end of the century and is expected to increase at a faster rate beyond 2100 (Meyer and Pachauri, 2014).

The impact of SLR is uneven across regions with the most severe effects concentrated in low-lying coastal areas. Due to SLR, coastal areas will likely experience flooding, submergence, and erosion during and beyond the 21$^{\text{st}}$ century (Meyer and Pachauri, 2014). Exacerbating this situation further is the fact that coastal regions are often densely populated. According to "National Coastal Population Report: Population Trends from 1970 to

*Jason Beck is an Associate Professor of Economics at Georgial Southern University, Savannah, GA. Meimei Lin is an Assistant Professor of Geography at Georgia Souther University, Svannah, GA. *Corresponding Author*: Jason Beck E-mail: jbeck@georgiasouthern.edu.

ISSN 1553-0892, 0048-49X (online)
www.srsa.org/rrs

2020," approximately 164 of 313 million people in the United States (approximately 52 percent) live in coastal watershed counties and the population density of coastal areas is roughly three times that of the U.S. in general (National Oceanic and Atmospheric Administration, 2013).

While the effects of SLR will likely be far reaching, one area where its effects will be particularly felt is in the real estate market. Given that real estate is typically the largest investment for the median U.S. household (Campbell, 2006), a sharp decline in the value of a significant fraction of the housing stock would represent a large decrease in wealth for many households in affected areas. Yale Climate Opinions map data (Howe et al., 2015) suggest that 61 percent of adults in Chatham County, GA (where Savannah is located and the focus of this study) "are worried about global warming," which is among the highest in coastal Georgian counties. If buyers recognize this threat, it is possible that the risk of SLR may be reflected in current home values for vulnerable properties.

A recent literature has emerged examining the effects of expected SLR on property values. Bernstein et al. (2019) use a national database of home transactions from 2007-2016 and find that vulnerable properties were associated with a 7 percent discount. They suggest that this discount may be driven in part by buyer sophistication in that non-owner occupied properties sell for a larger discount than owner-occupied units. They also note that this discount has increased over time. Furthermore, they find that among owner-occupiers, areas that express greater concern for (and belief in) SLR are associated with larger penalties than areas that are less worried about the effects of climate change.

Baldauf et al. (2018) further capitalize on the heterogeneity of beliefs regarding the negative effects of climate change to see how people in different areas have responded. They connect survey data on beliefs across the U.S. regarding climate change with a comprehensive dataset of housing transactions and find that the property value discount is 7 percent larger for "believer" areas compared to "non-believer" areas. Bakkensen and Barrage (2017) find that the heterogeneity of beliefs regarding SLR contributes to the selection into coastal homes. In particular, people living in the flood zone tend to underestimate their flood risks compared to those of inundation models, whereas people who live outside the flood zone are more concerned with flood risks.

Using data from the Chesapeake Bay area, Walsh et al. (2017) also find a discount for properties vulnerable to SLR but that the discount is offset in the presence of adaptive structures such as bulkheads and ripraps. They show that homes in the high risk inundation areas sell for an average of 19-23 percent less if there is a lack of protective structures. However, if certain protection structures are in place, property values of the high risk zones can increase up to 21 percent.

Based on hedonic analyses of property transaction data in Galveston County, TX, Atreya and Czajkowski (2014) argue that the impact of flood risk on housing value is dependent upon its water-related amenities such as distance to the coast. Houses within a quarter mile of the nearest coastline sell at a price premium despite having higher flood risks. Ortega and Taspinar (2018) discover that housing prices significantly dropped after Hurricane Sandy in New York City. Overall, they find a 9 percent reduction in property values in storm-affected areas compared with similar houses outside the storm.

This project uses Multiple Listing Service (MLS) data in a hedonic model to see if such properties vulnerable to SLR sell for less in Savannah, Georgia, a coastal region of the U.S. We find homes that are at high risk (i.e. ones that would be inundated with SLR of 0-3 feet) sell at a 3.1 percent discount relative to those that would only be inundated at SLR greater than 6 feet. Homes that would only be inundated with a 4-6 feet rise in sea level see no difference in price relative to safe[1] homes.

Our results suggest that climate change may already be having an impact on housing values. Such information could be valuable for policy makers when considering options to mitigate the impact of climate change, especially in the most vulnerable areas. As any policy response will weigh the costs and benefit of action, getting as clear of a picture as possible regarding the costs of SLR becomes important. Home devaluation from SLR would be a part of those costs.

2. FRAMEWORK FOR THE EMPIRICAL ANALYSIS

Real estate transaction data were obtained via the MLS of Savannah, GA over the period 2007-2016. Over this time, there were roughly 42,000 single-family homes sold through the MLS. The data are detailed enough to allow for a number of hedonic controls related to physical home characteristics, property location, and timing of sale.

To generate the variables associated with vulnerability to inundation, the GIS shapefile for Georgia was downloaded from the National Oceanic and Atmospheric Administration (NOAA) SLR Calculator. This online data portal provides access to an online SLR calculator viewer as well as the underlying shapefiles for all 48 lower U.S. States. This GIS shapefile of Georgia includes polygons of potentially impacted areas under 0-6 feet SLR and was further clipped to include just Savannah, GA. All home sales of Savannah were geocoded from the longitude and latitude data provided in the MLS and overlaid with 0-6 feet SLR zones to generate vulnerability measures to coastal inundation.

The housing data were restricted to include only existing (i.e. not newly built) homes with a reported age of 2 years or greater and selling for more than $50,000 and less than $2 million. Entries with blank or illogical values were likewise removed. Analysis begins with 34,807 sold homes.

To allow home characteristics to affect sales outcomes nonlinearly, we follow Levitt and Syverson (2008) by operationalizing all independent variables as binary regressors. The variables, $ONEBEDROOM$, $TWOBEEDROOM$, $THREEBEDROOM$, $FOURBEDROOM$, $FIVEBEDROOM$, and $SIXPLUSBEDROOM$ are dichotomous variables equaling one if the observation has one, two, three, four, five, or six plus bedrooms respectively, and zero otherwise. Full and half baths are controlled for in a similar fashion with the variables $ONEFULLBATH$, $TWOFULLBATH$, $THREEFULLBATH$, $FOURPLUSFULLBATH$, and $ZEROHALFBATH$, $ONEHALFBATH$, $TWOHALFBATH$, $THREEPLUSHALFBATH$. House size

[1]Here, the term "safe" is used in a relative context. Since Meyer and Pachauri (2014) estimates SLR to be in the range of one to six feet by 2100, we consider homes that would only be inundated with a SLR of over six feet to be "safe."

Table 1: Definitions of Variables in the Analysis

$PRICE$: real sales price of house, base year 2012
$LnPRICE$: the natural log of the real sales price
$SQFT1-SQFT5$: a series of binary variables to indicate if the house falls in the 1st square footage quintile (0-1311 sqft), 2nd sqft quintile (1312-1580), 3rd sqft quintile (1581-1930), 4th sqft quintile (1931-2541) or 5th sqft quintile (2542+)
$TWOBEDROOMS$: a binary variable to indicate if the house has two bedrooms
$THREBEDROOMS$: a binary variable to indicate if the house has three bedrooms
$FOURBEDROOMS$: a binary variable to indicate if the house has four bedrooms
$FIVEBEDROOMS$: a binary variable to indicate if the house has five bedrooms
$SIXPLUSBEDROOMS$: a binary variable to indicate if the house has six or more bedrooms
$TWOFULLBATH$: a binary variable to indicate if the house has two full bathrooms
$THREEFULLBATH$: a binary variable to indicate if the house has three full bathrooms
$FOURFULLBATH$: a binary variable to indicate if the house has four full bathrooms
$FIVEPLUSFULLBATH$: a binary variable to indicate if the house has five or more full bathrooms
$ONEHALFBATH$: a binary variable to indicate if the house has one half bathrooms
$TWOHALFBATH$: a binary variable to indicate if the house has two half bathrooms
$THREEHALFBATH$: a binary variable to indicate if the house has three half bathrooms
$FOURPLUSHALFBATH$: a binary variable to indicate if the house has four or more half bathrooms
$FIREPLACE$: a binary variable to indicate if the house has a fireplace
$ONEGARAGE$: a binary variable to indicate if the house has one garage space
$TWOGARAGE$: a binary variable to indicate if the house has two garage spaces
$THREEPLUSGARAGE$: a binary variable to indicate if the house has three or more garage spaces
$Y2007-Y2016$: a series of binary variables to indicate if the house was sold in year 2007-2016
$2-5YEARS$: a binary variable to indicate if the house was 2-5 years old at sale
$6-10YEARS$: a binary variable to indicate if the house was 6-10 years old at sale
$11-25YEARS$: a binary variable to indicate if the house was 11-25 years old at sale
$26-50YEARS$: a binary variable to indicate if the house was 26-50 years old at sale
$51-100YEARS$: a binary variable to indicate if the house was 51-100 years old at sale
$101+YEARS$: a binary variable to indicate if the house was 101 or more years old at sale
$POOL$: a binary variable to indicate if the house has a swimming pool
$WATERFRONT$: a binary variable to indicate if the house was marketed as a waterfront property
$SLR1$: a binary variable to indicate if the house would be inundated with a 0-1 foot rise in sea level
$SLR2$: a binary variable to indicate if the house would be inundated with a 1.01-2 foot rise in sea level
$SLR3$: a binary variable to indicate if the house would be inundated with a 2.01-3 foot rise in sea level
$SLR4$: a binary variable to indicate if the house would be inundated with a 3.01-4 foot rise in sea level
$SLR5$: a binary variable to indicate if the house would be inundated with a 4.01-5 foot rise in sea level
$SLR6$: a binary variable to indicate if the house would be inundated with a 5.01-6 foot rise in sea level
$HIRISK$: a binary variable to indicate if the house would be inundated with a 0-3 foot rise in sea level
$LOWRISK$: a binary variable to indicate if the house would be inundated with a 3.01-6 ft rise in sea level
$NORISK$: a binary variable to indicate if the house would only be inundated with a >6 ft rise in sea level
$ZIP1-ZIP167$: binary variables =1 when house was sold in the associated 6-digit ZIP code, 0 otherwise

is controlled for with dummy variables for square footage quintiles (see Table 1 for specific ranges). Yearly fixed effects are represented by the variables $Y2007$-$Y2016$. Age of the house is controlled for via five dummy variables for different age ranges, specifically $2-5YEARS$, $6-10YEARS$, $11-25YEARS$, $26-50YEARS$, $51-100YEARS$, and $101+YEARS$.[2] Additional physical characteristics, such as the presence of a fireplace, presence of a swimming pool, and the number of garage spaces are controlled for, as well as

[2]Recall that new homes are excluded from the sample.

Table 2: Descriptive Statistics

Variable	Mean	Std. Deviation
$PRICE$	222153.4	171802.4
$LnPRICE$	12.116	0.595
$SQFT1$	0.200	0.400
$SQFT2$	0.200	0.400
$SQFT3$	0.200	0.400
$SQFT4$	0.200	0.400
$SQFT5$	0.200	0.400
$ONEBEDROOM$	0.017	0.131
$TWOBEDROOMS$	0.104	0.305
$THREBEDROOMS$	0.584	0.492
$FOURBEDROOMS$	0.244	0.429
$FIVEBEDROOMS$	0.044	0.205
$SIXPLUSBEDROOMS$	0.006	0.077
$TWOFULLBATH$	0.693	0.046
$THREEFULLBATH$	0.157	0.363
$FOURFULLBATH$	0.030	0.171
$FIVEPLUSFULLBATH$	0.008	0.090
$ZEROHALFBATH$	0.688	0.463
$ONEHALFBATH$	0.299	0.457
$TWOHALFBATH$	0.012	0.109
$THREEHALFBATH$	0.0006	0.023
$FOURPLUSHALFBATH$	0.0001	0.009
$FIREPLACE$	0.620	0.485
$ZEROGARAGE$	0.345	0.475
$ONEGARAGE$	0.130	0.336
$TWOGARAGE$	0.483	0.499
$THREEPLUSGARAGE$	0.041	0.199
$2-5YEARS$	0.152	0.359
$6-10YEARS$	0.193	0.394
$11-25YEARS$	0.275	0.446
$26-50YEARS$	0.190	0.392
$51-100YEARS$	0.150	0.357
$101+YEARS$	0.037	0.188
$POOL$	0.053	0.224
$WATERFRONT$	0.116	0.320
$CONDO$	0.133	0.340
$SLR1$	0.018	0.134
$SLR2$	0.004	0.063
$SLR3$	0.014	0.117
$SLR4$	0.033	0.178
$SLR5$	0.034	0.181
$SLR6$	0.040	0.195
$HIRISK$	0.036	0.187
$LOWRISK$	0.107	0.308
$NORISK$	0.857	0.350

whether the home was a single-family dwelling or a condominium/townhouse.

Location is accounted for in the hedonic model via a series of dummy variables each representing a 6-digit zip code similar to Beck et al. (2018). These zip codes were constructed by truncating available 9-digit zip codes thereby creating 167 different locational controls. The largest represents 4.8 percent of the sample. Note that not all 5-digit zips will necessarily have ten distinct sub areas. By controlling for location with these 6-digit zip codes, an added degree of granularity is achieved.

In addition to being close to the coast, the Savannah area has many inland waterways and thus many homes adjacent to water. Since vulnerability to SLR will often be correlated with proximity to water, it is difficult to separate the potential price effects of SLR risk from the other effects associated with water adjacent homes. These effects could have a negative component, in that these properties may have a higher risk of non-SLR related flooding, and/or a positive component related to the amenity value of waterfront property. We control for a home being directly on the water with a dummy variable equaling one if the home is marketed as "waterfront." Unfortunately, since low elevation areas are susceptible to both SLR-related inundation and non-SLR flooding, it is difficult to disentangle the two effects. Thus, our estimates might be considered an upper bound for price effects due to SLR.

As is common in the literature, the dependent is the natural log of sales price. The nominal sales prices provided by the MLS were adjusted into year 2012 dollars via the Implicit Price Deflator.[3]

The average home in the sample has three bedrooms, two full baths, is 28 years old, and sold for $222,153. Tables 1 and 2 provide descriptions of each variable and summary statistics, respectively.

Following Haag et al. (2000), Levitt and Syverson (2008), Cebula (2009), Beck et al. (2018), and others, we employ a hedonic (logged) pricing model to estimate the effects of the independent variables on (logged) home prices. We estimate this model via OLS with robust standard errors:

$$ln(Price)_j = f(I_j, E_j, O_j) \tag{1}$$

where $ln(Price)_j$ is the natural log of the price of house j, I_j a vector of interior and exterior physical characteristics for house j, E_j is a vector of time of sale characteristics for house j, and O_j is a vector of characteristic controlling for SLR risk associated with house j.

3. EMPIRICAL RESULTS

Results for the hedonic model are presented in Table 3. Coefficients on the control variables largely match expectations and previous research. Larger homes sell for progressively more, as do homes with more full and half baths. Newer homes tend to sell for more, except relative to homes over one hundred years old. Given the presence of a well-known and desirable historical district in Savannah, it is unsurprising that historic homes are not associated with a sale price discount (see Cebula (2009)). Amenities such as a fireplace, a swimming pool, more garage spaces, and the property being waterfront are associated with higher selling prices. The negative coefficient on the bedroom variables can be explained by the inclusion

[3]https://fred.stlouisfed.org/series/GDPDEF

Table 3: OLS Estimates of the Hedonic Pricing Model for the Dependent Variable: ln(price)

	Model 1: 6 SLR Control Variables (SLR1-SLR6)			Model 2: 2 SLR Control Variables (HIRISK & LOWRISK)		
Variable	Coef	t-stat	p-val	Coef	t-stat	p-val
SQFT2	0.154	28.700	0.000	0.154	28.750	0.000
SQFT3	0.284	47.610	0.000	0.285	47.700	0.000
SQFT4	0.449	63.840	0.000	0.449	63.930	0.000
SQFT5	0.666	74.790	0.000	0.666	74.900	0.000
ONEBEDROOM	-0.149	-8.060	0.000	-0.149	-8.080	0.000
TWOBEDROOMS	0.020	2.670	0.008	0.020	2.650	0.008
FOURBEDROOMS	-0.025	-5.720	0.000	-0.025	-5.710	0.000
FIVEBEDROOMS	-0.064	-6.670	0.000	-0.064	-6.680	0.000
SIXPLUSBEDROOMS	-0.105	-3.260	0.001	-0.105	-3.250	0.001
TWOFULLBATH	0.160	19.750	0.000	0.159	19.730	0.000
THREEFULLBATH	0.298	29.340	0.000	0.298	29.320	0.000
FOURFULLBATH	0.516	34.150	0.000	0.516	34.140	0.000
FIVEPLUSFULLBATH	0.739	24.970	0.000	0.739	24.970	0.000
ONEHALFBATH	0.089	21.890	0.000	0.089	21.880	0.000
TWOHALFBATH	0.180	9.470	0.000	0.180	9.440	0.000
THREEHALFBATH	0.425	3.650	0.000	0.425	3.650	0.000
FOURPLUSHALFBATH	0.164	2.830	0.005	0.163	2.830	0.005
FIREPLACE	0.099	25.420	0.000	0.099	25.420	0.000
ONEGARAGE	0.073	13.160	0.000	0.073	13.190	0.000
TWOGARAGE	0.163	31.660	0.000	0.163	31.700	0.000
THREEPLUSGARAGE	0.316	31.740	0.000	0.316	31.770	0.000
Y2008	-0.037	-5.570	0.000	-0.037	-5.570	0.000
Y2009	-0.117	-16.830	0.000	-0.117	-16.830	0.000
Y2010	-0.178	-25.290	0.000	-0.178	-25.280	0.000
Y2011	-0.250	-35.450	0.000	-0.250	-35.450	0.000
Y2012	-0.217	-31.300	0.000	-0.217	-31.320	0.000
Y2013	-0.134	-20.180	0.000	-0.134	-20.200	0.000
Y2014	-0.063	-9.800	0.000	-0.063	-9.800	0.000
Y2015	0.015	2.470	0.014	0.015	2.470	0.014
Y2016	0.074	12.010	0.000	0.074	12.010	0.000
$6-10YEARS$	-0.020	-4.530	0.000	-0.020	-4.520	0.000
$11-25YEARS$	-0.048	-9.670	0.000	-0.048	-9.700	0.000
$26-50YEARS$	-0.108	-16.060	0.000	-0.108	-16.060	0.000
$51-100YEARS$	-0.059	-5.490	0.000	-0.059	-5.500	0.000
$101+YEARS$	0.047	2.450	0.014	0.047	2.450	0.014
POOL	0.089	12.440	0.000	0.089	12.470	0.000
WATERFRONT	0.198	34.600	0.000	0.198	34.550	0.000
CONDO	-0.092	-13.380	0.000	-0.091	-13.490	0.000
SLR1	-0.025	-1.860	0.062			
SLR2	-0.077	-3.450	0.001			
SLR3	-0.022	-1.420	0.156			
SLR4	0.000	0.040	0.965			
SLR5	0.006	0.690	0.487			
SLR6	0.005	0.630	0.528			
HIRISK				-0.031	-3.170	0.002
LOWRISK				0.004	0.690	0.493
R^2	0.788			0.788		
F	57.230			56.340		
N	34807			34807		

Note: 167 6-digit zip code fixed effects are present but not reported

of the square footage variables and is consistent with other research (see Salter et al. (2012), Waller and Jubran (2012), Seagraves and Gallimore (2013) Allen et al. (2015), among others).

Both the national decline in home values and the subsequent rebound over the last decade are visible in these results. Relative to 2007, Savannah housing prices appear to have bottomed out in 2011 before trending back upwards and approaching their 2007 levels by

2016.

Turning now to our variables of interest, we see that the coefficients on SLR1 and SLR2 are negative and statistically significant. They roughly exhibit a tapering effect, mostly decreasing in magnitude and statistical significance as the level of risk decreases. Properties that are the most vulnerable to sea level rise (i.e. those that would be inundated with a rise in sea level of one foot or less) are associated with a 2.5 percent penalty relative to those that are under little/no risk of being inundated. This result is statistically significant at the 10 percent level. Properties that would be inundated with a two-foot or three-foot sea level rise are associated with a statistically significant 7.7 percent discount. Homes inundated with a three to six foot rise were not associated with a statistically significant different sales price than safe homes. It is unclear why the associated coefficient on SLR2 is larger than the coefficient on SLR1. Despite the fairly rich set of control variables that are provided in the MLS data, unobservable heterogeneity is always a possibility and it could be that the homes that are most directly threatened by SLR are also associated with unobservable positive home characteristics such as beach access or an ocean view. Examined as a whole, a general picture emerges of an association between degree of property vulnerability and lower sales price.

A similar model (Model 2) was also estimated with the seven sea level rise variables (SLR1-SLR6 and "no risk") collapsed into three categories: no risk (as previously defined), low risk (homes that would be inundated with a four to six foot increase in sea level), and high risk (homes that would be inundated with a SLR of three feet or fewer). Relative to the reference group ("no risk"), homes designated as high risk were associated with a statistically significant 3.1 percent lower price. Low-risk homes saw no noticeable impact on sales price.

Over time, information levels regarding the risk of SLR may increase. Additionally, the time before the most direct consequences of SLR will be felt grows shorter. It is thus possible that the effects of SLR risk on housing prices may change over time. To examine this, we divide the ten years of available data into two five-year periods: 2007-2011 and 2012-2016. In estimating Model 2 on each of the two five-year sub-samples, we find that the discount associated with the highest risk properties increases from 3.4 percent to 4 percent across the two periods. This difference is statistically significant.

4. CONCLUSION

Since any public policy action will consider the costs and benefit of action, information on the costs of SLR is important when formulating a policy response. One of the many costs of SLR will be home devaluation in vulnerable areas. This paper combines MLS home transaction data from 2007-2016 for Savannah, Georgia with GIS mapping to explore the connection between properties at risk of inundation as a result of SLR and their observed price. The results suggest that properties that would be inundated with a sea level rise of three feet or less were associated with a 3.1 percent discount. Properties that would be inundated with a 4-6 feet SLR saw no discount relative to safe homes. Additionally, we find that the discount was statistically larger in the period of 2012-2016 than it was in 2007-2011. These findings suggest that buyers may be aware of the risk of vulnerable properties, are bidding accordingly, and this effect has grown over time. Our results are in line with other research, such as Bernstein et al. (2019), which reports a 7 percent discount for at risk homes.

This study is not without limitations. For example, it focuses on only one narrow geographic location and one should be cautious about extrapolating these results to other coastal areas where inundation risk and median home values may be different. Furthermore, work by Walsh et al. (2017) suggests that adaptive structures may reduce the impact of SLR on home values. This study does not take into account adaptations home owners may undertake as their understanding of SLR changes over time.

Future research could focus on other coastal areas and utilize newer data as they become available. Our results suggest the impact of inundation risk on home prices was greater in more recent years, but available data only extended to 2016. As new transaction data become available, it would be interesting to see if the effect continues to increase.

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