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Impact of Rising Sea Levels in Japan: A Study into the Price Dynamics of Residential Real Estate

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Summary

This paper provides an exploratory look at whether climate risk was incorporated in land prices. The data sample explored land transactions located in seven wards in Tokyo. The initial results indicate that land unit price was lower by 7% for land parcels located near live water bodies. Variables like area characteristics and land use zoning were statistically significant in explaining for the variation in land unit prices, lending support to the hypothesis that more informed buyers priced in climate risk in the land prices.

Introduction

"Global mean sea level (GMSL) is rising, with acceleration in recent decades due to increasing rates of ice loss from the Greenland and Antarctic ice sheets (very high confidence), as well as continued glacier mass loss and ocean thermal expansion. Increases in tropical cyclone winds and rainfall, and increases in extreme waves, combined with relative sea level rise, exacerbate extreme sea level events and coastal hazards (high confidence)." (IPCC, 2019)

The IPCC Special Report on the Ocean and Cryosphere in a Changing Climate sounded the alarm on changing weather patterns rising from climate change.

Japan is one of the countries who will be highly affected by rising sea levels. According to Mimura (2013), a study undertaken to estimate the risk of rising sea levels in the three major bays (Tokyo, Osaka, and Ise Bays) in the 2090s, projected that 63-72 km sq of areas would be under the threat of inundation, 300-350 thousand people will be at risk, and economic damage would amount to 1.8-2.3 trillion yen.

The purpose of this research is to understand the impact of rising sea level on residential property prices (specifically land prices) located in Tokyo areas with high risk of inundation due to sea level rise. The risk of rising sea level was projected to be highest in the Asia Pacific region. Hence, using Japanese data would contribute to a better understanding of the impending impact of rising sea levels on assets located in the high inundation risk areas.

Recent literature focused on understanding the impact of climate change on asset prices (Murfin and Spiegel, 2020; Bernstein, Gustafson and Lewis, 2019); however, many of these studies use data in the United States.

Bernstein et al. (2019) rightly pointed out that pricing sea level rise (SLR), considered a long-run and uncertain risk factor, is a largely unanswered empirical question. SLR is difficult to be priced into asset prices due to both behavioral biases and differential beliefs held by households. Using property data and the estimated exposure to SLR, Bernstein et al. (2019) affirmed a discount of 7% for coastal properties exposed to SLR. This discount does not surface for rental properties, thus, leading to their conclusion that homebuyers priced in the long-term SLR risk. Furthermore, sophisticated investors have a higher SLR discount than less sophisticated investors.

Barrage and Furst (2019) investigated the level of new housing construction with SLR exposure and climate change beliefs. Their results showed that SLR vulnerability is associated with significantly reduced construction in areas with high climate change beliefs. Murfin and Spiegel (2020) found that SLR has no effect on real estate prices. Their study controlled for location and elevation of the of the coastal home.

The most recent paper, Bakkensen and Barrage (2022) found that coastal housing prices were overvalued by 6% to 13%. Their survey and empirical work found significant sorting among households who chose to locate in coastal areas and those who do not. Those who chose to locate in the coastal areas were significantly less worried about flooding than those located outside the flood zone. Their study found significant flood risk underestimation by coastal households.

In an interesting paper, Severen et al. (2018) found agricultural land markets capitalize future climate change in their land prices. Land values in recent years trended closely with future climate predictions than land values in the 70s and 80s.

Overall, existing literature still provided mixed results as to whether climate changes are priced into asset prices. Taking the idea from Severen et al. (2018), this paper aims to explore whether land prices, rather than house prices incorporate climate change impacts in their pricing. The rationale followed those proposed in the literature that informed buyers would price in the climate risk and hence offer a lower price. Similarly, land buyers had to conduct site analysis prior to construction and would have had more information on the site area than ready-built property buyers. Therefore, this paper offers a preliminary analysis by looking at price differences in the land price for parcels located near live water bodies. Live water bodies were defined as rivers and streams, rather than parks or moats. The analysis is limited to seven wards within Tokyo.

Section 2 describes the data and provides a summary profile of the residential land transactions used in the paper. Section 3 provides the empirical framework and results. Finally, Section 4 concludes the paper and highlights the limitations.

Data

The land sales data was obtained from the Ministry of Land, Infrastructure, Transport and Tourism, Land General Information System website. The quarterly data spanned from 2005Q3 to 2022Q2. The data comprised of land sales in the Tokyo for wards located near the coast. The seven wards under study were: Chiyoda, Chuo, Edogawa, Koto, Minato, Ota, and Shinagawa. The administrative responsibilities of running Tokyo, such as water supply and sewage services, are uniformly under the responsibilities of the Tokyo Metropolitan government. Thus, in terms of provision of infrastructure to combat flooding and rising sea level threats, all wards should be governed uniformly by the Tokyo Metropolitan government and not handled separately under different wards.

Table 1 summarized the descriptive statistics for the variables used in the study.

<Insert Table1>

The average price per unit of land sold was ¥669,334 with an average plot size of around 200 sqm. In the sample, 53% was located near water bodies such as rivers and streams. The average plot was within 9 minutes walking distance to the nearest subway station. The land parcel frontage/width was about 8.81m, with a maximum building coverage ratio of 62.35% and a maximum floor-area ratio of 256.81%.

In terms of the shape of the land parcel, 15% of the data were odd-shaped (flag shaped and irregular shaped). Under the land zoning as obtained from city planning guidelines, 60% of the sample was designated as residential land, 18.4% as commercial land, and 21.6% as industrial land. In terms of the neighborhood characteristics, 83% was residential area, 15.6% was commercial area, and 1.4% was industrial area. As for where the parcels were located, the majority are located in the Ota ward, the Edogawa ward, and Shinagawa ward.

A one-way analysis of variance (ANOVA) was estimated to see if there were significant differences in the unit price of land and proximity to water bodies (see Table 2). The F-stat (296.07) was highly significant with a p-value of 0.00 indicating that there were substantial differences in the unit price of land located near water bodies.

<Insert Table 2>

In line with the hypothesis that a more informed buyer would capitalize climate risk in the asset price, a one-way ANOVA was carried out to check for significant differences in area characteristics (that is, residential, commercial and industrial). The result indicated that commercial and industrial area exhibited significant differences in the unit price of land located near water bodies.

A more granular one-way ANOVA was carried out to check if there are significant differences in the unit price of land and proximity to water bodies within each ward to control of ward effects.

The results were mixed. Significant differences were detected in the Chiyoda, Chuo, Edogawa, Ota, and Shinagawa wards but not for the Koto and Minato wards. Another ANOVA was conducted to test for differences in zoned land use and proximity to water bodies. The ANOVA tests indicated significant differences in the residential and commercial zoning but not for the industrial zoning and quasi-residential zone.

Finally, a one-way ANOVA was carried out on the zoning use. Except for industrial and quasi-residential, the other land zoning use exhibited significant price differences in the unit price of land located near water bodies. Thus, preliminary analysis point to price differences to land parcels located near water bodies via three matrices: location (ward), area characteristics and land use zoning.

Model Estimation and Results

The empirical analysis adopts a hedonic regression estimation. The hedonic model comprised of land characteristics, land use characteristics, neighborhood characteristics, proximity to water bodies and timing of transaction. Robust standard error estimation was applied to correct for heteroskedasticity. The baseline empirical model:

$$lnppsm = \beta_0 + \beta_1 near\ water + \beta_2 X + \beta_3 W + \beta_4 \mathrm{NC} + \Gamma + e_{it} \qquad \text{(Eqn 1)}$$

where the dependent variable is the natural logarithm of the unit land price (pricem2). The variable of interest is the dummy variable *near_water* where a value of 1 indicates the area (or cho) where the land was located bordered a live water body (e.g., river or stream). *X* represents a vector of land characteristics comprising of size of parcel (*aream2*), walking distance from nearest subway station (*stndist_min*), *frontage*, maximum building to land ratio (*bldratio*), and maximum floor ratio (*flrratio*). *W* represent a vector of dummy variables representing ward location and comprises all the wards analyzed in this data. *NC* represent a vector of neighborhood characteristics (i.e., residential area, commercial area, industrial area) Γ represents the quarter where the land was transacted to control for time effects.

The base equation represents a land parcel next to water bodies, located in the Ota ward in a residential area, zoned as Category I Residential with a flag-shaped land area.

The results for Equation 1 are shown in Table 3, column 1. All the signs were in line with expectations. The base equation explains for 52.2% of the variation in land unit price and the model has a high F-value (325.43). For land parcels located in areas near water bodies, land unit price decreases by 6.8%. An increase of one minute walking distance to the nearest station decreases the land unit price by 1.8%. An extra meter of land frontage increases land unit price by 1.0%. An increase in floor ratio increases land unit price by 0.14%. Compared to residential areas, land unit price is higher by 16.7% for commercial areas and is lower by 14.6% for industrial areas. These estimates are statistically significant at the 1% level.

The shape of the land parcel is extremely important in explaining for the variation in land unit price whereas the land use zoning shows mixed results. In general, residential land use zoning exhibits statistically significant estimates at least at the 5% level. Though not statistically significant, commercial and industrial land use zoning exhibit lower land unit price compared to Category I Residential Land zoning.

The ward fixed effects show variation within the wards, when compared to land prices in the Ota ward. The Edogawa ward and Koto ward exhibit lower land unit price whereas the other wards exhibit higher land unit price. The time fixed effect is statistically significant at the 1% level.

Interaction terms between area character and proximity to water bodies are introduced:

$$lnppsm = \beta_0 + \beta_1 near\ water + \beta_2 X + \beta_3 W + \beta_4 \mathrm{NC} + \beta_5 NC * near\ water + \Gamma + e_{it} \qquad \text{(Eqn 2)}$$

Where β_5 indicates whether there is a difference in land values for different land use areas. The hypothesis follows from current literature assumptions that businesses are more informed as investors than residential buyers and hence, are more likely to capitalize the environmental risk in the land valuation.

Referring to the results in Column 2, the *near_water* variable shows a smaller decrease of 5.6%. The interaction term for *region_cat*near_water* shows a further marginal decrease of 5.6% for commercial areas, significant at the 10% level. For industrial areas, land unit price shows a further marginal decrease of 27.8% and statistically significant at the 1% level.

Taking into account that location plays an important role in land price determination: within a ward, would there be significant differences between land parcels located near water bodies and those that were not?

$$lnppsm = \beta_0 + \beta_1 near\ water + \beta_2 X + \beta_3 W + \beta_4 \mathrm{NC} + \beta_5 W * near\ water + \Gamma + e_{it} \qquad \text{(Eqn 3)}$$

Results for Equation 3 are indicated in Column 3. The regression showed mixed results. For land parcels located near water bodies, the land unit price decreases by 7.6%. Within each ward, the interaction term *ward*near_water* shows negative coefficients for the Chiyoda, Chuo, and Koto ward. This indicates that within these wards, land located near water bodies exhibit lower land unit price. In Chiyoda, the decrease was 17.1% and statistically significant at the 5% level. In Koto, the decrease was 15.1% and statistically significant at the 10% level. In the Edogawa, Minato, and Shinagawa ward, the interaction term shows positive coefficients. In the Edogawa ward, the land unit price further marginally increases by 4.8% and statistically significant at the 5% level.

Conclusion and Limitations

The estimated discount seems in line with the housing discount by Bernstein et al. (2019) and in line with Severen et al. (2018). The initial analysis presented encouraging results that land buyers seemed to have capitalized climate change effects in the land valuation. However, the model is still in an initial exploratory stage. Further details needed to be controlled, for instance parcels located in the flood-zone, the expected level of flooding for the parcel and the incorporation of sea level data into the model.

Table 1: Descriptive Statistics

Variable	Obs	Mean	Std. dev.	Min	Max	Notes
pricetotal	13,548	139,000,000	579,000,000	70,000	22,000,000,000	(yen)
pricem2	13,548	669,334	875,409	350	20,000,000	(price per meter)
aream2	13,548	199	846	10	69,231	(meters)
near_water	13,548	0.5326	0.4990	0	1	Near rivers and streams
stndist_min	13,548	9	6	0	29	(minutes)
frontage	13,548	8.81	6.44	0	49.4	(meters)
bldratio	13,548	62.35	9.30	30	80	(percentage)
flrratio	13,548	256.81	131.18	80	1300	(percentage)
land_shape1	13,531	0.0194	0.1381	0	1	Flag-shape
land_shape2	13,531	0.1342	0.3409	0	1	Irregular-shape
land_shape3	13,531	0.3122	0.4634	0	1	Rectangular-shape
land_shape4	13,531	0.3440	0.4750	0	1	Semi-rectangular shape
land_shape5	13,531	0.0328	0.1782	0	1	Semi shape
land_shape6	13,531	0.0521	0.2222	0	1	Semi-square shape
land_shape7	13,531	0.0627	0.2424	0	1	Semi-trapezoid shape
land_shape8	13,531	0.0069	0.0826	0	1	Square shape

land_shape9	13,531	0.0357	0.1855	0	1	Trapezoida shape
usetype1	13,547	0.1282	0.3343	0	1	Category I Exclusively Low-story Residential Zone
usetype2	13,547	0.1704	0.3760	0	1	Category I Exclusively Medium-high Residential Zone
usetype3	13,547	0.2718	0.4449	0	1	Category I Residential Zone
usetype4	13,547	0.0016	0.0403	0	1	Category II Exclusively Low-story Residential Zone
usetype5	13,547	0.0124	0.1107	0	1	Category II Exclusively Medium-high Residential Zone
usetype6	13,547	0.0116	0.1070	0	1	Category II Residential Zone
usetype7	13,547	0.1033	0.3043	0	1	Commercial Zone
usetype8	13,547	0.0030	0.0549	0	1	Exclusively Industrial Zone
usetype9	13,547	0.0063	0.0794	0	1	Industrial Zone
usetype10	13,547	0.0808	0.2725	0	1	Neighborhood Commercial Zone
usetype11	13,547	0.2048	0.4036	0	1	Quasi-industrial Zone
usetype12	13,547	0.0058	0.0757	0	1	Quasi-residential Zone
region_cat1	13,548	0.1563	0.3632	0	1	Commercial Area
region_cat2	13,548	0.0128	0.1123	0	1	Industrial Area
region_cat3	13,548	0.8309	0.3749	0	1	Residential Area
ward1	13,548	0.0222	0.1474	0	1	Chiyoda Ward
ward2	13,548	0.0317	0.1753	0	1	Chuo Ward

ward3	13,548	0.2558	0.4363	0	1	Edogawa Ward
ward4	13,548	0.1110	0.3142	0	1	Koto Ward
ward5	13,548	0.0543	0.2267	0	1	Minato Ward
ward6	13,548	0.3622	0.4807	0	1	Ota Ward
ward7	13,548	0.1627	0.3691	0	1	Shinagawa Ward
ward1water	13,548	0.0111	0.1050	0	1	interaction ward*near_water
ward2water	13,548	0.0199	0.1398	0	1	
ward3water	13,548	0.2138	0.4100	0	1	
ward4water	13,548	0.1101	0.3131	0	1	
ward5water	13,548	0.0051	0.0712	0	1	
ward6water	13,548	0.1357	0.3425	0	1	
ward7water	13,548	0.0368	0.1882	0	1	
rcat1water	13,548	0.0837	0.2770	0	1	interaction region*near_water
rcat2water	13,548	0.0116	0.1070	0	1	
rcat3water	13,548	0.4373	0.4961	0	1	

Table 2: ANOVA

Ward	Obs	R-Square	Root MSE	F	Prob>F
Overall	13,548	0.0214	866,028	296.07	0.0000
region_cat1	2,118	0.0338	1.80E+06	73.95	0.0000
region_cat2	173	0.0061	248,260	1.05	0.3068
region_cat3	11,257	0.0585	357,616	699.07	0.0000
ward1	301	0.0132	1,700,000	4.00	0.0465
ward2	430	0.0530	2,400,000	23.97	0.0000
ward3	3,466	0.0035	162,089	12.00	0.0005
ward4	1,504	0.0003	328,405	0.43	0.5123
ward5	736	0.0003	1,900,000	0.24	0.6269
ward6	4,907	0.0018	320,142	8.99	0.0027
ward7	2,204	0.0082	315,013	18.28	0.0000
usetype1	1,737	0.0732	213,522	136.97	0.0000
usetype2	2,308	0.2059	358,405	597.95	0.0000
usetype3	3,682	0.0937	296,108	380.58	0.0000
usetype4	22	0.5429	151,692	23.76	0.0001
usetype5	168	0.2793	662,210	64.33	0.0000
usetype6	157	0.0359	719,666	5.77	0.0175
usetype7	1,399	0.0631	2,000,000	94.03	0.0000
usetype8	41	0.0000	-	0.00	0.0000
usetype9	86	0.0382	173,996	3.33	0.0715
usetype10	1,094	0.0174	804,882	19.39	0.0000
usetype11	2,775	0.0119	281,843	33.42	0.0000
usetype12	78	0.0062	229,111	0.48	0.4915

Table 3: Regression Results

The following regression were obtained using robust standard errors corrected for heteroskedasticity in the data. The dependent variable was lnppsm (logarithm of pricem2). The independent variables comprised of land parcel characteristics, zoning use, zoning permits, proximity to water bodies, area characteristics and time period of transaction. The t-statistics were indicated in parenthesis.

* indicates significance at 10% level, ** significance at 5%, and *** significance at 1%.

Variable	1		2		3	
constant	11.6289		11.6184		11.6204	
	100.28	***	100.12	***	100.3	***
near_water	-0.0659		-0.0541		-0.0730	
	-6.30	***	-5.02	***	-5.18	***
aream2	-6.30E-07		-1.91E-07		-4.07E-07	
	-0.14		-0.04		-0.09	
stndist_min	-0.0182		-0.0183		-0.0180	
	-20.12	***	-20.13	***	-19.68	***
frontage	0.0095		0.0095		0.0095	
	12.36	***	12.38	***	12.35	***
bldratio	0.0002		0.0003		0.0005	
	0.12		0.18		0.26	
flrratio	0.0014		0.0014		0.0014	
	13.13	***	13.06	***	12.66	***
region_cat1	0.1547		0.1865		0.1555	
	7.41	***	6.93	***	7.45	***
region_cat2	-0.1358		0.0768		-0.1402	
	-2.75	***	1.39		-2.84	***
rcat1water			-0.0540			
			-1.90	*		
rcat2water			-0.2454			
			-3.19	***		
ward1	0.6494		0.6512		0.7350	
	13.68	***	13.74	***	11.93	***
ward2	0.5404		0.5413		0.6136	
	12.78	***	12.79	***	8.66	***
ward3	-0.3727		-0.3770		-0.4095	
	-28.59	***	-28.94	***	-19.98	***
ward4	-0.0441		-0.0435		0.1008	
	-2.17	**	-2.14	**	1.29	
ward5	0.8630		0.8616		0.8579	
	28.81	***	28.84	***	26.95	***

ward7	0.2215		0.2230		0.2139	
	18.34	***	18.45	***	16.15	***
ward1water					-0.1580	
					-1.98	**
ward2water					-0.1063	
					-1.37	
ward3water					0.0470	
					1.92	**
ward4water					-0.1409	
					-1.77	*
ward5water					0.0742	
					1.00	
ward7water					0.0335	
					1.14	
land shape FE	Yes		Yes		Yes	
usetype FE	Yes		Yes		Yes	
Time FE	Yes		Yes		Yes	
Obs	13,531		13,531		13,531	
F-value	325.43		309.86		282.22	
Prob>F	0.0000		0.0000		0.0000	
R-sq	0.5217		0.5220		0.5224	
Root MSE	0.4955		0.4954		0.4953	

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Appendix 1

Data description

Data notes (MLIT)

- Residential land (land only) refers to transactions for land only.
- Nearest station: the name of the nearest train station and the time distance (minute) from the location of the property
- Total transaction value: (10,000 yen) is displayed (overhead costs, such as agent's commission are not included). Figures are rounded to two decimal places.
- Area (m^2): surveyed area (m^2) obtained from a survey of persons involved in transactions or the registered area (m2) specified in a register if the surveyed area is unknown
- Frontage of Land (m): frontage/width of land (the length of land in contact with a frontage road) is provided up to 50m. For longer frontages, the data is displayed as "50m or longer".
- Land Shape: the general shape of land is categorized as: square, almost square, rectangle, almost rectangle, trapezoid, almost trapezoid, irregular, almost irregular, and lot, etc. without road access.
- Purpose of use: provided unless if use is unknow, the field is left blank.
- Frontage Road: the width (m), type, and direction of the road in contact with the land are provided. Road types are displayed as:
    - Specified by Road Act: National Road, Prefectural Road, Municipal Road, etc
    - Road within land readjustment project area: District Road
    - Privately managed roads: Private Road
    - Other roads: Road
- City Planning: use districts designated by the City Planning Act
    - Category I exclusively low-story residential zone – 1 Exc Low
    - Category II exclusively low-story residential zone – 2 Exc Low
    - Category I exclusively medium-high residential zone – 1 Exc Med
    - Category II exclusively medium-high residential zone – 2 Exc Med
    - Category I residential zone – 1 Res
    - Category II residential zone – 2 Res
    - Quasi-residential zone – Quasi-Res
    - Rural Residential zone – Rural Res
    - Neighborhood commercial zone – Neighborhood Comm
    - Commercial zone – Commercial
    - Quasi-industrial zone – Quasi-Ind
    - Industrial zone – Industrial
    - Exclusively industrial zone – Exc Ind
    - Urbanization control area – Control Area
    - Non-divided city planning area – Non-Div
    - Quasi-city planning area – Quasi Plan
    - Outside city planning area – Out Plan
- Maximums Building Coverage Ratio and Maximums Floor-area Ratio (%): the designated Maximums building coverage ratio (%) and maximums floor-area ratio (%) are provided
- Transactional factors: provided when there is additional information that may have impact on transaction prices. They are provided only when relevant additional information is obtained via a questionnaire survey