Quantifying Flood Risk Impact on Residential Property Market in Tokyo

Introduction

Environmental disasters have threatened the resilience of society, bringing about big enough damages to even destroy civilizations throughout the human history. Recently, an addition has been made to the family of environmental risks, as intensified human economic activities have resulted in one of the major threats humanity has faced, that is, climate change (IPCC, 2014). Despite uncertainties, its impact is estimated to be at least 5% of the world's annual GDP with no adaptation policies in place (Stern, 2007), and excessive interference with the earth systems has now driven the rate of climate change to the point where it is irreversible (Rockström et al., 2009). Abrupt and irreversible changes in one of the earth systems then trigger changes in the subsystems, posing multifaceted environmental risks that need to be dealt with on many different levels.

Among such climate change-induced environmental risks, flood risk has been given an intense academic attention. Scientific evidence suggest that precipitation pattern has been increased in both intensity and frequency by climate change, thereby causing more frequent and intense floods than before all over the world (IPCC, 2014). In fact, in the U.S., the annual cost of damage from inland flooding is higher than any other disasters (U.S. Climate Resilience Toolkit, 2020). Under the 4°C scenario, the population in Central Europe, South Asia, South America and Japan that is projected to experience river flood is known to amount to ten times of that during 1976-2005 (Alfieri et al., 2017).

Given these, the recent trends in the real estate sector seem to show that the actors in the market started to take flood risk into serious considerations as a physical risk to assets and business operations. Global Estate Measurement Code for Occupiers, the unified valuation criteria for occupancy performance of properties offered by IPD (Investment Property Databank Limited), explicitly included flood risk in the checklist of factors used to measure sustainability of a property (IPD, 2013). The enforcement of TCFD (Task Force on Climate-related Financial Disclosures) worldwide, with the prevalence of ESG investment in the background, also drives recognition and integration of flood risk into portfolio management. GPIF, the largest institutional investor in the world, recently published a comprehensive report on its ESG status, reporting to what extent its domestic and overseas assets are exposed to climate change-related risk for each asset class based on TCFD framework (GPIF, 2019).

The aim of this paper is to reveal how flood risk is priced using big data that contain over 180,000 properties in the metropolitan areas of Tokyo. Provision of qualitative account of to whom and why quantified flood risk matters is also within the scope of this paper. This study uniquely targets the residential property market of Tokyo, Japan. In Asia, price implications of flood risk to property markets have generally remained unknown. Most flood risk studies have taken place mainly in the U.S., whereas in Asia these studies are scarce despite its geographical traits subject to significant flood risk and growing public concern. Following the methodology of the previous studies using hedonic techniques while utilizing market data of Japan, this paper discusses implications of quantified flood risk for the relevant actors in the housing market.

Literature review

It is essential that how flood risk might affect different actors in the real estate market be revealed, not only in quantitative terms but also qualitatively. Rather, quantitative evidence is utilized only when its qualitative implications are fully understood. However, while studies quantifying flood impact to property market have been accumulated as climate change became an increasingly well-discussed topic, those that qualitatively consider why it is important in the first place to investigate into flood discount are disproportionately scarce. A few meta-analyses of flood discount literature (Beltrán et al, 2018; Daniel et al., 2009b) and a study by Pryce and Chen (2011) are among the latter group of flood risk research. This chapter discusses why and to whom flood risk studies matter by reviewing previous literature.

Studies that investigate into flood risk impact on property price often utilize hedonic property price method, where it is assumed that a house as a differentiated market good represents a bundle of characteristics that constitutes the price (Rosen, 1974). In other words, the price of a house can be explained by its attributes, such as accessibility to the station or central business district (CBD), building area and the environmental factors such as noise, sunlight and air quality. Flood risk can theoretically be one of such attributes. Assuming rational and informed buyers, a house exposed to flood risk is expected to be discounted compared to a house that is otherwise identical, because flood risk, as a negative attribute, should be capitalized into price. The benefit of using this method is that by regressing the price by various hedonic characteristics, one can reveal whether and how much each specific factor contributes to the price. A number of previous studies employing hedonic property price method have examined the average market response to flood risk in quantified monetary value. (Bernstein et al., 2019; Bin, Crawford, et al., 2008; Bin, Kruse & Landry, 2008; Daniel et al., 2009a).

Quantifying flood risk is useful for the actors in the property market. For homeowners, the possibility that flood risk might undermine the value of a house is obviously a serious problem because real estate is usually the biggest asset in an average household, not to mention physical threat of flood. It also brings about systemic implications, because privately owned real estate plays an essential role in the financial system as a collateral for mortgages (Pryce & Chen, 2011). The failure of the market in appropriately pricing flood risk might trigger a sudden and devastating drop in the property price in case of an actual flood event (Bernstein et al., 2019). Given the importance of actively preventing such price swing, a study on flood discount can make a valuable contribution by examining whether there is flood discount beforehand, which could be used to inform homeowners if a risk factor is sufficiently perceived and capitalized or not.

Flood risk matters to investors in real estate market significantly, as it is expected to trigger devaluation of properties and all the relevant business operations. As climate change intensifies the existing environmental risks, asset owners will have to equip themselves with tools to quantify and manage further climate change risks in the portfolio, which they lack (Burgess & Rapoport, 2019). Institutional investors such as GPIF have started to quantify flood exposure in the portfolio.

Investment managers at REITs need to deal with flood risk, too. A recent report on REITs and climate change risk pointed out that 23% of 73,500 properties owned by 321 REITs were subject to flooding, and Japanese REITs were especially vulnerable to typhoons (Four Twenty Seven & GeoPhy, 2018). It is commonly understood that with ESG investment trend, REITs will frequently face requests from climate-concerned investors to disclose information about how they manage flood risk. REITs that are eager to attract ESG-enthusiastic institutional investors will find it unavoidable to manage flood risk either by investing in protection of or by retreating from properties whose sustainability is threatened. Quantified flood risk information is therefore valuable to both asset owners and REITs that need to determine the optimal risk-return with flood risk in sight.

Administrative authority has always been an actor that may benefit from a valuable insight flood studies offer, as identifying the optimal level of the government expenditure for future SLR flood adaptation by performing a cost-benefit analysis has long been one of the themes of environmental economics (Fankhauser, 1995; Yohe et al., 1996; Yohe &

Schlesinger, 1998). This line of research, however, has its own shortcomings, and flood risk study such as this one is capable of supplementing such shortcomings. First, the results are almost always unreliable due to unavoidable uncertainties in climate change scenarios. Regression approach this paper utilizes, on the other hand, has a better chance to provide results to be actually used as a tool to grasp the quantitative impact of flood to property market, because it is not subject to uncertainties as it reveals the average past response of the market participants to flood risk. Second, studies concerned with anticipation focus on flood damage rather than flood risk. The implication of this is that calculating rough estimate of potential flood damage does not necessarily reveal the real effect of flood damage and protection policy in terms of welfare, while calculating marginal willingness to pay (WTP) to flood risk can be used as a potential measure of welfare loss associated with flood risk (Pryce & Chen, 2011). Quantifying perceived flood risk in terms of property price discount can make calculation of the potential benefit of flood relief projects possible on a more accurate and regional scale by multiplying discount rate and the average property price, as Beltrán et al. (2018) demonstrates. For these reasons, flood risk research carries useful implications for administrative authorities.

Data and research method

Individual housing data with more than 200,000 initial observations were obtained from a Japanese real estate firm LIFULL. The dataset contains asking price of houses and other variables as of September 2019. Flood data were derived in 2012 through the following procedures: polygonal data were made from the digitized images of flood hazard maps, GIS data and digital cartographic data created by river administrators of the rivers flowing in or across Tokyo, as well as Kanagawa Prefecture, Saitama Prefecture and Chiba Prefecture which constitute the metropolitan area of Tokyo. Distinctions are made between below 0.5m, 0.5-1m, 1-2m, 2-5m, and 5m and higher, indicating the inundation depth in case of such event. Inundation here is defined as the result of the "Expected Maximum-scale Precipitation", determined by Flood Control Act, of either 690mm or 710mm in the total amount of rainfall. Flood data was then merged with individual housing data, giving floodplain identification to each property. When, for example, a property is located in a floodplain expected to be flooded by 1 to 2 meters because of the "Expected Maximum-scale Precipitation", the variable FLOOD(1-2m) takes the value of 1 while other flood dummies are 0 for this observation. The source of flood data is National Land Information Division of the Ministry of Land, Infrastructure, Transport and Tourism of Japan. Description of the variables and summary statistics are shown in Table 1 and Table 2, respectively. Figure 1 shows a map of the metropolitan area of Tokyo with floodplain overlay.

Given the discussion above, the research hypothesis of this study goes as follows: Properties located in flood-prone areas are priced lower than those that are otherwise identical. This research examined this hypothesis by regressing the following hedonic function:

$$\ln(P_i) = \sum_{k=1}^{K} \beta_k X_{ki} + \beta_F F_i + \varepsilon_i \quad (1)$$

where $F_i = 1$ if a property is located in a flood-prone area and 0 otherwise. Coefficient β_F is expected to show the negative sign and be statistically significant. P_i denotes the price of a property, whereas X_{ki} denotes a vector of hedonic characteristics that constitute the price.

Table 1

Description of the variables.

Variable	Description	Unit
PRICE	Asking price of a property.	Yen
AREA	Size of building area.	m^2
AGE	Building age.	Year
STATION DIST	Distance to the nearest station.	m
CBD DIST	Distance to Tokyo station. CBD stands for Central Business District.	m
BEDROOM	Number of bedrooms.	–
STRUCTURE	Dummy variable for house with wooden structure (1 if wooden, 0 if otherwise).	–
CITYPLAN	Dummy variable for house within designated urban area (1 if inside, 0 if otherwise).	–
FLOOD(0-0.5m)	Dummy variable for house within 0-0.5m flood area (1 if inside, 0 if otherwise).	–
FLOOD(0.5-1m)	Dummy variable for house within 0.5-1m flood area (1 if inside, 0 if otherwise).	–
FLOOD(1-2m)	Dummy variable for house within 1-2m flood area (1 if inside, 0 if otherwise).	–
FLOOD(2-5m)	Dummy variable for house within 2-5m flood area (1 if inside, 0 if otherwise).	–
FLOOD(5m-)	Dummy variable for house within 5m- flood area (1 if inside, 0 if otherwise).	–

Table 2

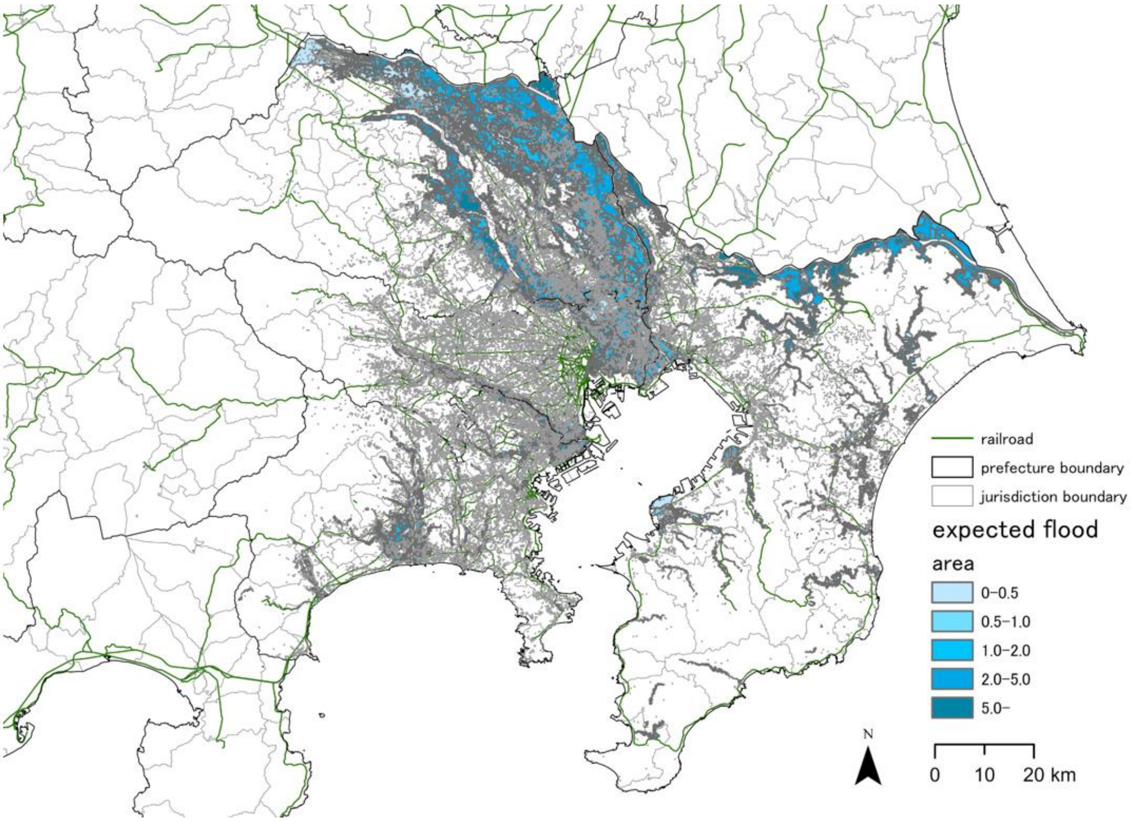
Summary statistics.

Variable	Mean	Std. Dev.	Min	Max
ln(PRICE)	17.286078	0.428325	10.021271	20.942401
ln(AREA)	4.57973	0.165925	2.037317	9.310548
ln(AGE)	0.619973	1.187065	0	5.480639
ln(STATION DIST)	6.88135	0.675916	2.250091	9.217625
ln(CBD DIST)	10.013705	0.556182	6.019051	11.502704
BEDROOM	3.610971	0.682839	1	5
STRUTCURE	0.980154	0.139471	0	1
CITYPLAN	0.937974	0.241203	0	1
FLOOD(0-0.5m)	0.065455	0.247327	0	1
FLOOD(0.5-1m)	0.055317	0.228598	0	1
FLOOD(1-2m)	0.076545	0.265869	0	1
FLOOD(2-5m)	0.060537	0.23848	0	1
FLOOD(5m-)	0.00194	0.044008	0	1

Note . Number of observations is 188,099. The samples are restricted to those that are identifiable to the block-level address.

Figure 1

A map of the metropolitan area of Tokyo with floodplain identification.



Note. Grey plots indicate the location of individual houses.

Result and discussion

Table 3 shows the regression results of (1) defined above. Statistically significant and negative coefficients were observed for all variables designed to indicate floodplain identification. This shows that flood risk does contribute to explaining changes in the price of properties. For example, properties located in 0.5-1m area were priced lower than those that are otherwise identical by 11.42%. Different discounts were observed across inundation depths, and the average discount rate was 16.2%. Properties within floodplain were priced about 16.2% cheaper on average than those that are otherwise equivalent.

As for other variables, building area was positive and statistically significant, illustrating that building area affected price positively. Building age accounted for decrease in the property price. Distance from the nearest station and CBD were both statistically significant. The negative coefficients suggest that the further a property is located from these, the lower it is priced. This is of no surprise given that in a city such as Tokyo where the public transportation is predominant in comparison to other means of transportation, the central location or proximity to the nearest stations explains much part of the amenity. Structure dummy was negative and statistically significant, indicating that a property with wooden structures is cheaper than similar properties with more resilient structures.

Table 3

Regression results.

Variable	Coef.	SE	t	
ln(AREA)	0.763	0.014	54.191	***
ln(AGE)	-0.1278	0.001	-151.911	***
ln(STATION DIST)	-0.1003	0.001	-92.613	***
ln(CBD DIST)	-0.3887	0.002	-253.102	***
BEDROOM	-0.0372	0.002	-22.628	***
STRUTCURE	-0.1646	0.009	-19.179	***
CITYPLAN	0.247	0.004	66.964	***
FLOOD(0-0.5m)	-0.1406	0.002	-57.447	***
FLOOD(0.5-1m)	-0.1142	0.003	-43.983	***
FLOOD(1-2m)	-0.1315	0.002	-57.976	***
FLOOD(2-5m)	-0.1883	0.002	-75.944	***
FLOOD(5m-)	-0.2353	0.016	-14.837	***
const.	18.5551	0.064	288.819	***
Adj. R-squared	0.588			
max VIF	1.251			
mean VIF	1.105			

Note . *** means 0.1% statistical significance; Coef. = Coefficient; SE = Standard Error; t = t value. Low VIF indicates there is no multicollinearity. SE is robust to heteroskedasticity.

In comparison, the discount rate obtained above is somewhat stronger than those derived from most previous studies. For example, a meta-regression analysis based on 314 observations performed by Beltrán et al. (2018) demonstrated that a house located in 100-year floodplain exposed to river-flood risk suffered 4.6% discount in the average property price. Another meta-analysis with 117 observations of previous estimates presented an even weaker discount rate, which was 0.6% (Daniel et al., 2009b). The rest of this section discusses some factors that can theoretically be responsible for this difference.

First, the parameters might reflect the effect of past flood events. Several previous studies have verified the importance of considering the occurrences of past flood events, as they influence buyers' risk perceptions (Bin & Landry, 2013; Bin & Polasky, 2004; Kousky, 2010). In 2018, Japan saw twice the damage from water-related disasters including flood compared to 2017. Heavy precipitation and resulting flood events most likely pushed up the level of risk perception in Japan, which might have caused strong discount. It, however, should be pointed out at the same time that the flood risk perception in Japan can have been originally high, since Japan has multiple climatic and topographic conditions that have resulted in a long history of flooding. Huang (2013) demonstrated that Japan has until today suffered from a high level of economic loss from flood disasters since the 1930s. For this reason, it is possible that high flood discount obtained from the Japanese market data was the honest reflection of Japanese people's strong risk perception.

Second, waterfront amenities this study did not control might have correlated with both floodplain identification and the property price, affecting the estimation of parameters. A major waterfront amenity is view/vista, which has been pointed out to be an important factor to control for by some previous studies, especially in the context of coastal flood (Bernstein et al., 2019; Bin, Crawford, et al., 2008; Fuerst & Warren-Myers, 2018). It, however, is also true that riverfront homes usually do not have as good views as coastal properties enjoy, which means that riverfront homes are not expected to enjoy strong premium related to proximity to water. Therefore, the cancelling effect between flood risk and waterfront amenities may not have affected the result too strongly. It is also important to note that even if such amenities did have positive effects on price, the lack of control of it would only have resulted in further discount rate, not the underestimation of it. For this reason, it is likely that the statistical significance of the obtained parameters was robust to omitted variables.

Conclusion

The purpose of this study has been to understand flood risk implications in Tokyo by employing regression analysis. Results of this study suggest that statistically significant and negative coefficients of floodplain identification variables reflected the perceived and capitalized flood risk, where discount rate amounted to as high as 11.9% on average. The research hypothesis “properties located in flood-prone areas are priced lower than those that are otherwise identical” is therefore correct, presenting evidence of flood discount in the Japanese housing market which was previously unknown. As this clarifies that flood risk negatively impacts social welfare measured by house price, governmental intervention is needed to ensure resilience and sustainability of the housing market. Those with interests in properties located in the flood-prone areas, both professional investors and residents, are also to be concerned by flood risk, as it could lead to significant devaluation at any moment in the future. Flood risk information this study provided can be used to inform relevant actors of the level of flood risk they are facing, thereby helping them make economic decisions.

Nevertheless, there are limitations as to the interpretation of the results, and these limitations point to the future possibilities in flood risk research in Japan. Past flood events that might affect the current level of risk perception, waterfront amenities that presumably have a correlation with floodplain identification, and the quality of the properties that might also have a correlation with floodplain identification need to be controlled to assure consistency in estimation of parameters. Use of a more comprehensive dataset could achieve higher explanatory power of the econometric model and less possibility of omitted variable bias. Moreover, previous literature suggested that other factors should be taken into consideration. Differentiating investors in terms of risk evaluation (Bernstein et al., 2019), information disclosure that affects risk perception (Fuerst & Warren-Myers, 2019; Troy & Romm, 2004), and the price implications of insurance programs and government aids (Bin, Kruse & Landry, 2008; Bin & Landry, 2013; McCoy & Zhao, 2018) are among the topics that should concern future research. Furthermore, future research should take into account that Japanese Flood Control Act assumes 1000-year floodplain. Since flood risk studies usually assume 100- or 500-year floodplain, understanding the numerical implication of different risk assumptions should also be needed for further development of the literature in Japan.

References

Alfieri, L., Bisselink, B., Dottori, F., Naumann, G., de Roo, A., Salamon, P., Wyser, K., & Feyen, L. (2017). Global projections of river flood risk in a warmer world. *Earth's Future, 5*(2), 171–182. https://doi.org/10.1002/2016ef000485

Beltrán, A., Maddison, D., & Elliott, R. J. R. (2018). Is flood risk capitalised into property values? *Ecological Economics, 146*, 668–685. https://doi.org/10.1016/j.ecolecon.2017.12.015

Bernstein, A., Gustafson, M. T., & Lewis, R. (2019). Disaster on the horizon: The price effect of sea level rise. *Journal of Financial Economics, 134*(2), 253–272. https://doi.org/10.1016/j.jfineco.2019.03.013

Bin, O., Crawford, T. W., Kruse, J. B., & Landry, C. E. (2008). Viewscapes and flood hazard: Coastal housing market response to amenities and risk. *Land Economics, 84*(3), 434–448. https://doi.org/10.3368/le.84.3.434

Bin, O., Kruse, J. B., & Landry, C. E. (2008). Flood hazards, insurance rates, and amenities: Evidence from the coastal housing market. *Journal of Risk & Insurance, 75*(1), 63–82. https://doi.org/10.1111/j.1539-6975.2007.00248.x

Bin, O., & Landry, C. E. (2013). Changes in implicit flood risk premiums: Empirical evidence from the housing market. *Journal of Environmental Economics and Management, 65*(3), 361–376. https://doi.org/10.1016/j.jeem.2012.12.002

Bin, O., & Polasky, S. (2004). Effects of Flood Hazards on Property Values: Evidence before and after Hurricane Floyd. *Land Economics, 80*(4), 490–500. https://doi.org/10.2307/3655805

Burgess, K., & Rapoport, E. (2019). *Climate risk and real estate investment decision-making*. Retrieved December 21, 2020, from http://www.heitman.com/wp-content/uploads/2019/02/ULI-Heitman-Climate-Risk-Report.pdf

Daniel, V. E., Florax, R. J. G. M., & Rietveld, P. (2009a). Floods and residential property values: A hedonic price analysis for the Netherlands. *Built Environment, 35*(4), 563–576. https://doi.org/10.2148/benv.35.4.563

Daniel, V. E., Florax, R. J. G. M., & Rietveld, P. (2009b). Flooding risk and housing values: An economic assessment of environmental hazard. *Ecological Economics, 69*(2), 355–365. https://doi.org/10.1016/j.ecolecon.2009.08.018

Fankhauser, S. (1995). Protection versus retreat: The economic costs of sea-level rise. *Environment and Planning A: Economy and Space, 27*(2), 299–319. https://doi.org/10.1068/a270299

Four Twenty Seven., & GeoPhy. (2018). *Climate risk, real estate, and the bottom line*. Retrieved December 21, 2020, from http://427mt.com/wp-content/uploads/2018/10/ClimateRiskRealEstateBottomLine_427GeoPhy_Oct2018-4.pdf

Fuerst, F., & Warren-Myers, G. (2019). *Sea level rise and house price capitalisation*. Retrieved December 21, 2020, from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3359289

GPIF. (2019). *ESG report*. Retrieved December 21, 2020, from https://www.gpif.go.jp/en/investment/GPIF_ESGREPORT_FY2019.pdf

Huang, G. (2013). Does a Kuznets curve apply to flood fatality? A holistic study for China and Japan. *Natural Hazards, 71*(3), 2029–2042. https://doi.org/10.1007/s11069-013-0994-2

IPCC. (2014). *Climate change 2014: Synthesis report. Summary for policymakers. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Retrieved December 21, 2020, from https://www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_SPM.pdf

IPD. (2013). *Global estate measurement code for occupiers tenth edition*. Retrieved December 21, 2020, from https://www.msci.com/documents/1296102/0/GEMCode+2013_English.pdf/c602bee6-17e8-4fee-8481-4567bc575c09#:~:text=The%20IPD%20Global%20Estate%20Measurement,by%20copyright%20and%20database%20right

Kousky, C. (2010). Learning from extreme events: Risk perceptions after the flood. *Land*

Economics, 86(3), 395–422. https://doi.org/10.3368/le.86.3.395

McCoy, S. J., & Zhao, X. (2018). A city under water: A geospatial analysis of storm damage, changing risk perceptions, and investment in residential housing. *Journal of the Association of Environmental and Resource Economists, 5*(2), 301–330. https://doi.org/10.1086/695611

Pryce, G., & Chen, Y. (2011). Flood risk and the consequences for housing of a changing climate: An international perspective. *Risk Management, 13*(4), 228–246. https://doi.org/10.1057/rm.2011.13

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S. III., Lambin, E., … Foley, J. (2009). Planetary boundaries: Exploring the safe operating space for humanity. *Ecology and Society, 14*(2). https://doi.org/10.5751/ES-03180-140232

Rosen, S. (1974). Hedonic prices and implicit markets: Product differentiation in pure competition. *Journal of Political Economy, 82*(1), 34–55. https://doi.org/10.1086/260169

Stern, N. (2007). *The economics of climate change: The Stern review*. Cambridge: Cambridge University Press.

Troy, A., & Romm, J. (2004). Assessing the price effects of flood hazard disclosure under the California natural hazard disclosure law (AB 1195). *Journal of Environmental Planning and Management, 47*(1), 137–162.

https://doi.org/10.1080/0964056042000189844

U.S. Climate resilience Toolkit. (2020). *Inland flooding*. Retrieved December 21, 2020, from https://toolkit.climate.gov/topics/coastal-flood-risk/inland-flooding#footnote3_hrm17p6

Yohe, G., Neumann, J., Marshall, P., & Ameden, H. (1996). The economic cost of greenhouse-induced sea-level rise for developed property in the United States. *Climatic Change, 32*(4), 387–410. https://doi.org/10.1007/bf00140353

Yohe, G., & Schlesinger, M. (1998). Sea-level change: The expected economic cost of protection or abandonment in the United States. *Climate Change, 38*, 447-472. https://doi.org/10.1023/A:1005338413531