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*The Value of Resilience:
Flood Risk, Information Disclosure, and Housing Markets in New York City*

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A Dissertation
submitted in partial fulfillment of the
requirements for the degree of

Doctor of Philosophy

University of Washington

2026

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Abstract

The Value of Resilience:

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Flood risk increasingly shapes where households live, how much they pay for housing, and how safety is traded off against affordability in U.S. urban housing markets. As climate change intensifies flooding hazards and expands exposure beyond traditionally recognized high-risk areas, many households face constrained choices between safer locations and affordable housing. Historically, housing markets have often failed to fully price flood risk, reflecting limited disclosure, uneven risk communication, and uncertainty about whether public mitigation investments meaningfully reduce risk. As flood risk information becomes more visible and as governments invest in resilience, understanding how households and markets navigate the trade-off between safety and housing costs is critical for equitable urban policy. This dissertation examines how flood risk, information disclosure, and mitigation investments interact to shape housing market outcomes, with a particular focus on New York City.

The first study systematically reviews the empirical literature on climate-related hazards and housing prices, highlighting how research has evolved from disaster-focused analyses toward frameworks that examine ongoing risk exposure and household decision-making. The review emphasizes how flood risk introduces a persistent safety-affordability trade-off in housing markets and identifies gaps in how studies account for information disclosure and mitigation as mechanisms that may alter this balance.

The second study examines how the evolving flood-risk information environment, including the release of risk data on real estate platforms and new disclosure requirements, affects housing prices over time using an interrupted time series approach. The findings show modest and uneven market responses, with disclosure events shifting housing price trends rather than causing abrupt repricing, suggesting gradual diffusion of flood-risk information in housing markets.

The third study evaluates whether community-level flood mitigation activities influence the relationship between flood risk and housing prices using transaction-level hedonic models. The findings show that some mitigation investments can partially offset the negative capitalization of flood risk by signaling improved safety and resilience, although the magnitude of these effects varies across neighborhoods and types of intervention.

Taken together, these studies demonstrate that flood risk is not simply capitalized into housing prices but negotiated through trade-offs among safety, affordability, and trust in public action. Risk disclosure can gradually reshape market behavior by increasing the visibility and salience of climate risk, while mitigation investments influence whether households view flood-prone locations as viable long-term housing options. By linking flood risk analytics, market behavior, and public investment, this dissertation provides policy-relevant insights into how cities can manage climate risk while addressing housing affordability and social equity.

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List of Acronyms

BLS	Bureau of Labor Statistics
ESG	Environmental, Social, and Governance
FEMA	Federal Emergency Management Agency
FIRMs	Flood Insurance Rate Maps
FSF	First Street Foundation
GRI	Global Reporting Initiative
GRESB	Global Real Estate Sustainability Benchmark
IPCC	Intergovernmental Panel on Climate Change
LAUS	Local Area Unemployment Statistics
MDC	Miami-Dade County
NYC	New York City
NFIP	National Flood Insurance Program
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SFHA	Special Flood Hazard Areas

ACKNOWLEDGEMENTS

I did not begin this journey knowing how difficult it would be. There were moments when I felt lost, moments when I had to start over, and moments when the path forward was unclear. Like many long journeys, this one was not a straight line. There were setbacks, frustrations, and times when everything seemed to collapse and needed to be rebuilt from the beginning. Yet looking back now, I realize that the meaning of this experience lies not only in the final result but in the process itself: the persistence, the learning, and the people who helped me continue when I could not move forward alone. This dissertation is the result of many acts of trust and generosity.

I am deeply grateful to my advisor, Rachel, whose guidance, patience, and belief in my work shaped this dissertation and helped me grow as a scholar. I would also like to thank my committee members Vince, Qing, Dafeng, and Ken-Yu, whose thoughtful feedback and encouragement pushed me to think more critically and more broadly about the questions I pursue. Your trust in me gave me the confidence to continue during moments of uncertainty. I am thankful for the community of the Urban Infrastructure Lab and for the many colleagues, mentors, and collaborators who made this intellectual home possible. I am especially grateful to Himanshu, Jan, and many faculty members at the University of Washington who generously shared their time, advice, and opportunities with me. Their willingness to support students with kindness and openness made an enormous difference in my journey.

This work was also made possible through the generous support of many institutions. I sincerely thank the Fulbright Program, the Taiwan Ministry of Education, the College of Built Environments, the Clean Energy Institute, and the Graubard Fellowship in the Program on Climate Change for supporting my research and education. Their support allowed me to pursue questions at the intersection of urban planning, climate policy, and infrastructure resilience. Beyond the university, I am grateful to mentors who inspired my intellectual path, including Mark Huppert, Charlie Donovan, Shih-Liang Chan, Nixon Chang, and Tse-Jen Lee. I am also thankful for the opportunity to work with colleagues at the New York City Comptroller's Office, especially Bailey Schweitzer, where I witnessed how research, public policy, and public service can come together to address real challenges facing cities. I also want to thank the communities that sustained me along the way, including the University of Washington's Taiwanese Graduate Student Association (TGSA) and the Campus Sustainability Fund (CSF). These communities reminded me that academic journeys are never undertaken alone.

My deepest gratitude goes to my family, whose love and belief in me made this journey possible. I am especially grateful to my partner, Hsuan, whose support and encouragement carried me through the most difficult moments. There were times when the path felt overwhelming, and that steady support reminded me why continuing mattered. I also want to thank my home country, Taiwan, and the people who shaped me. Taiwan's resilience, creativity, and commitment to freedom and democracy have always been a source of strength and inspiration in my life. Growing up in a society that learns to survive, adapt, and innovate in challenging circumstances has profoundly shaped how I see the world. It reminds me that nothing we achieve is guaranteed or inevitable. Every opportunity is the result of countless efforts by people who came before us.

During this Ph.D. journey, the world itself was also changing rapidly. I experienced the isolation of the COVID-19 pandemic, the uncertainties of political and social transformation, and the accelerating impact of social media, new technologies, and artificial intelligence on our societies. At times, these changes made me step back and question the meaning of higher education, scientific knowledge, and policy work in a rapidly transforming world. Yet through these reflections, I came to appreciate something fundamental: while technology may transform how we work and how societies operate, the most essential capacities remain deeply human: collaboration, negotiation, passion, trust, partnership, and creativity. These are the foundations that allow societies to build institutions, solve conflicts, and imagine better futures.

Urban planning constantly confronts difficult questions. How do we balance value and price? Where do we draw the line between efficiency and ethics? What responsibilities do we carry when our decisions shape the lives of others? These questions do not always have clear answers, but they remind me that planning is not only about technical solutions; it is about values, choices, and the kind of society we hope to build. Perhaps this is why I still consider myself a pragmatic idealist. I believe progress matters more than perfection. I believe that thoughtful processes, inclusive dialogue, and careful consideration of long-term impacts are more meaningful than simply pursuing the most efficient outcomes. And I believe that where we stand, our values, perspectives, and commitments, matters deeply.

One lesson that stayed with me throughout this journey is a simple but humbling realization: people are not always rational and often act with speculation, hope, and uncertainty. Our behaviors, decisions, and expectations are reflections of the societies we live in. Housing markets, planning decisions, and policy outcomes are therefore not purely technical or economic processes; they also mirror collective beliefs, norms, incentives, and aspirations. Recognizing this complexity is essential for planning and policymaking. Good planning must acknowledge not only models and forecasts but also the imperfect, human realities that shape how societies evolve.

Finally, I would like to thank myself for staying on this path. There were many moments of doubt: moments when everything seemed to collapse and I had to rebuild from the beginning. But I kept going. Through struggle, reflection, and persistence, I continued to learn and grow. This dissertation represents not only a long academic achievement but also a personal journey shaped by resilience, trust, and partnership. Along the way, I was often reminded not to forget where I come from. My Mandarin name, 陳勁璋, carries the meaning of strength and energy: to act with determination and give one's full effort. Coincidentally, it also echoes the phrase "change the way." Over time, this meaning has become a quiet personal motto: to approach challenges with determination, to work with integrity, and to always be willing to rethink how things can be done better. Remembering this has helped me continue forward, even during the most uncertain moments of this journey.

For everyone who supported me along the way, and for all the experiences that shaped this journey, I am deeply grateful. Accepting imperfection brings a certain freedom, and I hope to carry that freedom forward by pursuing sincere and meaningful research that begins with people and seeks to create value for society.

Chapter 1. Introduction

1.1 Problem Statement

Flood Risk Tradeoffs: Safety Versus Affordability in the Era of Climate Change

Climate change is one of the pressing challenges of the 21st century and has increased hazard risks that impose varying levels of negative impacts on cities. Looking back at historical data, the United States has experienced an increasing frequency of climate-related disasters. Among these, flooding has been the most costly hazard, affecting more than a million people annually over the last two decades. Households across the country have faced a growing number of extreme weather events, events that are statistically rare for a given location and time of year, typically falling at or beyond the 10th or 90th percentile of a probability distribution derived from historical observations (IPCC, 2022). When such patterns of extreme weather conditions persist over time, they evolve into extreme climate events, such as heavy rainfall over a season, leading to cumulative effects that are themselves extreme. These climate extremes intensify flooding and pose significant economic challenges in housing markets. Recent research indicates that the \$20 billion nationwide property loss in 2020 will increase to over \$32 billion by 2050, attributable to climate change (FSF, 2021). As floods have become more frequent and severe, houses may be destroyed by flooding and rendered uninhabitable. Even worse, people are more likely to lose their lives in extreme flooding events. Staying safe has become a priority as risks associated with climate change increase.

At the same time, housing affordability remains a critical issue for policymakers. Extreme climate events further exacerbate affordability challenges by disrupting housing supply, increasing housing demand, and raising costs. In most populous cities in the United States, growth in new housing units has failed to keep pace with population growth (Jones, 2024). Climate-related disasters, especially flooding, sweep away existing homes and displace people. The costs related to rebuilding, construction, and renovation have also risen, alongside increases in flood insurance premiums, further driving up the cost of living. As a result, housing affordability has worsened. According to recent research, nearly 33% of all households in the United States are now cost-burdened, meaning they spend more than one-third of their expenses

on housing; and in 2023, over 20 million households fell into this category, continuing a troubling trend that began in 2019, the starting point of the pandemic (Whitney et al., 2024).

Flood risk is an increasingly salient factor shaping residential location decisions in climate-vulnerable urban regions, and households are increasingly confronted with trade-offs between housing affordability and environmental safety. In response to rising housing costs, many individuals seek more affordable living arrangements, often relocating to lower-cost areas that may be more vulnerable to flooding. This pattern raises concerns about climate-induced displacement and environmental gentrification (Keenan et al., 2018). While lower-cost housing options may provide financial relief, they often entail increased flood risk due to inadequate infrastructure and services and limited flood-mitigation measures in these areas. Households facing affordability constraints are thus confronted with a difficult tradeoff: secure, higher-cost housing in safer areas or more affordable housing in higher-risk flood zones, perpetuating a cycle in which they must choose between safety and affordability. Recent scholarship debates whether constructing housing in flood-prone areas is a viable strategy for addressing housing shortages or simply a practice that exacerbates residents' exposure to flooding hazards (Hino et al. 2024).

When heightened flood risks and inadequate housing conditions intertwine, residents should not be forced to prioritize one over the other. Policies should aim to balance both objectives. Households may be able to reside in flood-prone areas if sufficient mitigation measures are in place. Likewise, strategic investments in resilient infrastructure and well-designed housing policies can help mitigate flood risks while maintaining affordability within an acceptable level of climate risk. Figure 1 presents a conceptual framework illustrating how flood risk under climate change influences the housing market.

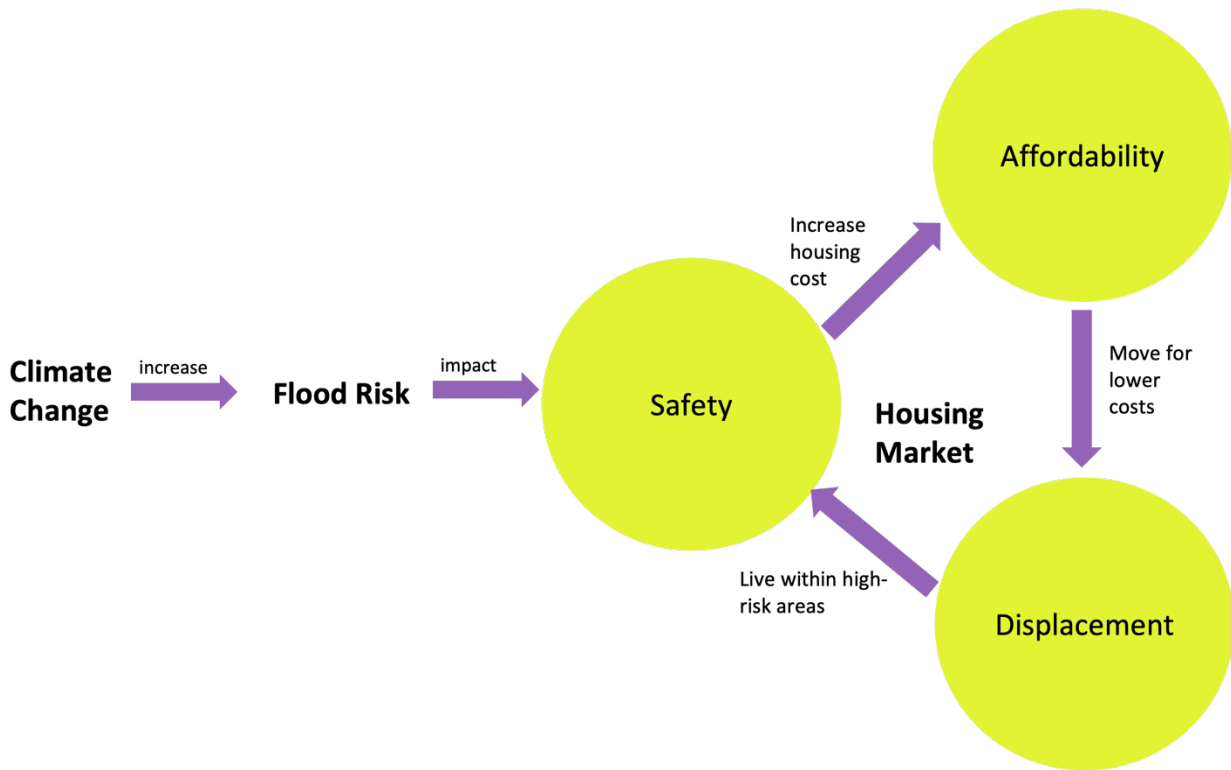


Figure 1. Conceptual Framework between Flood Risk and Housing Problems

(Source: Author)

To further explore the above framework, this dissertation examines the relationship between flood risk and housing markets in the United States, with a particular focus on how flood risk information and mitigation measures influence housing market dynamics within the broader context of urban design and public policy. The dissertation comprises three interrelated studies that collectively provide a comprehensive understanding of how flood risk shapes housing market outcomes across multiple levels of analysis. Together, these studies integrate a systematic synthesis of existing scholarship, a temporal market analysis of the evolving flood-risk information environment and disclosure interventions, and a transaction-level evaluation of mitigation effects. By combining these approaches, the dissertation offers a coherent and multi-scalar perspective on how flood risk, risk communication, and public intervention interact to influence housing market behavior and property valuation in climate-exposed urban areas.

1.2 Objectives

This dissertation aims to advance research on the climate-housing nexus from an urban planning and policy perspective, with a particular focus on how flood risk, information disclosure, and public mitigation investments shape housing market outcomes in climate-vulnerable cities. Despite increasing scholarly attention to climate change and housing markets, important gaps remain in the literature. In particular, limited research has examined how newly available climate risk information diffuses through housing markets over time, how different disclosure mechanisms influence housing price dynamics, and how community-level flood mitigation investments interact with these processes to shape housing market resilience.

This dissertation pursues three interrelated objectives. Specifically, the dissertation aims to: (1) examine how environmental hazards and flood risk have been conceptualized and incorporated into housing price research, identifying key methodological patterns and research gaps through a systematic review of the existing literature; (2) investigate how the evolving flood-risk information environment influences housing market dynamics, including how newly available flood risk information introduced through digital real estate platforms and regulatory interventions affect housing price adjustments and spatial heterogeneity over time; and (3) assess whether and to what extent community-level flood mitigation investments offset the negative capitalization of flood risk into housing prices, thereby contributing to housing market resilience and informing climate policy.

1.3 The Structure of the Dissertation

To achieve the objectives outlined above, this dissertation is organized around three overarching and interrelated themes: (1) flood risk under climate change, (2) housing prices and housing market dynamics, and (3) hazard mitigation measures. These themes provide the conceptual foundation for examining how climate-related hazards, information disclosure, and public interventions interact to influence housing market outcomes. These themes are operationalized through three substantive subthemes that correspond to the core analytical chapters of the dissertation. The first subtheme involves a systematic review of climate-related hazards and housing price research, synthesizing existing scholarship to identify key methodological patterns and research gaps. The second subtheme presents an empirical analysis of housing market

responses to evolving flood-risk information and disclosure interventions, examining how newly available risk information influences housing price dynamics over time. The third subtheme evaluates the role of community-level flood mitigation activities in shaping housing prices, assessing whether mitigation investments offset the negative capitalization of flood risk in housing markets. Figure 2 illustrates the conceptual structure of the dissertation and the relationships among these themes and subthemes, highlighting how the three studies collectively contribute to understanding the interactions between flood risk, information disclosure, and housing market behavior.

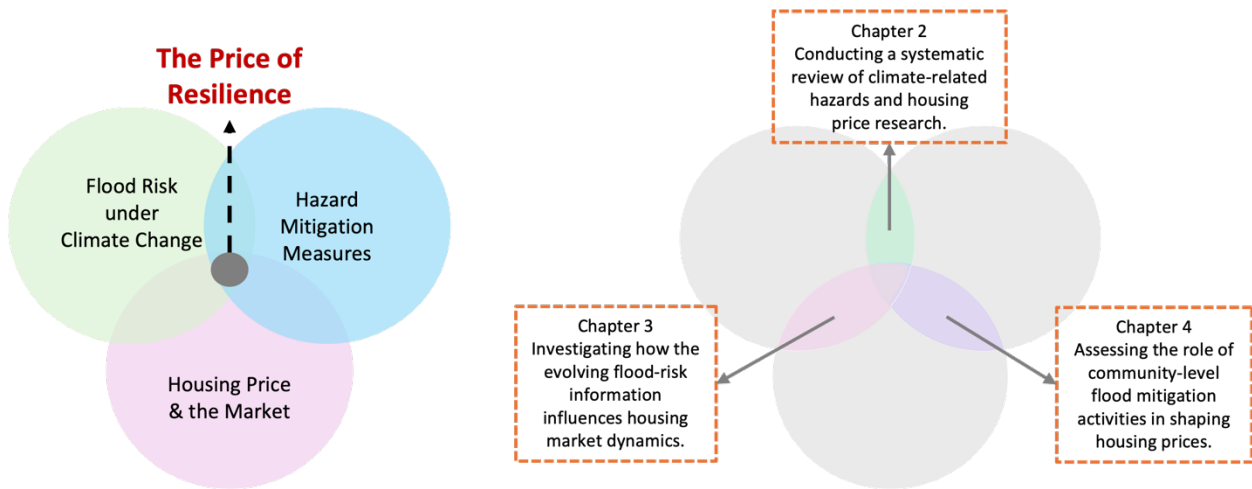


Figure 2. Dissertation Themes and Subthemes

(Source: Author)

Conceptually, the dissertation proceeds from a macro-level synthesis of existing scholarship to increasingly fine-grained empirical analyses. It begins by examining how climate-related hazards and risks have been incorporated into housing price research over time, and how the growing availability of flood-risk information has influenced housing market dynamics. The analysis then shifts to a more localized, property-oriented perspective, examining the relationship between flood risk and housing prices and assessing whether community-level flood mitigation activities moderate this relationship. Throughout, the dissertation situates housing market responses to flood risk within the broader context of urban planning, urban design, and public policy. The dissertation consists of five chapters, summarized as follows:

- **Chapter 1** introduces the research problem, situates the study within the broader climate risk–housing literature, and outlines the dissertation's objectives, scope, and structure.
- **Chapter 2** presents a systematic literature review of existing research on climate-related hazards versus risks and housing prices. Using the PRISMA framework, this chapter synthesizes recent scholarship to build a foundational understanding of how homebuyers incorporate flood risk into residential decision-making and location preferences. Particular attention is given to the growing integration of flood risk and other environmental hazards into housing price analysis. The review examines hazard types, geographic focus, methodological approaches, and key explanatory variables across studies, highlighting how flood risk has become embedded within broader housing pricing mechanisms and how research emphases have evolved over time.
- **Chapter 3** presents an empirical examination of how the evolving flood risk information environment influences housing market trends over time. Employing Interrupted Time Series (ITS) analysis with subgroup analyses, this chapter evaluates how sequential flood risk disclosure interventions, including the release of third-party flood risk data on major real estate platforms and the implementation of New York State’s flood risk disclosure law, affect housing price dynamics. Using New York City as a case study, the analysis investigates whether newly available flood risk information generates short-term market reactions, gradual adjustments in price trends, or both. The chapter highlights the growing role of digital real estate platforms in disseminating climate-risk information and shaping housing market behavior.
- **Chapter 4** builds on the preceding analyses by shifting to a transaction-level perspective to evaluate the relationship between flood risk and housing prices and the moderating role of flood mitigation activities. Using multivariate regression models grounded in the hedonic pricing framework, this chapter examines whether community-level flood mitigation measures can offset or reduce the negative capitalization of flood risk into housing prices. The findings provide empirical evidence on the effectiveness of local adaptation investments in enhancing housing market resilience and offer policy-relevant insights into the economic benefits of proactive flood mitigation strategies.

- Chapter 5** synthesizes the findings from the three core analytical chapters and discusses their broader implications for households, developers, planners, and policymakers. This chapter highlights how risk information, market responses, and mitigation investments interact to shape housing market outcomes and risk-safety trade-offs. It concludes by discussing policy implications for future flood risk disclosure and communication, and resilience-oriented public investment, and reflects on how cities can more proactively address the intersecting challenges of climate change and housing affordability. Figure 3 illustrates the conceptual and empirical connections among the three core chapters.

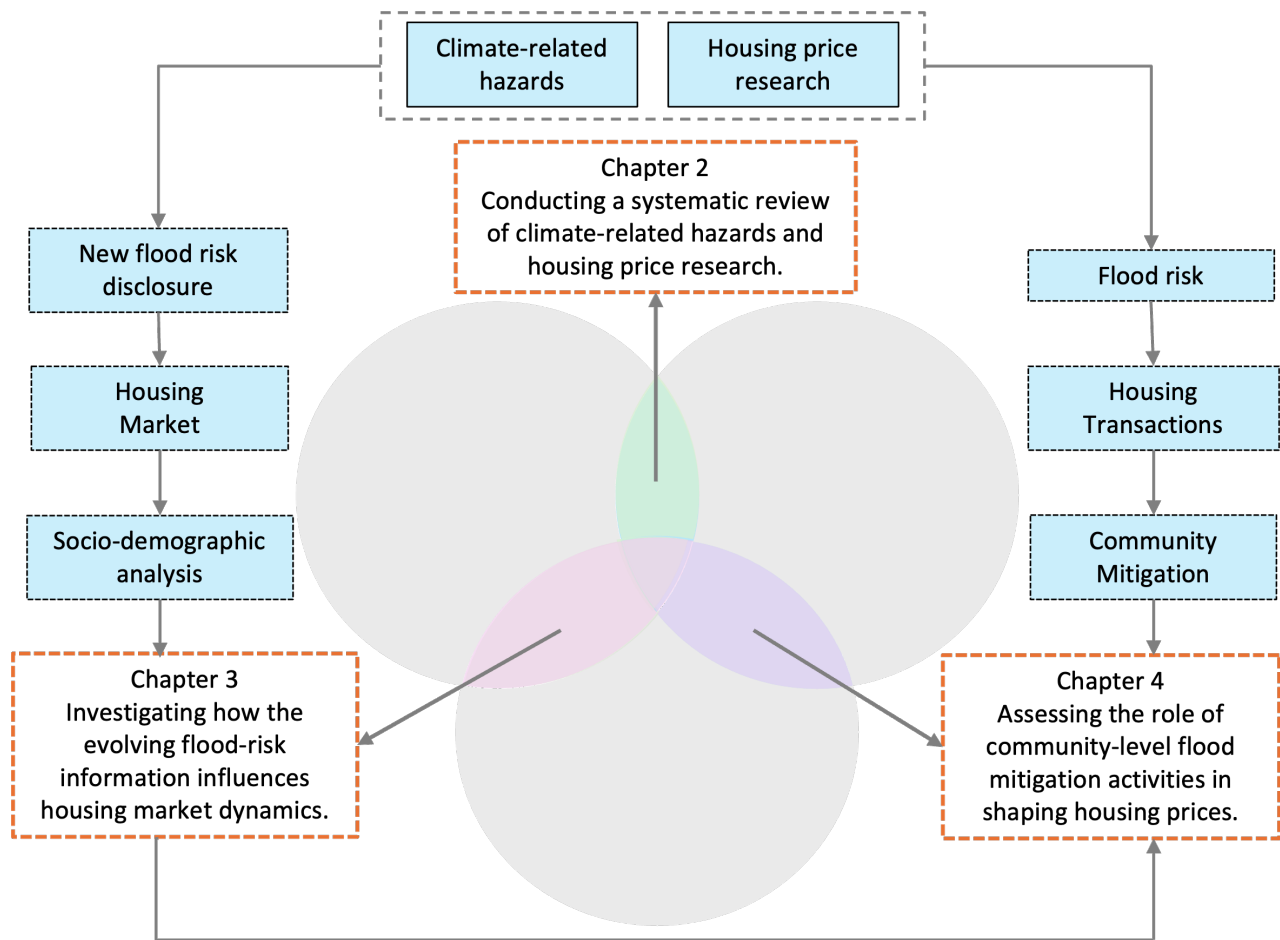


Figure 3. Main Chapters Connections

(Source: Author)

1.4 NYC Case Study

This dissertation will use New York City (NYC), shown in Figure 4, as a case study to conduct empirical studies in Chapter 3 and Chapter 4, to explore how flood risk information disclosure and community mitigation activities impacts the NYC housing markets and housing prices.

There are several reasons for selecting New York City as the case study for this dissertation. Firstly, NYC has ambitious goals to manage flood risks, making it an ideal case to examine the role of cities as frontline implementers of flood risk reduction strategies and climate adaptation measures. Flooding after Sandy in 2012, took lives, brought damage, and destroyed homes, and caused harmful mental health impacts to New Yorkers. The aftermath of Hurricane Sandy served as a tipping point for NYC to address flood risks. The city established the NYC Mayor's Office of Climate and Environmental Justice (MOCEJ) to coordinate long-term resilience efforts (NYC, 2025). Additionally, the city has integrated its flood risk management framework, covering planning, infrastructure investments, community education, and financial support mechanisms, into a single accessible website for New Yorkers (NYCEM, 2025).

Since then, the NYC government has put in lots of efforts to address flooding impacts. Several programs and flood risk management strategies have been adopted to mediate these impacts through various policies, programs, infrastructure projects, and adaptive capacity-building initiatives at multiple scales. Additionally, given its waterfront setting and high vulnerability to coastal flooding, NYC proactively adopts higher standards to meet the needs of residents, protect lives, and secure property. Recognizing potential conflicts with higher levels of government in disaster management, the city has undertaken independent initiatives to enhance its flood resilience. Secondly, NYC has developed several strategic plans to address flood risks, including the PlaNYC: Getting Sustainability Done, NYC Hazard Mitigation Plan, the NYC Stormwater Resiliency Plan, and Adapt NYC (NYC, 2024; 2022; 2021; NYC MOCEJ, 2023). These plans outline suggested mitigation strategies and vulnerability assessments, enhancing the city's capacity to withstand extreme weather events. The provision of open data and mapping tools, such as NYC Open Data, further enables informed decision-making and increases public awareness (NYC Open Data, 2024).

Thirdly, public education and awareness campaigns play a crucial role in NYC's flood preparedness efforts. Initiatives such as NotifyNYC emergency alerts and the Ready New York

guides help residents create individualized emergency plans (NYC, 2025). Additionally, resources like the Individual Emergency Preparedness and Evacuation Planning Checklist ensure that residents understand how to respond effectively during flood events. Fourthly, in addition to flood mitigation, NYC implements adaptation strategies that extend to property-level resilience measures. Programs like "Reduce Your Risk" assessments, rain garden installations, and Rainfall Ready NYC provide homeowners with guidance to reduce their flood exposure (NYC DEP, 2025; NYC, 2025). Moreover, financial support options, including loan assistance programs and FloodHelpNY, offer resources for flood insurance, property retrofits, and other risk reduction measures. By proactively managing flood risk through planning, education, mitigation, and financial support, NYC demonstrates how cities can lead in flood preparedness and climate adaptation. Its comprehensive approach serves as a model for other local governments facing similar flooding and climate-related challenges.

Therefore, this dissertation includes two empirical studies conducted at different analytical scales to examine how flood risk influences homebuyers' behavior. These studies capture both market-level and transaction-level responses to flood risk and highlight the role of flood mitigation strategies in fostering more flood-resilient communities. Further details are provided in Chapter 3. Housing Market Responses to Evolving Flood Risk Information & Disclosure and Chapter 4. The Role of Community-Level Flood Mitigation Activities in Shaping Housing Prices.



Figure 4. New York City's Zoning & Land Use Map
(Source: Map created by NYC Planning, 2026)

Chapter 2. Climate-Related Hazards, Risks, and Housing Prices: A Systematic Review

2.1 Introduction

2.1.1 Climate Change and Flood-Related Housing Market Impacts

Growing scholarly and policy attention has increasingly focused on climate change and its impacts on housing markets. According to the latest assessment by the Intergovernmental Panel on Climate Change (IPCC), climate-related risks to people and assets have intensified globally, with human and economic losses from climate-related disasters and extreme events rising sharply, particularly in urban areas (IPCC WGII, 2023). In the United States alone, more than 370 extreme weather and climate disasters causing at least \$1 billion in damages have occurred since recordkeeping began in 1980, with cumulative losses exceeding \$2.6 trillion (NOAA, 2024). These high-cost events have become increasingly frequent. Among climate-related hazards affecting housing markets, flooding consistently ranks among the top three billion-dollar disaster categories, generating widespread damage, service disruption, and long-term recovery costs (NOAA, 2024). Reflecting this growing exposure, recent survey evidence indicates that more than 80% of homebuyers now consider climate risks when purchasing a home (Zillow, 2023).

Different climate-related hazards exert heterogeneous and hazard-specific effects on housing markets. Climate-related hazards such as flooding, extreme heat, hurricanes, and wildfires influence housing systems through multiple channels, including direct physical damage, depreciation in asset values, displacement pressures, and emotional and psychological burdens borne by households; factors that are central to understanding the housing-climate nexus (IPCC WGII, 2023, p. 934). Beyond the academic literature, climate risk has also become a salient concern in private-sector real estate decision-making, particularly at the city and portfolio levels (Re & PGGM, 2019). Frameworks such as the Global Reporting Initiative (GRI) and the Global Real Estate Sustainability Benchmark (GRESB) increasingly incorporate climate risk considerations into Environmental, Social, and Governance (ESG) reporting, providing benchmarking tools to evaluate performance, efficiency gains, and emissions-reduction targets in

real estate portfolios (CFA Institute, 2023, p. 404; GRESB, 2022). However, these frameworks are primarily oriented toward commercial real estate and institutional portfolios, with comparatively limited attention to owner-occupied housing markets and residential price dynamics.

Among the range of climate-related hazards, flooding poses a particularly severe and persistent threat to housing markets. In the United States, flooding has increasingly undermined housing market stability, generating substantial economic impacts through property value depreciation, disruptions to public infrastructure, and interruptions to essential services (Gourevitch et al., 2023; U.S. Global Change Research Program, 2023). Empirical evidence suggests that, in some markets, properties exposed to flooding experience fewer transactions than comparable non-exposed properties (Bernstein et al., 2018; Harrison et al., 2001). Over the past two decades, flooding has been the costliest natural hazard in the United States, affecting more than one million people annually (NOAA 2024; U.S. Global Change Research Program, 2018). Repeated flood events constrain housing availability and increase future insurance costs, thereby raising overall housing costs and exacerbating broader affordability pressures. A central challenge in estimating the economic impacts of flood risk on housing markets lies in uncertainty regarding the magnitude, timing, and spatial distribution of future climate-related damage (Beckett, 2021). Flood exposure and flood risk remain insufficiently incorporated into urban development, housing policy, and long-term planning decisions.

2.1.2 Conceptual Pathways: Flood Events versus Flood Risk in Housing Prices

Flood-related information plays a critical role in shaping housing market behavior, yet it encompasses two conceptually distinct dimensions: flood events and flood risk. Flood events are typically defined as temporary conditions in which normally dry land becomes partially or fully inundated due to water overflow, mudflows, or rapid runoff (NOAA, 2026; FEMA, 2020). Depending on analytical objectives, floods may be classified by their spatial context within the built environment, such as urban, inland, or coastal flooding, or by causal mechanisms, including heavy precipitation, river overflow, storm surge, or coastal erosion (FEMA, 2024). NOAA (2024) further distinguishes flooding into three primary categories: flash flooding, river flooding, and coastal flooding.

By contrast, flood risk is a forward-looking concept derived from the interaction of flood events, exposure, and vulnerability, often operationalized through probabilistic metrics or composite indices (IPCC WGII, 2023). In the United States, the Federal Emergency Management Agency (FEMA) produces Flood Insurance Rate Maps (FIRMs), which delineate floodplain boundaries and risk zones based on flood frequency, proximity to water bodies, flood drivers, and structural characteristics of properties (FEMA, 2022). These maps serve as the official source of flood risk information for insurance requirements and land-use regulation. Flood risk may also be expressed probabilistically, reflecting the likelihood of inundation at a given location. For example, the National Weather Service evaluates river flood risk at forecast locations using three severity levels: minor, moderate, and major flood levels (National Weather Service, 2024). Similarly, FEMA's National Risk Index aggregates coastal and riverine flood risks nationwide and categorizes them on a five-level scale from very low to very high at the county and census tract levels (FEMA, 2024). Flood risk is further embedded in insurance pricing mechanisms through the National Flood Insurance Program (NFIP), where premiums are determined by flood zone classifications and property attributes such as elevation, number of stories, and basement presence (Kousky et al., 2020). FIRMs also define commonly referenced thresholds such as the 100-year floodplain (1% annual flood probability) and the 500-year floodplain (0.2% annual flood probability) (NYC, 2016).

Importantly, flood events and flood risk influence housing prices through distinctly different mechanisms. Studies focusing on flood events typically adopt pre- and post-disaster analytical frameworks. For example, using a meta-analytic approach, Daniel et al. (2009) compare ex-ante and ex-post housing prices and find that flood events and risk disclosures generate price effects that are often modest. Other studies examining major flood disasters document housing price discounts following flooding events (Ahmad et al., 2016; Kropp, 2012). These effects are shaped by factors such as heterogeneous risk perceptions, locational desirability, local flood mitigation investments, and government recovery policies. This event-based literature highlights flood shocks and short- to medium-term market responses, reflecting damage, recovery dynamics, and post-event information updates. However, these approaches are limited in their ability to assess how ongoing flood risk is incorporated into housing prices prior to disaster occurrence.

In contrast, studies centered on flood risk emphasize the capitalization of anticipated risk into housing prices. Some scholars suggest that properties located in high flood-risk zones are valued lower than comparable properties outside flood-prone areas (Ahmad et al., 2016), and subsequent empirical studies largely support a negative association between flood risk and housing prices, although the magnitude and direction of effects vary across contexts. In some contexts, however, coastal housing prices continue to rise despite high exposure to flood risk, underscoring the complexity of market responses (McNamara et al., 2024). Meta-analytic evidence reveals a wide range of estimated price impacts, from negative discounts to positive premiums (Beltrán et al., 2018). One challenge to evaluating flood risk is that FEMA flood risk data, the primary and official source of flood risk information in the United States, have faced sustained criticism regarding accuracy, spatial resolution, and relevance under changing climate conditions. Critics argue that FEMA’s methodologies may underestimate flood risk, particularly in the context of climate change and urban development (CFPB, 2025). Although FEMA has undertaken modernization efforts through initiatives such as Risk MAP and Risk Rating 2.0 (implemented in 2023), concerns remain regarding the ability of these tools to capture future climate risks, and many existing studies continue to rely on earlier data vintages (CFPB, 2025). Moreover, FEMA flood maps are typically produced at relatively coarse spatial scales, such as census tracts, which may limit their precision for assessing parcel-level effects on housing prices (Guin, 2023).

Despite a growing body of empirical research examining the relationship between flood-related hazards and housing prices, several important gaps remain. Existing literature reviews and meta-analyses largely synthesize studies up to the late 2010s and therefore do not capture the rapid expansion of climate risk research since 2020, a period marked by intensified climate disasters, structural shifts in housing markets, and heightened public awareness of environmental risk in the wake of the COVID-19 pandemic. Moreover, the literature remains heavily concentrated in the United States, limiting insight into how climate-related hazards are capitalized into housing prices in institutional, regulatory, and regional contexts outside of the United States. Prior research has also focused predominantly on realized hazard events rather than forward-looking measures of flood risk and probabilistic exposure. Finally, despite substantial advances in data availability and artificial intelligence, it remains unclear whether and how recent studies have

incorporated different methods and design approaches into analyses of housing prices related to flood risk.

This study addresses these gaps by providing a systematic review of climate-related hazard research on housing prices, with flood risk as the central focus, and hurricanes, storms, and wildfires examined as related comparative hazards. By incorporating studies published through 2024 and emphasizing the post-2020 period, an interval not fully captured by existing literature reviews and marked by an acceleration in climate-related disasters, the review captures recent shifts in research attention, data use, and methodological practice that are not reflected in earlier syntheses. The study further offers a global perspective by systematically documenting the global distribution of case studies and tracing the evolution of analytical approaches, identifying key methodological transition points that reflect growing concern with causality, spatial dependence, and risk anticipation. These concerns are critical because they shape the validity of empirical inference and the extent to which housing price signals can inform climate adaptation, risk disclosure, and urban planning policies. Finally, it evaluates how flood risk is operationalized in the literature, documenting the emergence of newer risk measures and data sources and clarifying how anticipated flood risk, rather than solely realized disaster events, is increasingly incorporated into housing price research.

2.2 Theory and Evidence of Climate Hazards, Flood Risks, and Housing Prices

2.2.1 Housing Prices and the Market

Housing affordability and the economic impacts of climate-driven flood risk have become growing concerns in real estate markets. As extreme weather events increase in frequency and severity, housing markets face rising exposure to both physical damage and economic instability. Scholars analyze housing markets from both macroeconomic and microeconomic perspectives. From a macroeconomic standpoint, real estate economics focuses on market-wide dynamics, including housing supply and demand, interest rates, credit availability, demographic change, and development cycles. DiPasquale and Wheaton (1996, p. 31) emphasize the role of development cycles and price dynamics, while Meen and Whitehead (2020, p. 41) highlight how interactions between supply and demand shape housing prices over time. Recent research has

placed greater emphasis on new housing supply, reflecting renewed attention to construction constraints and development feasibility (Gibb et al., 2024). Key macroeconomic drivers of housing prices include interest rates, credit conditions, population growth, and commuting patterns, all of which influence affordability and market stability.

Microeconomic analyses, by contrast, focus on individual property values and neighborhood characteristics, emphasizing the demand side of the housing market. McDonald and McMillen (2010) describe how property prices are jointly determined by internal characteristics, such as size, age, and structural attributes, and external factors, including proximity to amenities, environmental features, and public services. Urban land use and location play a central role in determining housing values, as accessibility and neighborhood desirability strongly shape buyer preferences (DiPasquale & Wheaton, 1996, p. 25). The microeconomic perspective, therefore, provides a detailed framework for understanding how property-specific attributes and local environmental conditions influence housing prices.

The hedonic pricing model is the dominant analytical framework for linking housing prices to property characteristics. Formalized by Lancaster (1966), the hedonic pricing model treats a home as a collection of features, such as size, location, and environmental conditions, and explains the sale price as the combined value of those individual features, even though they are not bought or sold separately. In simple terms, the hedonic pricing model asks how much buyers are willing to pay for each feature of a home. In housing markets, this approach estimates transaction prices (the buying and selling of homes) as functions of structural, locational, environmental, and socio-economic characteristics. McDonald and McMillen (2010, p. 185-192) emphasize that location, structural features, environmental conditions, and neighborhood characteristics are central determinants of housing prices within this framework. More broadly, housing prices can be conceptualized as functions of property-level, neighborhood-level, and regional attributes (Belke & Keil, 2018). Sirmans et al. (2005) provide a foundational systematic review of the hedonic pricing literature, and Khoshnoud et al. (2023) extend this synthesis through 2021. However, these reviews do not reflect more recent developments following major climate disasters, such as the 2021 California wildfires and the 2023-2024 hurricane and flooding events noted above.

Housing prices warrant particular attention because they reflect both current market conditions and expectations about future value increases or decreases. Prices are grounded in supply-and-demand dynamics, forward-looking expectations, and anticipated streams of housing services, shaping transactions, taxation, and insurance markets. Housing is also the primary component of household wealth, and fluctuations in property values have important implications for consumer spending and financial stability. Importantly, market prices provide a direct indicator of housing value, as they are based on realized transactions rather than appraisals or estimates (Gaca, 2018). Housing prices play a central role in linking asset and space markets and help determine how much homebuyers are willing to pay for housing services (Geltner et al., 2014). From a policy perspective, housing prices are a critical concern in debates over affordability and access to homeownership (Rappaport, 2007). Recent evidence highlights growing affordability challenges for younger cohorts: more than 90% of Generation Z identify housing affordability as a top issue, reflecting rising living costs and barriers to homeownership (Redfin, 2024). Urban economic theory further suggests that changes in housing prices influence population sorting, income distribution, and regional economic structure (O’Sullivan, 2019; Geltner et al., 2014). Home sale prices are, therefore, a central indicator of housing market health and dynamics.

2.2.2 Flood Risk and Housing Price Research

Flood risk carries long-term financial implications for homeowners, particularly given the prevalence of 30-year mortgages and the potential for repeated flood exposure over a property’s lifetime. Properties located in flood-prone areas may experience declining values, rising insurance costs, and reduced market liquidity, all of which affect household balance sheets and long-term housing affordability (Meen & Whitehead, 2020). Building on the hedonic pricing framework, a substantial body of research has examined how both realized flood events and anticipated flood risks are capitalized into housing prices. Housing constitutes a core component of household well-being, and climate change introduces additional stressors that amplify social and economic vulnerability. As the primary asset for many households, housing plays a critical role in shaping financial stability and economic resilience, making flood risk a central consideration in housing market analysis. Climate change further intensifies these dynamics by increasing both the frequency and severity of flooding and the uncertainty surrounding future exposure (Palacios, 2023).

Most empirical studies identify a negative association between flood risk and housing prices. Using FEMA floodplain designations, Harrison et al. (2001) document housing price discounts in Alachua County, Florida, based on transactions from 1980 to 1997. Bin et al. (2008) find similar price penalties for properties located within flood zones in Carteret County, North Carolina. More recent research by Hino and Burke (2021) examines whether properties are located in flood-prone areas and identifies persistent flood risk discounts in housing prices. Beyond standard hedonic models, some studies employ Difference-in-Differences (DiD) designs and spatial econometric techniques to isolate flood risk effects while controlling for confounding factors and spatial dependence. Keenan et al. (2018), for example, use a single flooding date as a cutoff in a DiD framework to estimate flood risk impacts on housing prices. Zhang and Leonard (2019) apply a spatial DiD approach and find that housing price discounts increase by 8-13% for properties located within FEMA floodplains in the Fargo-Moorhead metropolitan area.

While much of the literature relies on FEMA flood risk data, recent studies have begun incorporating flood risk information developed by private-sector and nonprofit organizations. First Street Foundation (FSF) flood risk scores, for example, have been used to evaluate long-term exposure and impacts on multi-unit residential buildings and community infrastructure over 30-year horizons (Porter et al., 2021, 2022). Other studies use FSF data to estimate national housing overvaluation driven by previously unpriced flood risk (Gourevitch et al., 2023). Comparative analyses between FEMA and FSF methodologies highlight important differences in risk distributions, insurance coverage implications, and valuation outcomes (CFPB, 2025; Ding et al., 2024; Galster et al., 2024). Despite these advances, relatively little research has directly used these new flood-risk datasets to estimate housing price discounts, underscoring an important gap in the empirical literature.

2.2.3 Study Focus

Through systemic review, this study clarifies the conceptual and empirical focus of climate-related events, risks and housing prices literature. Specifically, this study examines *how climate-related environmental hazards are conceptualized and operationalized in the housing price literature*. To address this focus, the review systematically synthesizes how hazard-related factors, including flooding, hurricanes, wildfires, and storms, have been incorporated into

housing price analyses across different regional contexts, time periods, and methodological approaches.

Flood risk is examined as the primary focus in the study and the most policy-relevant hazard for several reasons. First, flooding is the most frequent and economically costly climate-related hazard affecting housing markets in the United States and many other countries, with repeated events imposing persistent impacts on property values, insurance costs, and housing affordability. Second, unlike some climate hazards that are episodic or difficult to spatially delineate, flood risk is uniquely embedded in formal policy and regulatory systems, including land-use planning, mortgage lending, insurance requirements, and mandatory disclosure regimes. In particular, flood risk is institutionalized through publicly available risk maps, insurance pricing mechanisms, and disclosure policies, making it directly observable to market participants and policymakers. Third, flood risk represents a forward-looking and probabilistic measure of climate exposure, rather than a realized disaster event, which aligns with the dissertation's broader emphasis on how anticipated climate risks, rather than only past damage, are capitalized into housing prices. Accordingly, while the review includes studies on other climate-related hazards such as hurricanes, storms, and wildfires, these hazards are treated as comparative cases that help contextualize whether and how flood risk differs in its pricing mechanisms, data availability, and policy relevance.

2.3 Data & Method

2.3.1 Literature Search Strategy

This study utilizes a structured literature search and appraisal protocol, following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework (as illustrated in Figure 5), to conduct a systematic review of the literature (Page et al., 2021). The primary objective is to provide a comprehensive overview of how prior studies conceptualize and empirically link environmental hazards with housing prices, while ensuring rigor, transparency, and reproducibility throughout the review process.

Web of Science and JSTOR are selected as the primary bibliographic databases to support a systematic and replicable review of peer-reviewed research on environmental hazard impacts on housing prices. These databases were chosen because they provide stable, well-documented

search results that can be precisely replicated using identical search terms and criteria. Both platforms allow strict filtering of peer-reviewed journal articles and enable full export of bibliographic metadata, which is essential for PRISMA-compliant screening, documentation, and reporting. Web of Science offers extensive coverage of citation-indexed journals across disciplines, while JSTOR is well known for its high-quality coverage of peer-reviewed journals in social science, urban studies, economics, geography, and sociology; fields that closely align with the focus of this study and include key historical contributions (JSTOR, 2026). In contrast, other databases, such as Google Scholar, employ proprietary search algorithms and non-transparent ranking mechanisms that do not consistently apply reproducible logic and therefore limit transparency and replicability for systematic reviews.

The literature search targets global, peer-reviewed journal articles published between January 1, 2001, and December 31, 2024. The search strategy applies a title, abstract, and keyword query based on two conceptual categories: (1) housing market outcomes and (2) environmental or hazard risks. Rather than exhaustively including all possible lexical variants, this study makes a deliberate tradeoff to prioritize conceptual precision and relevance in the selected search terms. The initial search was conducted using the following query: ("housing price" OR "property value" OR "real estate") AND ("flood risk" OR flooding OR hurricane* OR storm* OR wildfire* OR "natural hazard*" OR "climate risk"), which quotation marks indicate exact phrases, OR links synonymous terms, AND requires both housing and hazard concepts to appear, asterisks capture word variants, and parentheses group terms to control search logic. This structure ensures both conceptual precision and reproducibility.

A Web of Science search yielded 655 records, whereas applying the same search logic in JSTOR returned 8,883 records. Duplicate articles, records outside the specified time period, non-peer-reviewed publications, and records flagged as ineligible by automated screening tools were subsequently removed, resulting in 640 records retained for the next stage of review.

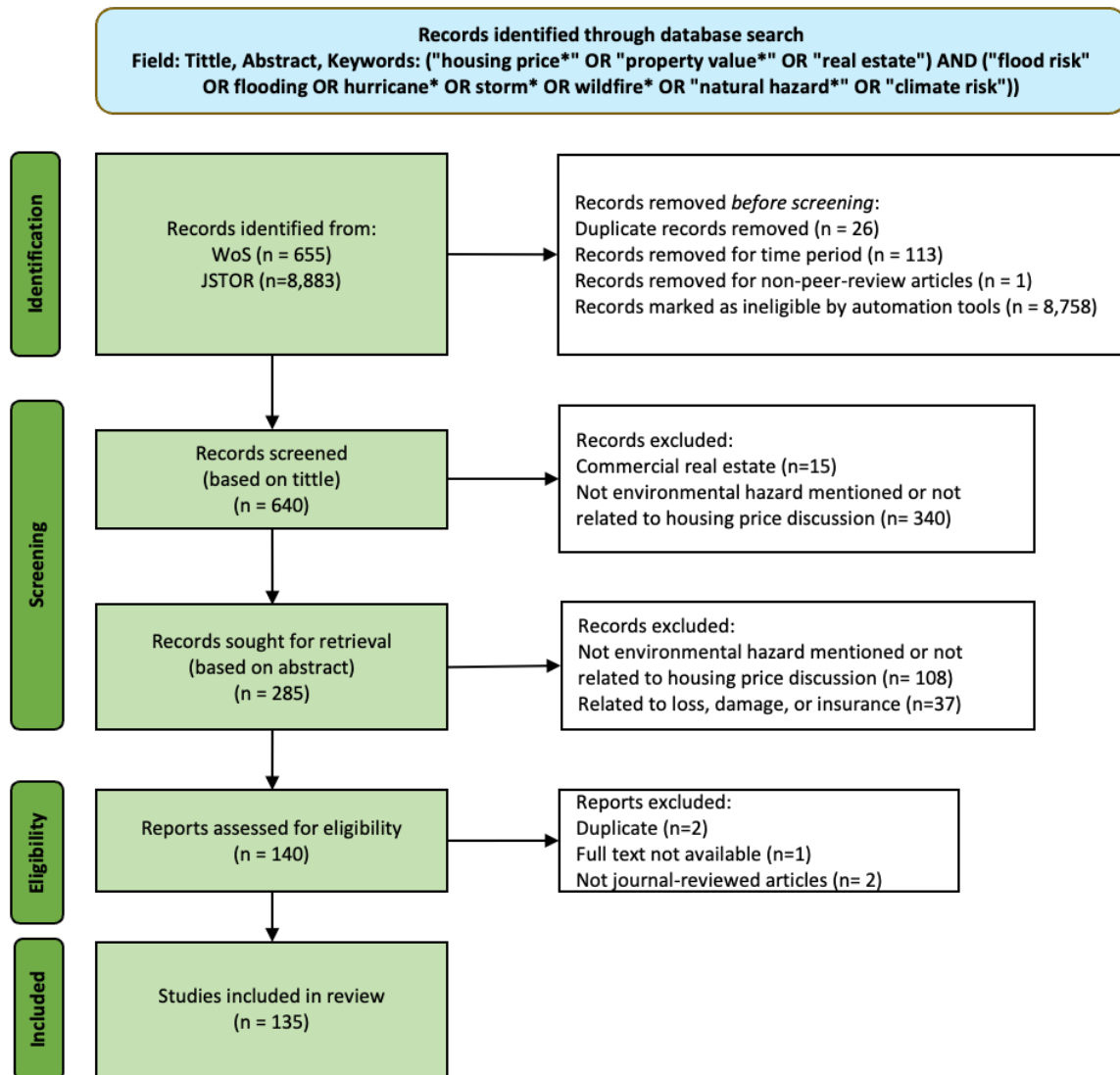


Figure 5. Number of Studies included/excluded using the PRISMA framework

(Adapted from Page et al., 2021, Fig 1)

2.3.2 Inclusion and Exclusion Criteria

To extract relevant studies from the initial identification stage, this research defines a set of pre-specified inclusion and exclusion criteria for use in the screening process. These criteria are designed to ensure that the resulting body of literature enables a comprehensive understanding of how environmental hazard considerations have been incorporated into housing market research, and focus on newer concerns between 2001 and 2024. Studies were excluded if they did not incorporate any environmental variables or were not related to housing research. Studies were included if they met the following criteria:

- The study focuses on residential real estate markets, including housing prices, losses, market dynamics, and policy discussions.
- The study references at least one environmental hazard variable in the title or abstract.
- The document type is a peer-reviewed journal article.
- The study is published in English.

Screening began with a title review to ensure alignment with the research question. At this stage, 15 studies focused exclusively on non-residential real estate markets were excluded. An additional 340 studies were excluded because they did not reference any environmental hazard or disaster and were not related to housing markets, housing policy, or housing prices.

Next, abstracts were reviewed using the same screening logic, resulting in the exclusion of 108 additional studies. To ensure that the final sample directly addressed how environmental hazards are incorporated into housing price analyses, this study further excluded 37 studies that focused primarily on losses, damages, policy frameworks, ecosystem services, or insurance programs rather than housing prices.

Finally, during the eligibility and quality appraisal stage, 2 duplicate studies, 1 study with an unavailable full text, and 2 non-journal-reviewed publications were removed. This screening process yielded a final dataset comprising 135 studies. The complete list of reviewed studies is provided in Appendix A: Systematic Literature Review List.

2.3.3 Coding Reviewed Studies

Data extraction and analysis center on the systematic coding of the studies in the dataset to develop a comprehensive understanding of how environmental hazards are discussed and operationalized in housing market research. Each full-text study was reviewed in detail. Initial coding focused on hazard type and publication year to provide a high-level overview of dominant disaster categories and temporal trends in scholarly attention.

Additional coding dimensions capture the journal of publication, which helps identify disciplinary perspectives and dominant narratives shaping the literature. The regional location of each case study is coded to assess spatial patterns in research attention. The analysis begins with a global perspective to identify countries with the largest number of studies, then narrows to U.S.-focused research, examining how state and local governmental contexts are incorporated into discussions of climate-related hazards and housing markets. Finally, the review documents the methodological approaches used to examine housing prices, with particular attention to studies employing hedonic pricing models and econometric techniques.

A structured codebook and coding protocol guide the analysis and serve as a standardized framework for identifying patterns and insights across studies. The use of a consistent coding scheme helps minimize sampling error and ensures reliability and transparency in text coding. This study develops the codebook using a deductive, theory-driven approach, following the methodological guidance of Bernard et al. (2017, p. 129), to ensure alignment with the established analytical framework. At the same time, flexibility is maintained by allowing inductive coding when emergent themes or concepts arise that are not captured by the predefined codebook. This hybrid approach enables the inclusion of novel insights while preserving analytical consistency. The primary analytical categories include:

- Hazard types and Year of publication
- Journal of publication
- Regional location of the study
- Hazard measurement
- Research design, methods, and techniques
- Key factors considered

Findings are presented narratively and supported by thematic maps, coding tables, and timeline visualizations. The complete codebook is provided in Appendix B: Coding Protocol and Codebook

2.4 Results

A total of 135 studies is included in this systematic review to examine the landscape of research at the nexus of environmental hazards and housing prices. The reviewed studies are categorized by year of publication, regional location and country of study, and primary research methods employed. This section presents the key results of the systematic literature review.

2.4.1 Hazard Types and Year of Publication

Figure 6 presents the number of reviewed studies published between 2001 and 2024, organized chronologically and further disaggregated by the environmental hazard types examined in each year. Overall, the figure reveals a gradual upward trend in publications over time. The largest number of studies published in a single year was 16, in 2020 and 2022. Across hazard categories, flooding is the most frequently studied hazard, accounting for 38 studies in total and consistently representing the largest share of publications in most years. Flooding has therefore been identified as the priority hazard in the literature over time. Loss aversion has also received increasing scholarly attention in recent years, while other behavioral biases have gradually gained momentum, indicating substantial underexplored areas.

A deeper examination of flooding-related studies shows that approximately 50% of these studies focus on the United States. This concentration may be attributed to the United States' position as one of the world's largest financial and capital markets, as well as its extensive scientific and technical capacity for catastrophe modeling and flood risk assessment. These conditions have prompted housing researchers to examine the nexus between real estate investment and flood risk to better understand how flooding is capitalized into housing prices and how physical risks may be mitigated in the future. In addition, the U.S. housing market may be particularly sensitive to severe economic shocks, such as the 2008 financial crisis and the 2020 COVID-19 pandemic, which may further motivate empirical research in this context.

As flood risk information has become increasingly open-sourced and housing data more accessible, researchers have gained greater capacity to conduct empirical analyses using digital platforms, government open-data portals, and proprietary databases. Several temporal peaks in publication activity appear to correspond to major disaster events. For example, Hurricane Katrina in 2005 was followed by a noticeable increase in studies focusing on flooding and

hurricanes between 2007 and 2011. Since 2020, the global COVID-19 pandemic and the occurrence of multiple large-scale disasters worldwide have coincided with a shift in research focus from single-hazard analyses toward multi-hazard discussions. In particular, wildfires have received increasing attention in housing price research, driven by catastrophic events such as the 2019-2020 Australian bushfires and the 2023 Canadian wildfires. By contrast, studies examining sea-level rise do not exhibit a consistent pattern of publication over time.

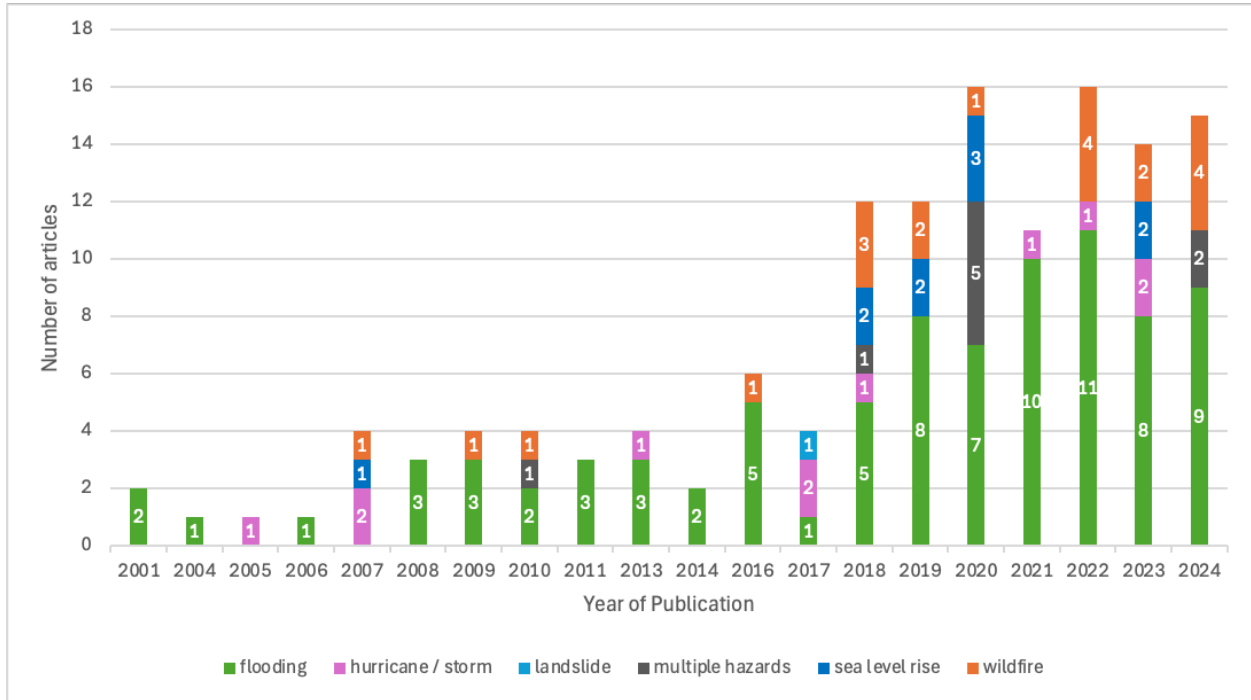


Figure 6. Studies Distribution by Year of Publication

(Source: Author)

2.4.2 Journal of Publication

Figure 7 summarizes the distribution of reviewed studies across academic journals. In total, 135 studies were published across 81 journals, indicating a high degree of disciplinary involvement. Among these, 15 journals published three or more studies related to environmental hazards and housing prices. The Journal of Land Economics, Journal of Real Estate Finance and Economics, and Ecological Economics rank as the top three journals, collectively publishing 22 studies on the capitalization of environmental hazards in housing prices between 2001 and 2024. The Journal of Land Economics is the most prominent outlet, with 10 published studies, nine of which focus on flooding and sea-level rise.

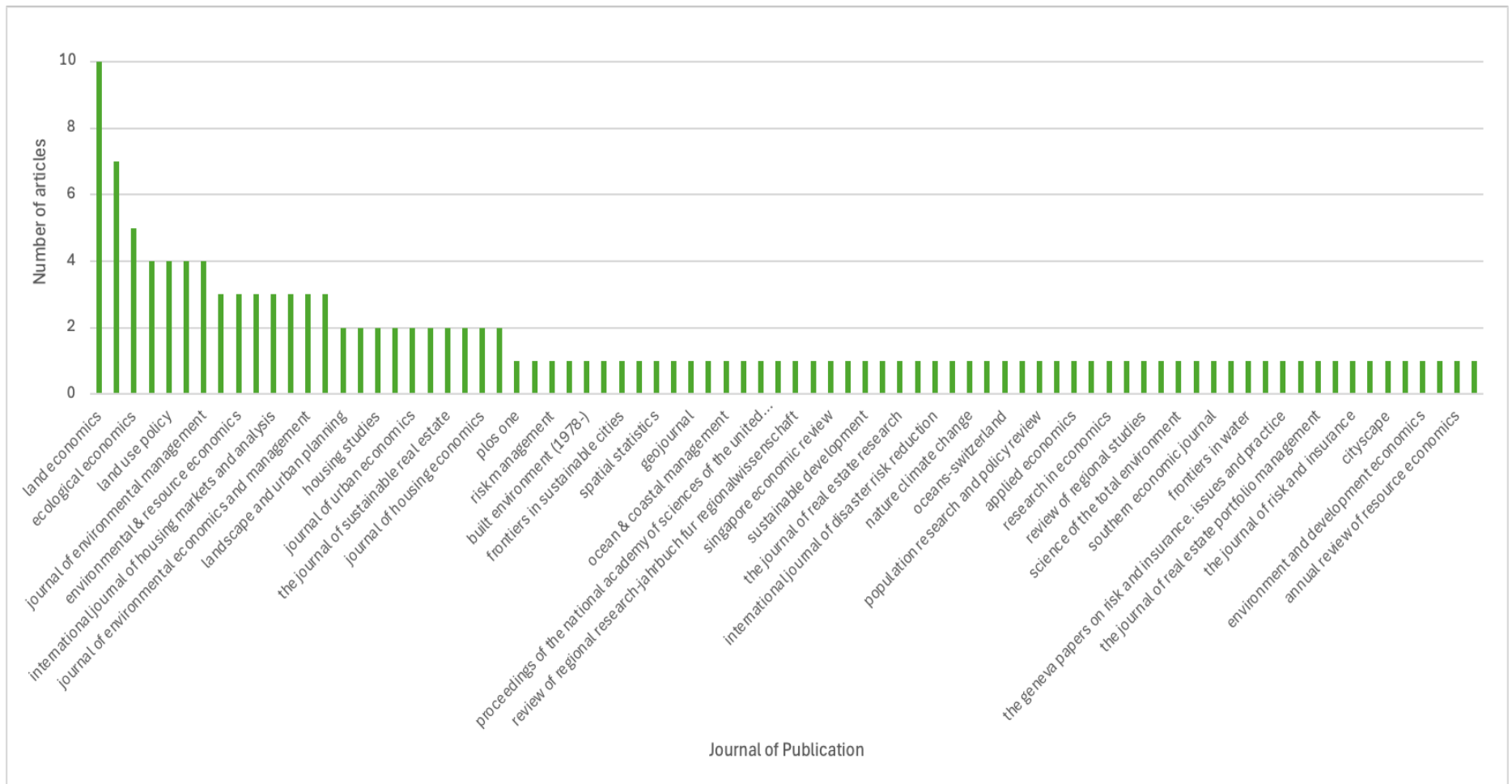


Figure 7. Studies Distribution by Journal of Publication

(Source: Author)

2.4.3 Location of Study

Figure 8 and Figure 9 examines the distribution of reviewed studies using country and regional location as key metrics to assess where scholarly attention has been concentrated globally. Over the past 25 years, the United States has accounted for more than 60% of the reviewed studies, making it the most frequently studied country. Among U.S.-focused studies, more than half examine flooding-related impacts on housing markets, while wildfires have emerged as another major hazard of interest, particularly in the past five years. Australia ranks second, with 10 reviewed studies, primarily focused on flooding and wildfires. Most Australian case studies are concentrated in Queensland, often referred to as Australia's "Sunshine State", the country's third-most populous region. Major disaster events such as the 2010-2011 Brisbane floods and the 2015 Sampson Flat bushfires are frequently cited across these studies. China ranks third in the review, with all identified studies focusing exclusively on flooding.

Several other countries and regions also show notable scholarly engagement with environmental risk and housing prices. The Netherlands and Canada have multiple studies evaluating the impact of floods on housing values. In East Asia and Southeast Asia, countries including South Korea, Malaysia, Taiwan, Thailand, Vietnam, and Indonesia have seen increasing research attention on hazards, particularly in the past five years (2020-2024). Notably, all studies from these regions focus on flood events. By contrast, Japan appears in only one study on flooding, which may reflect a research focus on other hazards, such as extreme heat, tsunamis, and earthquakes.

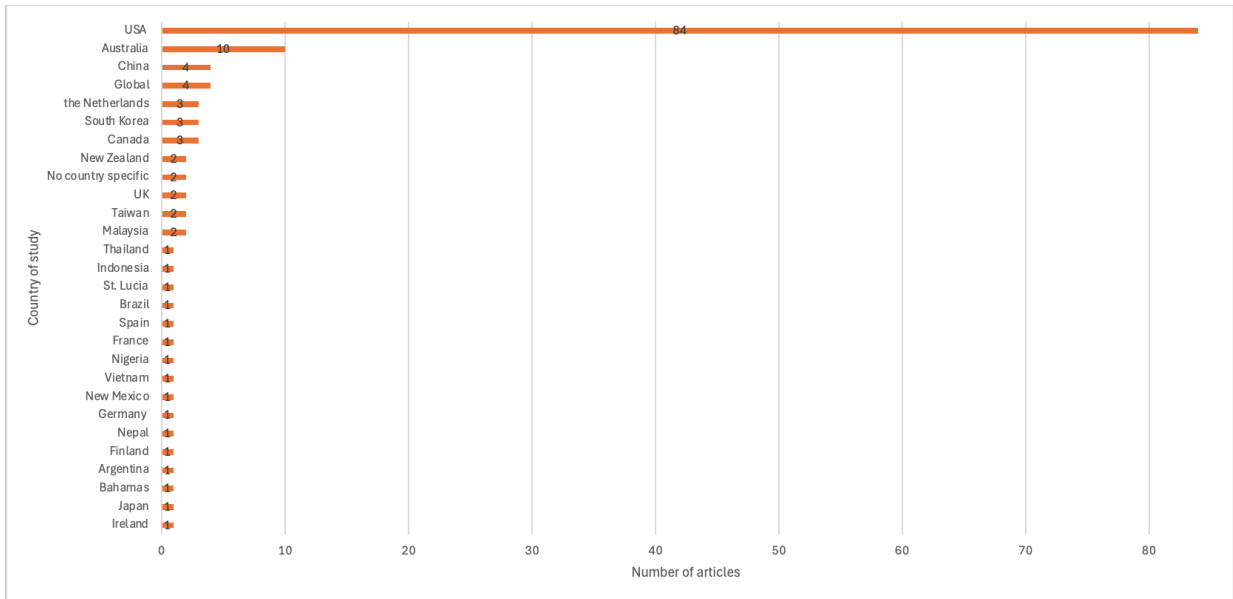


Figure 8. Frequency Distribution based on the Country of Data Collection

(Source: Author)

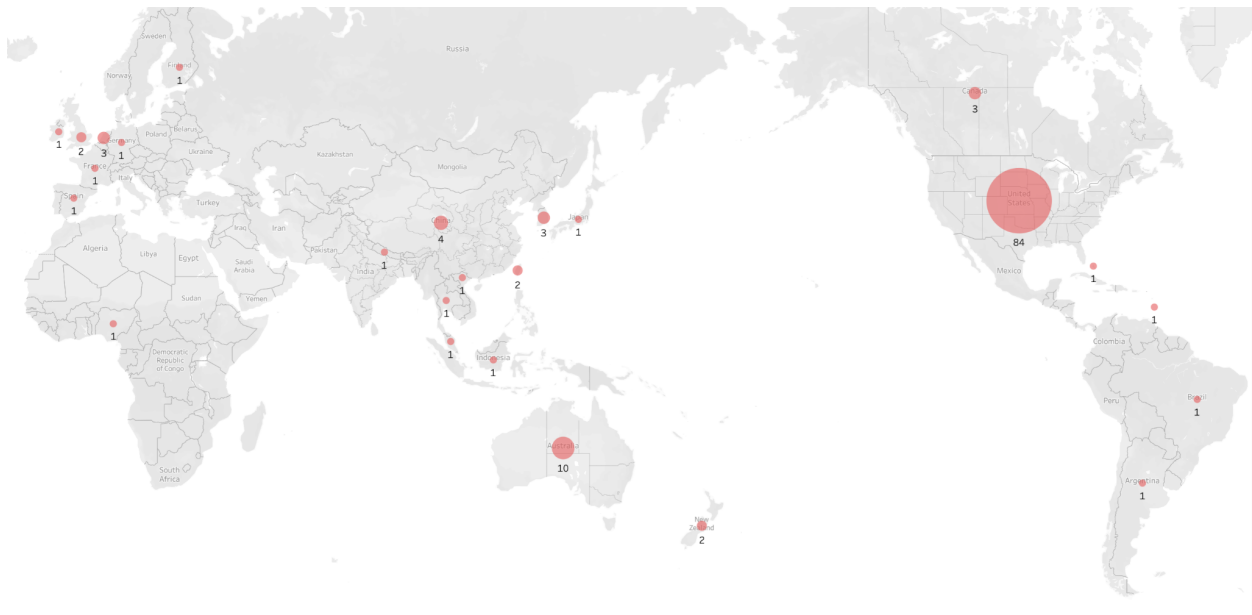


Figure 9. Global Distribution of Reviewed Articles by Study Location

(Source: Author)

Focusing more closely on the United States, Table 1 presents the distribution of reviewed studies by hazard type at the state level. Florida, New York, North Carolina, and Colorado emerge as the most frequently studied states. Water-related disasters dominate housing price analyses in most states; however, Colorado stands out for its greater emphasis on wildfires, with more wildfire-focused studies than flood-related ones. California has experienced numerous recent disasters, including the 2024 California wildfires and multiple atmospheric river events that caused widespread flooding in early February 2024 (CNN, 2025; The New York Times, 2024). The reviewed literature places greater emphasis on wildfire impacts, with relatively limited attention to flooding-related effects on the housing market.

At a finer spatial scale, the review also classifies studies by whether they focus on local jurisdictions. More than 50% of the reviewed studies center on specific counties or cities, reflecting the localized nature of housing markets and substantial variation across submarkets and socio-demographic contexts. Miami-Dade County, Florida, and New York City, New York, are the most frequently examined local case studies since 2018. Additionally, numerous studies focus on Southern California and New Orleans, Louisiana, particularly regarding the impacts of flooding on local housing markets. The concentration of studies in these municipalities is often attributable to major disaster events and their profound effects on housing markets. For example, Hurricane Katrina in 2005 and Hurricane Sandy in 2012 have drawn sustained scholarly attention to flood-related impacts on housing. Variations in federal administrations and disaster-related funding priorities may also have direct or indirect effects on the volume and direction of research in this area.

Table 1. Frequency Distribution in the USA by Hazard Types

State name	Flooding	Hurricane / storm	Landslide	Multiple hazards	Sea level rise	Wildfire	Grand total
FL	9	3		1	1		14
NY	2	2			2		6
NC	4	2					6
CO	2					4	6
LA	4					1	5
CA				1		3	4
ND, MN	3						3
SC	2						2
PA	2						2
GA	1				1		2
TX	1			1			2
MD et al. ¹					2		2
MS	2						2
FL, NY				1			1
MT						1	1
TX, FL, NC		1					1
HI					1		1
AZ						1	1
NJ	1						1
50 states and D.C.				1			1
IA	1						1
WA	1						1
OH	1						1
CT	1						1
OR, CO, ND	1						1

¹: including MD, VA, WV, DE, PA, NY, Washington, D.C.

(Source: Author)

2.4.4 Hazard Measurement

Across the reviewed literature, environmental hazards are operationalized using two primary measurement approaches: realized hazard events and forward-looking hazard risk. The results of this systematic review indicate a clear imbalance between these approaches, shown in Table 2. Among flood-related studies, fewer than 25% explicitly operationalize flooding using measures of flood hazards, while the majority focus on flood risk and their effects on housing prices. This pattern suggests that the flood-related literature emphasizes the capitalization of anticipated flood risk. However, wildfire studies put more focusing on event-based measures and research post-disaster market responses to events, especially in work published after 2020.

Event-based flood measures are typically constructed using the timing and location of major flood disasters, such as hurricanes, storm surges, or riverine flooding, and are often analyzed using pre-post or quasi-experimental designs. These studies primarily examine short- to medium-term housing price adjustments following a flood event, including price discounts, transaction delays, and recovery trajectories. While this approach provides valuable insights into market responses to realized damage, it does not directly capture how ongoing or probabilistic flood exposure is priced into housing markets prior to disasters.

By contrast, flood risk-based studies operationalize hazard exposure using probabilistic or spatially defined risk indicators. In the United States, FEMA flood risk data, particularly Flood Insurance Rate Maps (FIRMs) and floodplain designations, remain the dominant source of flood risk information used in housing price research. Studies in other countries similarly rely on official flood risk maps or nationally standardized risk assessments produced by government agencies. These risk-based approaches are more closely aligned with policy and regulatory frameworks; however, such measures remain underutilized relative to event-based indicators in the flood-housing literature.

The use of flood risk data from private-sector or nonprofit organizations is notably limited in the reviewed studies. Only a small subset of recent research incorporates alternative flood risk measures developed by private firms or NGOs, reflecting both the relatively recent availability of these datasets and ongoing debates about comparability with official government sources. Empirical evidence on how non-governmental flood risk information is capitalized into housing prices remains sparse, representing an important gap in the literature.

In contrast to flood-related research, studies examining wildfires more frequently adopt risk-based measures, particularly in work published after 2020. Many wildfire studies incorporate modeled wildfire risk, burn probability, or exposure indices rather than focusing exclusively on realized fire events. This shift may reflect differences in data availability, recent critical disaster events, and regulatory context, as well as growing recognition of wildfire risk as a chronic and spatially diffuse threat rather than a purely episodic disaster.

Overall, these patterns indicate that the housing price literature remains largely risk-driven for flooding, while event-based approaches are more prevalent in wildfire research. This divergence has important implications for understanding how different climate-related hazards are priced in housing markets and for assessing the extent to which anticipated climate risks, rather than realized disasters, are incorporated into market valuations.

Table 2. Event-based vs. Risk-based Measures by Hazard Types

Hazard types	Both	Event	Risk	Total
flooding	8	19	57	84
hurricane / storm	0	5	6	11
landslide	0	1	0	1
multiple hazards	0	6	3	9
sea level rise	0	1	9	10
wildfire	2	11	7	20
Grand Total	10	43	82	135

(Source: Author)

2.4.5 Research Methods and Analytical Techniques in the Reviewed Literature

Figure 10 summarizes the methodological approaches used in the reviewed studies to examine the relationship between environmental hazards and housing prices. Hedonic pricing regressions are the most commonly employed technique, accounting for approximately 35% of the reviewed studies. Many studies build on the hedonic framework by incorporating methodological enhancements to better capture local market conditions and control for heterogeneity. These

enhancements include the use of fixed effects to account for temporal and spatial variation, as well as explicit modeling of spatial dependence in housing prices. Additional approaches include matching methods (e.g., propensity score matching and nearest-neighbor matching), semi-parametric splines, and distance-decay optimization techniques. Building on the hedonic framework, many studies employ DiD designs, a quasi-experimental approach widely used in urban and policy research, to strengthen causal inference. Variants of DiD used in the literature include panel DiD regressions, triple-differences (DDD), dynamic DiD (event-study designs), and staggered DiD specifications. Spatial methods are also integrated into research designs and statistical models to account for geographic relationships, such as proximity, contiguity, and spatial dependence. Commonly used spatial techniques include spatial error models, spatial autoregressive (spatial lag) models, and geographically weighted regression (GWR).

In addition to econometric and quasi-experimental approaches, several studies adopt narrative literature reviews and meta-analyses to assess how environmental hazards affect housing markets. Some papers employ systematic review frameworks to synthesize prior findings and conceptualize the impacts of environmental disturbances on housing prices (Contat et al., 2024; Craig, 2022; Nicholls, 2019; Pryce & Chen, 2011). Others provide broader commentary on the economic implications of climate risk for housing and financial systems (Craig, 2022; Kellenberg & Mobarak, 2011). Meta-analytic studies aggregate effect estimates from existing research using statistical weighting to derive pooled estimates of flood risk capitalization in housing prices (Beltrán et al., 2018; Daniel et al., 2009). Qualitative methods are also employed in some studies, including survey-based research examining perceptions of sea-level rise and its adverse effects on housing prices (Mohsen et al., 2024).

To address multiple research questions and enhance robustness, some studies employ mixed-methods approaches that combine multiple analytical techniques. For example, Hino and Burke (2021) employ DiD, panel regressions, and cross-sectional analyses to estimate flood-risk capitalization in U.S. housing markets. Atreya & Czajkowski (2019) integrate spatial autoregressive models, DiD designs, and hedonic regressions with fixed effects to examine flood risk in Texas. Beyond flooding, Dong (2024) applies DiD, propensity score matching, and spatial panel regression models to analyze the impacts of wildfires on home values in California.

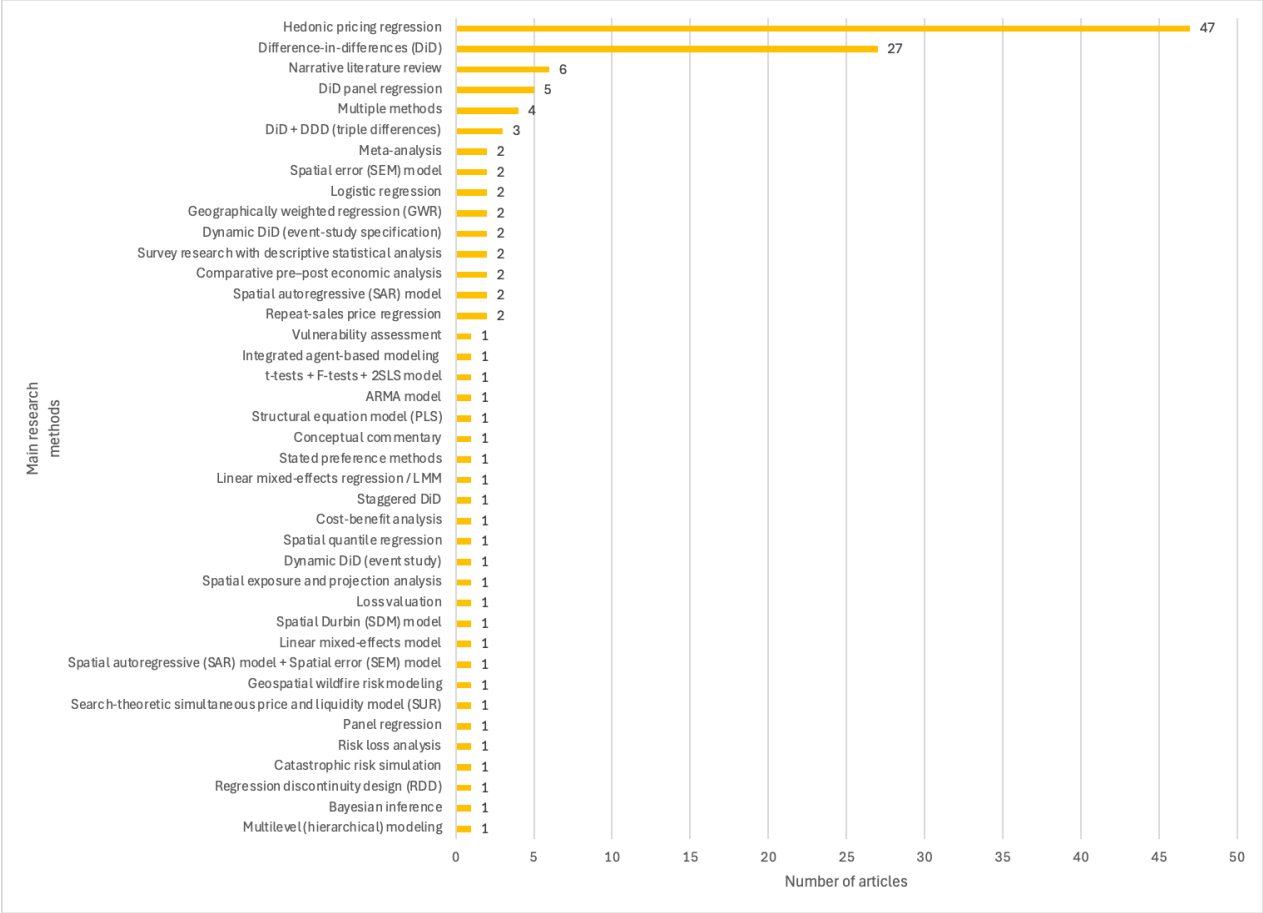


Figure 10. Frequency of Main Research Methods used in the study

(Source: Author)

Examining methodological trends over time reveals several key shifts in the literature. Figure 11 highlights a clear methodological evolution across three temporal cutoff points. Early studies between 2001 and 2009 relied primarily on hedonic pricing regressions and comparative pre-post economic analyses, focusing on hazard capitalization without explicit causal identification. Around 2010, research increasingly moved beyond descriptive associations toward more advanced causal inference strategies.

Another transition emphasizes the shift from static analyses to dynamic, heterogeneous effects. Based on hedonic modeling, after 2016, studies expanded the use of spatial econometric methods and increasingly employed dynamic DiD models, RDD, and repeat-sales approaches. Finally, following 2020, the literature further evolved to incorporate spatially explicit climate-risk modeling, simulation-based approaches, and meta-analyses. This progression signals a broader

transition from event-based impact estimation toward systemic assessments of climate risk in housing markets.

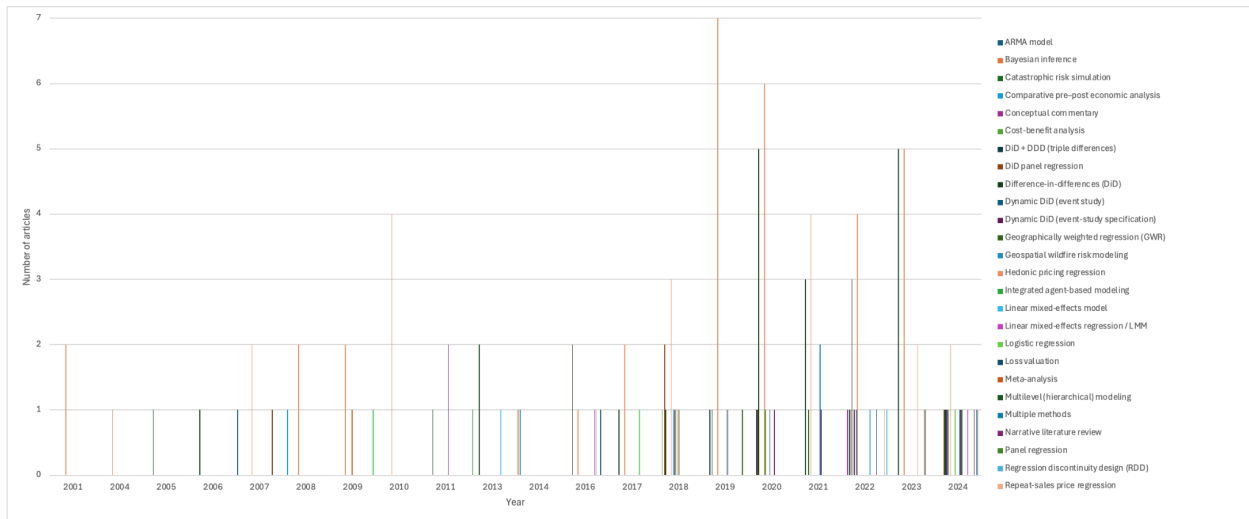


Figure 11. Frequency of Research Methods by Published Year

(Source: Author)

2.4.6 Key Factors Considered in the Reviewed Studies

In examining the relationship between climate-related risks and housing prices, the reviewed studies consistently control for a range of additional factors known to influence housing prices. Within the hedonic pricing framework and focusing on flood hazard, these factors are incorporated as control variables to isolate the marginal effect of flood hazards on housing prices. Controlling these characteristics is essential, as housing prices reflect a bundle of structural, locational, environmental, and socio-economic attributes, many of which are correlated with climate exposure.

Location and geographic characteristics are among the most fundamental determinants of housing prices and are universally controlled for in the reviewed studies. Location captures access to employment centers, transportation networks, amenities, and neighborhood desirability. For example, Baldauf et al. (2020) demonstrate that location and land size are persistent and dominant drivers of housing prices. In climate-housing research, location controls are particularly important because environmental hazards are spatially correlated, and failure to account for geographic variation may confound hazard effects with broader neighborhood or regional price differentials.

Property and structural characteristics are also routinely included in housing price models. These attributes typically encompass building size, number of bedrooms and bathrooms, lot size, age of the structure, and construction type. Hino and Burke (2021) find that square footage, room counts, and building age significantly influence how flood risk is capitalized into housing prices. Similarly, Bin et al. (2008) report that structural characteristics such as building age and lot size are statistically significant predictors of home values in flood-prone areas. Additional property-level amenities, including swimming pools, garages, and overall property condition, are often included to capture quality differences across homes (Miller et al., 2019). Controlling for these factors ensures that estimated hazard effects are not driven by systematic differences in housing quality.

Environmental and amenity-related characteristics, which refer to neighborhood-level facilities and environmental attributes, represent another important category of control variables. Early work by Diamond in 1980s shows that waterfront properties command price premiums relative to inland properties, a finding supported by later studies documenting a 7.2% premium for waterfront homes in Tampa, Florida (Dumm et al., 2016). Access to public amenities, such as proximity to downtown areas, highways, parks, coastlines, and open space, also significantly influences housing prices (Bin et al., 2008). The price effects of environmental amenities may extend over considerable distances; for example, proximity to large parks has been shown to increase housing prices well beyond adjacent parcels (Crompton & Nicholls, 2020). Some studies further incorporate composite amenity indices, land-use characteristics, and zoning controls at aggregated spatial scales, such as the zip-code level, to capture broader environmental and regulatory contexts (Baldauf et al., 2020).

Socio-demographic, market, and regulatory characteristics are also commonly included as controls in climate-housing price studies. Socioeconomic factors such as household income, education levels, and population characteristics influence housing demand and willingness to pay. Daniel et al. (2009) find that although households invest in reducing risk exposure, higher-income homebuyers may negotiate more favorable prices, suggesting heterogeneous responses to environmental risk. Baldauf et al. (2020) control for population, income, education, and political preferences at the zip-code level when examining the relationship between climate change beliefs and housing prices, while Mueller et al. (2014) include median household income and

education levels in their analyses. Market conditions and macroeconomic dynamics further shape housing prices and are often controlled for using time-varying indicators or fixed effects. Studies incorporate variables such as unemployment rates, vacancy rates, and mortgage interest rates to account for broader economic cycles that affect housing demand and affordability (Kim, 2020; Mueller et al., 2009). To address unobserved market fluctuations, many studies employ location-by-time fixed effects, such as zip-code-by-year or county-by-year fixed effects, which absorb localized market trends and policy changes (Kelly & Molina, 2023; Gourevitch et al., 2023).

Finally, regulatory and insurance-related factors play a critical role in shaping housing prices in hazard-prone areas. Flood zoning, insurance requirements, and premium costs directly influence ownership costs and risk perceptions. Bin et al. (2008) find that properties located within designated flood zones sell for approximately 6-8% less than comparable properties outside such zones, reflecting higher insurance costs and perceived risk. These regulatory variables are particularly important in studies examining flood risk, as they represent institutional mechanisms through which environmental hazards are translated into housing market outcomes. Table 3 summarizes the key categories of factors commonly included in the reviewed studies.

Table 3. Key Control Variables Used in Hedonic Housing Price Studies

Category	Determinants
Location and Geography	location, lot size, elevation
Property and Structure	living area, property type, rooms, bedrooms, bathrooms, year built, additional improvement areas and amenities (swimming pools, garages...), base elevation, story
Environment	Access to natural resources (parks), distance to water bodies, waterfront properties, access to public amenities (Metro, Bus, schools, downtown and commercial areas, highways, brownfield), historical flood events and experience, flood risk exposure, future flood risk projections
Socio-demography	Race (White/non-white), income, education levels, fraction of renter, climate change beliefs
Market dynamics	Mortgage interest rates, new home units, unemployment rates, vacancy rates, Great Recession, Covid-19 pandemic
Regulation	land use, flood zoning controls, insurance premiums rate, CRS communities

(Source: Author)

2.5 Discussion

This study conducts a systematic literature review to develop a high-level understanding of how environmental hazard factors are examined in relation to housing prices. Several key findings emerge from the review. Firstly, over the past 25 years, most reviewed studies have focused on flood hazards and flood risk, with a substantial increase in publications since 2020. More recent work has also expanded attention to the relationship between wildfires and housing prices. Notably, many of these studies examine pricing effects in the post-disaster period, reflecting growing interest in how housing markets respond to realized climate shocks rather than to anticipated risks alone.

Secondly, the distribution of journal publications indicates that economics-oriented journals account for the largest share of the reviewed studies. From a regional perspective, the United States dominates the literature, whereas Australia is the second most frequently studied country. In both contexts, flooding and wildfires are the primary hazard types examined. Zooming in on the U.S. housing market, Florida and New York are the most frequently cited case-study locations, with many studies explicitly referencing major disaster events that significantly affected local housing markets. These findings highlight the concentration of research in regions with high exposure to climate-related hazards and substantial housing market activity.

Third, in terms of methodology, hedonic pricing regressions and DiD approaches are the most widely used empirical techniques, often supplemented with spatial methods to address housing price dependence and geographic spillovers. Despite the rapid growth of data science and artificial intelligence applications in related fields, machine learning approaches remain relatively limited in the reviewed housing price literature. This may be partly attributable to the study's search terms and analytical focus, which emphasize explicit links between climate risk and housing prices rather than purely predictive modeling.

Future Research and Limitations

Several avenues for future research emerge from these findings. First, additional work could explore the effectiveness of mitigation strategies and policy interventions, as well as their potential moderating or mediating effects on the relationship between climate risk and housing prices. To maintain a clear focus on hazard types and physical climate risks, this study

deliberately excludes mitigation policies and programs from the review. However, understanding how adaptation investments and regulatory interventions alter housing market responses to environmental hazards represents an important extension of the existing literature.

Second, future research could place greater emphasis on behavioral and emotional dimensions of the homebuying process. Residential housing is not merely an investment asset but also an emotionally significant component of household life, often likened to a “A home serves as a sanctuary, a shelter, and a safe haven”, providing security and stability. Insights from behavioral economics suggest that individuals do not always make housing decisions based solely on rational calculations or objective risk assessments (Singh et al., 2023). In the reviewed literature, most studies link climate risk to housing prices using hazard risk maps or historical disaster events, implicitly assuming that housing decisions are rational responses to objective information and exogenous shocks in perfectly competitive markets (Gibb et al., 2024). However, relatively few studies explicitly acknowledge market imperfections, bounded rationality, or the complex ways in which risk perceptions shape decision-making. Within this review, only a limited number of studies examine irrational decision-making, behavioral biases, or asymmetric information in housing markets (Pryce et al., 2011; Pope, 2008). More recently, Dubos-Paillard et al. (2024) estimate homebuyers’ perceptions of flood risk in Paris between 2003 and 2012, illustrating how subjective risk perception can be incorporated into housing market analysis. Expanding this line of inquiry could significantly enrich the understanding of how households internalize climate risks.

Third, although most reviewed studies rely on regression-based and quasi-experimental designs, the limited adoption of data science and machine learning techniques is notable. Given the rapid expansion of artificial intelligence applications since 2020, one might expect greater use of nonlinear algorithms in housing price research. However, only one study in this review employs Bayesian inference. This may reflect the scope and structure of the study's search terms, which prioritize hazard-related conceptualization over predictive performance. Future systematic reviews could broaden keyword strategies to capture studies that apply machine learning and other nonlinear approaches to housing price prediction in the context of climate risk.

Finally, future research could more closely examine the effects of newly released climate risk information and regulatory disclosure requirements on local housing markets, particularly in urban contexts. As governments increasingly emphasize climate risk transparency, relatively few studies evaluate how voluntary or mandatory disclosure policies affect housing prices and market dynamics. Although more than 50% of the reviewed studies focus on county- or city-level analyses globally, few studies explicitly examine how temporal information shocks, such as the introduction of new risk maps or disclosure laws, affect housing market behavior, particularly in the United States.

A small number of studies provide relevant insights. Chiang Hsieh (2021) investigates the impact of public flood risk disclosure on housing prices in Taiwan; Rajapaksa et al. (2016) compare the effects of flood risk information and actual flood events on housing prices in Australia; and Votsis and Perrels (2016) document significant price declines following flood risk disclosure in Finland. While Hino and Burke (2021) examine the association between flood-risk disclosure laws across 50 U.S. states and price discounts in flood zones, further research is needed to understand how different disclosure regimes shape housing market outcomes. For example, future studies could explore whether variations in disclosure design, such as the level of detail provided on property flood histories, the timing of disclosure, and penalties for noncompliance, produce distinct pricing effects in housing search and transaction processes.

Several limitations of this study should be acknowledged. First, the literature collection process may be subject to search-term and selection bias. To maintain a clear focus on understanding how existing research links environmental hazard risks to housing prices, this study employs a deliberately narrow, conceptually precise set of search terms. While this approach improves relevance and interpretability, it may have excluded studies that examine housing prices using alternative terminology, related outcome measures, or adjacent analytical frameworks. Secondly, although Web of Science and JSTOR were selected to ensure transparency, replicability, and access to high-quality peer-reviewed journals, reliance on these databases may introduce publication bias (De Long & Lang, 1992). For example, applied or technical research published in engineering or hazard modeling journals, particularly those outside economics and social science domains, may be underrepresented. Restricting the review to English-language publications may bias the findings toward Global North perspectives and underrepresent research

conducted in highly vulnerable regions where climate hazards pose substantial housing risks. In addition, only a limited number of reviewed studies incorporate flood risk measures derived from private-sector or non-governmental sources. This pattern may partly reflect publication bias, as peer-reviewed journals have traditionally favored the use of official, government-produced datasets.

Third, the reviewed literature exhibits substantial heterogeneity in how environmental hazards are defined, measured, and operationalized. Flood risk, for instance, is captured in various ways, including FEMA floodplain designations, historical flood events, probabilistic risk models, insurance claims, and satellite-based exposure measures. This lack of standardization complicates direct comparison across studies and may partially explain inconsistent findings regarding the magnitude and direction of housing price effects. Also, the literature reviewed in this study is disproportionately concentrated in urban, coastal, and data-rich housing markets, particularly in the United States and other high-income countries. Rural areas, lower-liquidity markets, and informal housing contexts remain underrepresented, which may limit the generalizability of findings and bias conclusions toward higher-value housing markets with more readily available transaction data. Moreover, many studies focus on short-term or post-disaster price responses, with relatively limited attention to long-run adjustment processes, cumulative exposure, or the compounding effects of repeated hazard events over time.

Finally, while many reviewed studies employ econometric or quasi-experimental designs to address endogeneity, housing markets may partially anticipate environmental risks through insurance pricing, lending practices, or informal information channels. As a result, estimated price effects may reflect a combination of realized impacts and anticipatory behavior rather than discrete causal shocks. Together, these limitations suggest that existing evidence on environmental hazard capitalization in housing prices should be interpreted with caution and underscore the need for future research that integrates standardized risk measures, longer time horizons, broader geographic coverage, and complementary institutional and behavioral perspectives.

Chapter 3. Housing Market Responses to Evolving Flood Risk Information & Disclosure

3.1 Introduction

3.1.1 Flood Impacts on the Housing Market under Climate Change

Increasing attention has been on climate change, particularly flood risk, and its impacts on housing markets. According to the latest report by the Intergovernmental Panel on Climate Change (IPCC), climate risks to people and assets have increased, with human and economic losses from climate-related disasters and extreme events rising, particularly in urban areas (IPCC WGII, 2023). In recent years, the United States has experienced an increasing frequency of extreme flooding. In the last two decades, flooding has been the costliest hazard affecting more than a million people annually (NOAA, 2025). Repeated flood events impact housing availability as well as future costs of insurance, which in turn increase costs of housing.

Zooming in on the housing market, the impacts of flooding risk under climate change include physical damage, loss of property value, and heightened exposure to flooding, all of which are critical factors in the relationship between housing and climate change (IPCC WGII 2023, P934). Additionally, flooding has increasingly threatened the stability of the U.S. housing market (Gourevitch et al., 2023), causing significant economic impacts through depreciation of housing values, shutdowns of public infrastructure, and disruptions to essential services (U.S. Global Change Research Program, 2023). Research has indicated that, in some markets, residential properties exposed to flooding experience fewer transactions than non-exposed properties, controlling for property characteristics (Bernstein et al., 2018; Harrison et al., 2001). These impacts underscore that flooding influences housing markets not merely through realized damages, but also through expectations of future risk.

A key challenge in assessing the economic impacts of climate change on housing markets lies in uncertainty about flood risk. Unlike discrete hazard events, flood risk reflects a probabilistic, forward-looking assessment of potential damage that evolves over time with climate change, land use, and infrastructure conditions. This uncertainty can generate multiple, overlapping economic effects for households, including increased insurance premiums, mortgage risk,

declining asset values, and in some cases, climate-induced relocation (Beckett, 2021). As a result, housing serves simultaneously as a physical shelter and a financial asset whose value is increasingly shaped by expectations of future climate risk rather than past flood events alone. This distinction between realized flood events and anticipated flood risk is central to understanding contemporary housing market dynamics under climate change.

3.1.2 Flood Risk & Information Asymmetry in Housing Markets

The United States Federal Emergency Management Agency (FEMA) is the primary agency for disaster response and assistance, including flood risk management. FEMA's efforts encompass risk mapping, public education, mitigation investments, and assistance programs. FEMA's flood maps are widely utilized by key stakeholders. For instance, insurers rely on these maps to determine flood insurance premiums, while banks use them to assess mortgage approvals and loan-to-value ratios for borrowers. In collaboration with the National Flood Insurance Program (NFIP), FEMA develops Flood Zone Maps, which categorize areas based on the probability and severity of flooding. These classifications consider multiple factors, including flood frequency, proximity to water bodies, causes of flooding, and property characteristics. High-risk flood areas, designated as Special Flood Hazard Areas (SFHAs), are identified by zones labeled A or V on FEMA flood maps. Additionally, FEMA's flood data informs the NFIP's Flood Insurance Rate Maps (FIRMs), which serve as the official flood risk assessments used by communities to establish flood insurance requirements and premium rates. Despite their institutional importance, FEMA flood maps have been widely criticized for their coarse spatial resolution, infrequent updates, and limited incorporation of climate change projections (CFPB, 2025; Urban Institute, 2024; Guin, 2023). As a result, they often fail to capture property-level variation in flood exposure or emerging risks driven by changing precipitation patterns, sea-level rise, and urban development.

In response to these limitations, an increasing number of private-sector organizations are providing climate data services, such as flood-risk data, which are now more accessible to the general public. For example, First Street Foundation (FSF), originally a nonprofit organization, has evolved into a climate risk data service provider. In 2020, FSF launched the First Street Foundation Flood Model (FSF-FM), which provides property-level flood risk assessments. The FSF-FM has been widely adopted by academic researchers, public agencies, financial

institutions, and banks. Unlike traditional flood models, FSF-FM integrates a complex, physics-based framework that incorporates various hydrological and hydraulic models, climate projections, adaptation infrastructure, and other environmental considerations to assess both current and future flood risks (First Street Foundation, n.d.). FSF’s flood data is now publicly available and helps address information asymmetry in the real estate market. By providing detailed flood risk information, FSF enables homebuyers to make more informed financial and insurance decisions (Urban Institute, 2024). This transparency contrasts with FEMA’s more generalized, less dynamic flood maps, which do not provide property-specific insights.

Since 2020, FSF’s Flood Factor scores have been integrated into major real estate online platforms, including Realtor.com, Redfin, and Zillow (as illustrated in Figure 12). This innovation introduced a forward-looking approach to real estate by integrating physical flood-risk modeling with climate projections. As a result, flood risk information is now more accessible to homebuyers, helping them make more informed decisions. The availability of standardized flood risk data has influenced the broader housing market. Banks, insurers, and real estate investors now have improved tools to assess flood risk exposure, which may shape mortgage lending, insurance premiums, and property valuation practices.



Figure 12. Availability and Adoption Timeline of FSF’s Flood Factor Across Key Real Estate Online Platforms

(Depicted by Author; based on data from Zillow (2024); Redfin (2021); Realtor.com (2020); FSF (2020))

Even with the current climate data service provision, homebuyers still face challenges related to fluctuating housing prices and adverse selection, which occurs when they make decisions based on limited or incorrect information, leading to secondary or undesirable options. This issue often arises from information asymmetry between buyers and sellers, particularly before market transactions occur. For instance, in a community experiencing an increasing frequency of flood

events due to more intense precipitation, the stormwater system may become overwhelmed more frequently. In response, some homeowners may implement flood mitigation measures, while others may take no action. Even within the same community, individual homes may face varying levels of flood risk and will not be uniformly affected. However, homebuyers may struggle to determine which properties are more vulnerable to future flooding. In such cases, a "market for lemons" may emerge, wherein sellers possess more information about flood risks than buyers, creating an imbalance in the housing market (Beckett, 2021, p. 18). Among all stakeholders affected by these risks, issues related to housing prices are the most critical economic consideration, especially under increasingly frequent and severe flooding events. These dynamics raise critical questions about whether, when, and how newly disclosed flood risk information is capitalized into housing prices.

3.2 Literature Review

3.2.1 Research Related to Flood Risk and Housing Market

Research has used FEMA's flood risk data and FSF's Flood Factors for different purposes in housing market research. Much of the existing literature has focused on FEMA's flood data to examine the relationship between flood risk and property damage losses (Highfield & Brody, 2017) and to estimate the impact of FEMA-designated flood risk on housing sale prices (Hino & Burke, 2021). Other studies have explored the economic consequences of flooding in coastal communities (Bin et al., 2008) and compared housing sale prices in SFHAs versus non-SFHAs (Bernstein et al., 2018). These studies collectively provide valuable insights into how historical flood exposure affects housing prices and economic resilience in flood-prone areas.

Most research examining the impacts of flooding on housing markets has focused on using FEMA's historical flood exposure or realized flood events, rather than on forward-looking assessments of flood risk under climate change. While FEMA flood maps have long served as the dominant source of flood risk information in both policy and market contexts, they have some critics related to data scale and accuracy (Guin, 2023). More recent studies have begun to incorporate the FSF's Flood Factor data, which provide property-level, forward-looking estimates of flood risk that account for climate change, hydrological processes, and adaptation infrastructure. Existing applications of FSF data have largely focused on long-term projections,

such as evaluating climate impacts on multi-unit residential buildings and community infrastructure over multi-decade horizons (Porter et al., 2021, 2022), or estimating national-scale housing market overvaluation arising from unpriced flood risk (Gourevitch et al., 2023).

Comparative analyses between FEMA and FSF methodologies further highlight important discrepancies in flood risk distributions, insurance coverage, and implied property valuation outcomes (CFPB, 2025; Ding et al., 2024; Galster et al., 2024). However, much less is known about how forward-looking flood risk information, once disclosed to households, lenders, and market participants, actually affects housing market behavior in real time. In particular, limited empirical research has examined whether and how the introduction of FSF's flood risk information is capitalized into housing prices, how quickly markets respond to such disclosures, or whether these effects differ from those associated with traditional, regulatory flood maps. Addressing these questions is critical for understanding the role of emerging climate risk information in shaping housing market dynamics under climate change.

Another significant research direction examines how newly disclosed flood risk information affects housing markets and homebuyer perceptions. It is intuitive to expect that newly disclosed flood risk information will affect housing markets. Properties located in current and future high flood risk areas may take longer to sell and command lower transaction prices than those without such disclosures. Several studies have found that flood risk disclosures can lead to longer selling times and lower transaction prices in high-risk areas (Kelly & Molina, 2023). Additionally, research suggests that residents of coastal flood zones often underestimate their flood risk relative to inland residents (Bakkensen & Barrage, 2022). The perception of flood risk can also vary across communities; for example, properties in "believer" neighborhoods, where residents are concerned about climate change, sell at lower prices than in "denier" neighborhoods (Baldauf et al., 2020). Further studies have examined the extent to which flood risk disclosures affect homebuyer choices and housing prices. Some research has shown that housing prices in FEMA-designated flood zones decline following flood-risk disclosures (Fairweather et al., 2023; Pope, 2008). Moreover, new flood map updates have been found to significantly alter homebuyers' risk perceptions, with a negative impact on housing prices both before and after map disclosures (Gibson et al., 2019; Chiang Hsieh, 2021). These findings suggest that flood risk information plays a critical role in shaping housing market dynamics.

Additionally, state-level flood-risk disclosure requirements may affect housing markets. New York State amended its real estate contract disclosure law, New York Real Property Law Sec. 462(2), effective March 20, 2024, requiring home sellers of 1-4 family dwellings to provide flood-related disclosures to homebuyers before signing a contract of sale. The new items that must be disclosed include whether the property structure has experienced flood damage, whether any flood insurance claims have been made, whether the property is located within FEMA’s floodplain map, and whether flood insurance is required (New York State Senate, 2024; NRDC, 2024, 2025; FSF, 2024; Ranzenhofer, 2023). Importantly, the new law closes a loophole that allows sellers to avoid disclosing flood risk by offering a \$500 credit at closing.

3.2.2 Key Methodology to Explore Temporal Interventions of Flood Risk Disclosure on Housing Price

Current research has used different statistical models to evaluate the impact of temporal or threshold-based interventions. A quasi-experimental design (QED) approach is widely used in public policy, urban planning, and other social science research to evaluate economic programs or policy interventions. QEDs accommodate certain research design barriers in real-world social settings (Harris et al., 2006). Unlike true experiments, in which researchers control treatment assignment, QEDs rely on external treatments that create conditions that resemble an experiment.

There are a wide range of QED designs. Interrupted Time Series (ITS) is one such quasi-experimental research design, also known as the “one-group before-after design,” used to evaluate the impact of an intervention or policy change over time. ITS is particularly well suited to analyzing temporal interventions or those triggered by specific thresholds (McDowall et al., 2021; Box-Steffensmeier et al., 2014, pp. 58-67). The ITS model can assess the immediate and sustained effects of each intervention on housing trends, and a combined model incorporating multiple interventions can determine whether the impact of later interventions is contingent on prior ones. A recent study applied ITS and hedonic price models to investigate the effects of harm reduction sites on housing prices (Schaefer & Panagiotoglou, 2024). On the other hand, Difference-In-Differences (DiD) is another widely used quasi-experimental research design, often referred to as the “two-group, two-period design.” It estimates causal treatment effects by comparing pre- and post-treatment differences between treatment and control groups (Chen et

al., 2021, pp. 172–174; Stock, 2020). DiD requires a temporal cutoff point and a defined treatment, creating treated and untreated groups to estimate the average treatment effect (ATT).

Scholars have long examined information disclosure as a regulatory tool, showing that disclosure is most effective when the information provided is salient, credible, and embedded in the routine decision-making processes of both information users and disclosers (Weil et al., 2006). In housing and energy markets, empirical evidence suggests that mandatory disclosure regimes, such as energy performance certificates or regulatory transparency requirements, are associated with measurable housing price premiums and capitalization effects, reflecting improved market transparency and reduced information asymmetry (Cassidy, 2023; Frondel et al., 2020). Parallel research also finds that voluntary disclosure, particularly related to energy efficiency and sustainability attributes, can generate housing price premiums, indicating that buyers value transparent information even in the absence of regulatory mandates (Fuerst & Warren-Myers, 2018).

However, empirical evidence on how evolving flood risk information environments influence housing markets remains limited and mixed. Existing studies suggest that the disclosure of flood risk information, such as flood maps, can affect housing prices in localized ways, but these effects are often heterogeneous and context-dependent. Differences in risk salience, buyer awareness, and institutional settings may shape how homebuyers interpret and respond to risk information. More broadly, identifying the market impacts of climate risk disclosure remains challenging because information interventions rarely occur in isolation. In many urban contexts, multiple policy and information changes, including updated flood maps, disclosure requirements, insurance reforms, and third-party risk communication platforms, are introduced over time. These overlapping interventions create a dynamic policy-information environment in which isolating the effects of any single disclosure mechanism becomes difficult (Leuz & Wysocki, 2016). As a result, relatively little research has examined how the cumulative evolution of flood risk information and disclosure policies influences housing market dynamics over time. Understanding how housing markets respond to a sequence of policy and information interventions, rather than to individual disclosure mechanisms in isolation, represents an important gap in the literature on climate risk communication and housing markets.

Building on this literature, several important gaps remain. First, although FEMA flood maps have been extensively critiqued, relatively few empirical studies have incorporated flood risk data from private climate service providers to examine housing market responses. As private flood risk models increasingly influence consumer behavior, financial decision-making, and policy debates, there is a growing need to assess whether and how these more detailed risk signals are reflected in housing prices. Second, existing studies have paid limited attention to the role of online real estate platforms as intermediaries of climate risk information. As homebuyers, particularly younger and first-time buyers, rely heavily on digital platforms during the housing search process, the integration of flood risk scores into these platforms represents a structural shift in how climate risk information is communicated and consumed in housing markets. Yet empirical evidence on how such platform-based disclosures influence housing price dynamics remains sparse. Third, few studies have examined flood risk disclosure within a dynamic policy and information environment, where multiple interventions, including digital platform disclosures and regulatory requirements, are introduced sequentially over time. Most prior research relies on cross-sectional or hedonic approaches, which are limited in their ability to capture market adjustments following evolving information environments and overlapping policy changes. Finally, despite growing policy interest in climate risk transparency, there is limited empirical evidence evaluating the housing market implications of recent flood risk disclosure initiatives in New York State. In particular, little research has examined how the combined evolution of flood risk information sources and disclosure policies shapes housing market behavior over time.

This study makes several contributions to the literature on flood risk, information disclosure, and housing markets. First, it advances existing research by incorporating newly available flood risk information from FSF, moving beyond the traditional reliance on FEMA flood maps. By integrating alternative flood risk measures, this study helps evaluate how emerging climate risk datasets influence housing market dynamics. Second, this study provides one of the first empirical assessments of online flood risk disclosure as a structural change in housing market information environments, examining how the integration of FSF's Flood Factor scores into major real estate platforms coincides with shifts in housing price dynamics over time. Third, rather than focusing on a single policy change, this study examines a sequence of flood risk-related information and disclosure interventions, allowing for an analysis of how housing

markets respond within an evolving policy-information environment. This temporal perspective enables the identification of incremental and cumulative market adjustments that are difficult to capture using conventional cross-sectional approaches. Finally, this study provides policy-relevant evidence on how expanding climate risk transparency, including private risk models, platform-based disclosures, and regulatory initiatives, interacts with housing market behavior in a high-risk and highly regulated housing context. These contributions help clarify how evolving flood risk information environments reshape housing markets and inform ongoing debates about disclosure-based climate adaptation policies.

3.2.3. Research Hypotheses

This study asks: *How does the evolving flood risk information and disclosure interventions influence housing prices over time?* Specifically, it examines how the introduction of newly available flood risk information sources and the implementation of enhanced flood risk disclosure requirements collectively shape housing market dynamics. This study adopts a market-level analytical approach to evaluate how a sequence of flood risk-related information and policy interventions, including the release of new flood risk data and the enactment of strengthened flood risk disclosure legislation, coincide with changes in housing market trends over time. Rather than treating these interventions as isolated events, this study considers them as components of an evolving information environment that may influence market expectations and behavior.

The analysis investigates whether these shifts in flood risk transparency are associated with immediate, long-term, or cumulative effects on housing prices. By examining how housing markets respond to newly available flood risk information and disclosure policies, this study provides insights into how homebuyers, sellers, and real estate intermediaries interpret and incorporate climate risk signals into market decision-making. This study is guided by the following research questions:

- How has the integration of forward-looking flood risk information into major real estate platforms (e.g., Realtor.com, Redfin, Zillow) coincided with changes in housing price dynamics in NYC over time?

- How is the implementation of New York State’s revised flood risk disclosure law associated with shifts in housing market behavior?
- Do housing market responses to evolving flood risk information vary across different submarkets, such as areas with differing flood risk severity, prior flood loss experience, household income levels, or educational attainment?

By examining housing market responses within an evolving flood risk information environment, this analysis contributes to the growing literature on climate risk disclosure and housing markets by identifying whether greater flood risk transparency alters housing price signals in meaningful and sustained ways.

3.3 Data and Method

3.3.1 Data Collection and Processing

NYC provides a particularly appropriate case for examining housing market responses to flood risk information and disclosure, given its high exposure to coastal and pluvial flooding, dense and heterogeneous housing stock, and active policy environment surrounding climate risk management. Data for this study were assembled from multiple sources, including NYC housing transaction records, key temporal disclosure and policy interventions, FSF’s forward-looking flood risk information, macroeconomic and housing market indicators, and neighborhood-level socio-demographic characteristics, which were harmonized and processed to support longitudinal analysis.

3.3.1.1 Housing Sale Price Data

The NYC rolling sales and historical data are the primary sources of housing price information, comprising all property transaction records from January 01, 2003, to December 31st, 2024. NYC releases detailed property transaction data for sales within NYC, organized by the five boroughs (Manhattan, Bronx, Brooklyn, Queens, and Staten Island). A total of 2,016,057 property transactions occurred between 2003 and 2024, including all transfer types and below-market transactions, as shown in Figure 13. The NYC housing sale price data also include location details (neighborhood, zip code, and address) and property characteristics, such as building class category, number of residential and commercial units, land square footage, gross square footage, and year built.

To prepare the dataset for analysis, this study selects building class category 1, which includes residential properties such as one- to three-family dwellings and condominiums, and excludes categories labeled "Vacant Land" and "Others." Next, this study excludes implausibly low-value transactions, those below \$10,000, are excluded from the analysis (Goodman & Thibodeau, 2008; Bernstein et al., 2018). These values typically do not reflect true market transactions but rather indicate family transfers, estate inheritances, divorces, data entry errors, co-op share transactions, or nominal transactions used to record legal changes.

Additionally, to reduce the influence of extreme values and improve the robustness of the analysis, outliers in the housing price data will be identified and removed using the Interquartile Range (IQR) method. Specifically, observations falling below $Q1 - 1.5 * IQR$ or above $Q3 + 1.5 * IQR$ will be excluded from the sample. This approach preserves most of the data while eliminating only extremely high or low prices that may reflect data-entry errors or highly unusual transactions. However, one limitation is that the data may not permit the complete exclusion of affordable housing transactions, which may not be fully influenced by broader market conditions and could lead to an underestimation of results.

Finally, this study generates monthly time-series data from 2016 to 2024, including monthly median housing sale prices at the zip code level (zip-month housing sale prices). All housing price series are adjusted to real dollars using the Consumer Price Index (CPI-U, 2020 = 100) to account for inflation over the study period. Then, this study will include 96 monthly median housing price records over time for each zip code. Monthly median housing prices at zip code i in NYC will be denoted as:

$$y_{it}, t = 1, 2, 3, \dots, 96 \text{ (Jan 2016 to Dec 2024)}; i = \text{five digit zip code}$$

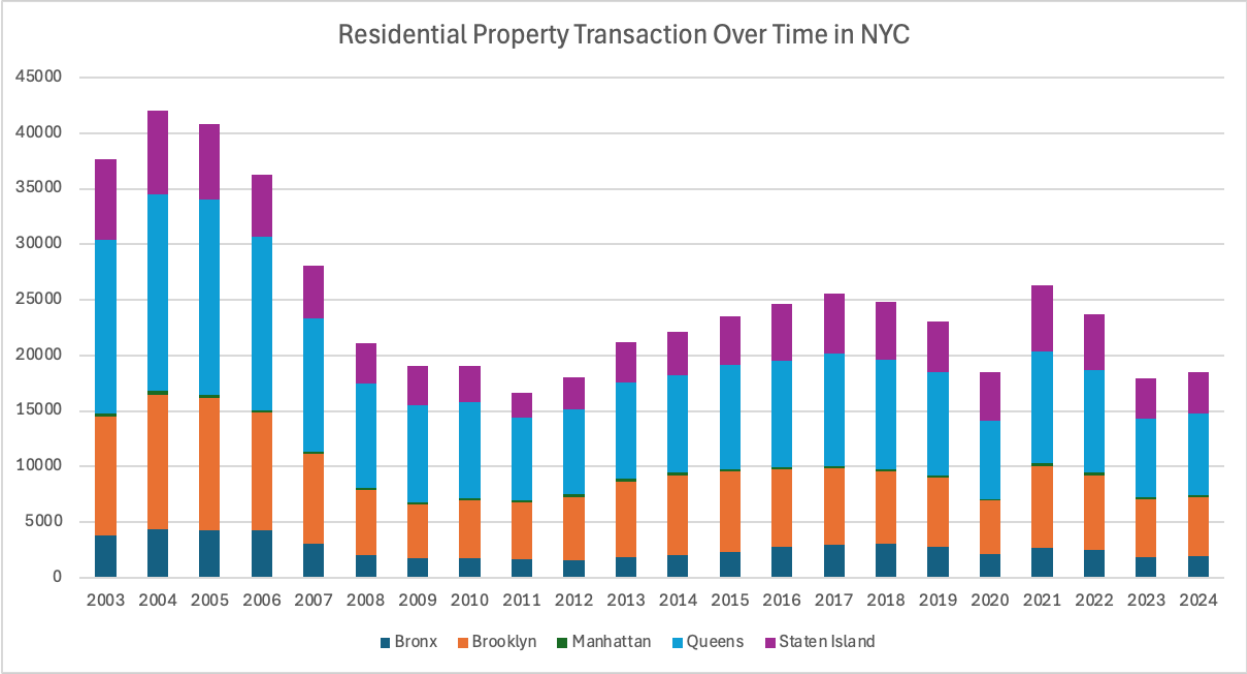


Figure 13. Residential Property Transaction by Boroughs
(Source: Author)

3.3.1.2 Temporal Intervention

This study examines a sequence of temporal interventions related to the expansion of flood risk information and disclosure in the NYC housing market. These interventions reflect key moments when newly flood risk information became available to market participants through digital platforms and regulatory policy changes. First, this study identifies several intervention points associated with the release and integration of flood risk scores developed by FSF on major online real estate platforms. FSF publicly launched its national flood risk model in June 2020. Shortly thereafter, Realtor.com became the first major real estate platform to integrate FSF flood risk scores into property listings in August 2020. Additional platforms subsequently adopted these data, including Redfin in February 2021 and Zillow in September 2024, further expanding the accessibility of forward-looking flood risk information to prospective homebuyers. In addition to these platform-based information interventions, this study incorporates March 2024 as another key intervention point corresponding to the implementation of New York State’s revised flood risk disclosure law. This legislation strengthened requirements for sellers to disclose flood risk information during residential real estate transactions. Figure 14 shows median housing prices

over time with critical intervention points, and key definitions of temporal interventions are provided in Table 4.

Table 4. Key Temporal Interventions used in Chapter 3

Time of interventions	Descriptions
June 2020	FSF releases Flood Factor data on their website
August 2020	Availability of Flood Factor data on Realtor.com
February 2021	Introduction of Flood Factor data on Redfin
September 2024	Availability of Flood Factor data on Zillow
March 2024	Newly state-level flood risk disclosure requirements implemented

(Source: Author)

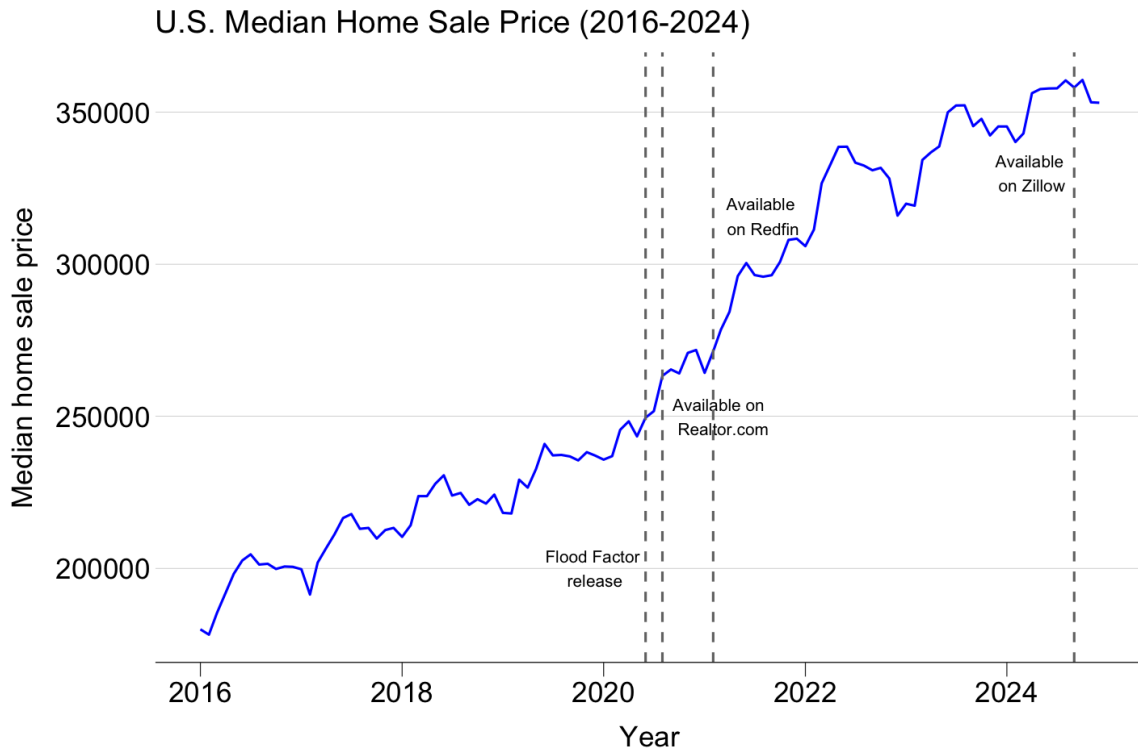


Figure 14. Monthly Median Housing Price Over Time

(Source: Author)

3.3.1.3 Control and Other Variables

In addition to the main variables of interest, this study includes several variables used to control for broader economic and demographic trends and to support further analysis. First, this study will use the monthly unemployment rate from the New York State Department of Labor for the NYC Region and monthly mortgage interest rates from Freddie Mac to control for macroeconomic fluctuations that may influence housing demand and pricing (Kim, 2020; Mueller et al., 2009).

Secondly, monthly building permits by boroughs will be collected from NYC Planning and categorized into seven distinct COVID phases to capture major shifts in market and public health conditions in NYC. Periods prior to February 2020 are coded as 0 (Pre-COVID). The subsequent phases include 1 (Lockdown Period: March-May 2020), 2 (Partial Reopening and Early Recovery: June-December 2020), 3 (Vaccine Rollout and Housing Boom: January-June 2021), 4 (Delta/Omicron Wave and Housing Surge: July 2021-February 2022), 5 (Federal Reserve Tightening and Market Cooldown: March-December 2022), and 6 (Post-Pandemic/Endemic Period: Jan 2023-Dec 2024). This coding scheme enables the analysis to account for structural breaks and behavioral shifts in housing market dynamics associated with evolving pandemic and macroeconomic conditions.

To better prepare for subsequent submarket analysis and market variation, this study constructs four variables: risk severity, hazard exposure, household income, and educational attainment. First, risk severity variables use flood risk scores at the zip code level, provided by FSF; each zip code is assigned a score from 1 to 10, representing a gradient from minimal to extreme flood risk. This study creates a binary variable, with a score of 6 as the benchmark cutoff, to classify zip codes in NYC as low-flood-risk or high-flood-risk (scores 6-10). This classification follows a methodology similar to that used by FSF (2020) to compare FEMA's SFHAs, based on nationwide results. Secondly, hazard exposure is operationalized as a binary variable indicating whether a given zip code has experienced flood events prior to the housing transaction. This measure is derived from the FEMA Flood Insurance Mitigation Administration's NFIP Flood Redacted Claim dataset, which records historical flood insurance claims at the zip code level. For each observation, if any flood claim occurred in the zip code before the transaction date, the variable is coded as 1 (flood-exposed); otherwise, it is coded as 0 (non-exposed). This approach

captures the presence of localized flood experience that may influence buyer perceptions and property market responses.

Lastly, household income and education level are classified using data from the U.S. Census Bureau's 2023 American Community Survey (ACS), accessed via the `tidycensus` R package, at the Zip Code Tabulation Area (ZCTA) level to capture socioeconomic variation across neighborhoods. Following the U.S. Department of Housing and Urban Development (HUD) income classification guidelines, this study adopts a \$100,000 annual household income threshold to distinguish between high- and low-income areas (HUD, 2026). A binary variable, high-income neighborhood, is created as follows: zip codes with a median household income of \$100,000 or more are coded as 1 (wealthy), whereas those below this threshold are coded as 0 (low-income). This indicator serves as a proxy for neighborhood affluence, enabling examination of income-related heterogeneity in housing market responses to environmental risk and information disclosure. On the other hand, this study measures educational attainment as the share of adult residents (aged 25 and over) holding a bachelor's degree or higher, reflecting the overall educational attainment level within each zip code. Highly educated zip code is then constructed to capture neighborhoods with relatively higher educational attainment. Zip codes with a share of residents holding at least a bachelor's degree above the citywide median are coded as 1 (high-education), while those below the median are coded as 0 (low-education). This classification enables analysis of how educational and demographic characteristics may shape housing market responses to flood-risk information and environmental hazards. Table 5 presents descriptive statistics for the key variables used in the empirical analysis, including housing price indicators, macroeconomic controls, and flood-risk related variables.

Table 5. Descriptive Statistics for Variables used in Chapter 3

Variable	Measurement	Obs	Mean	SD	Min	Max
median housing price	Monthly median residential sale price (USD) at the zip-code level in NYC, CPI adjusted.	14068	749765	256606	10609	1752812
time	Continuous variable measuring the number of months since the start of the study period.	14068	52.79	30.72	1	108
permits	Monthly count of residential building permits issued in each zip code.	14068	18.98	15.20	0	74
new units	Monthly number of newly completed residential housing units in each zip code.	14068	358.51	423.66	0	2580
unemployment rate	Monthly unemployment rate (%) representing local labor market conditions.	14068	6.23	3.30	3.8	21.5
mortgage rate	Monthly average 30-year fixed mortgage interest rate (%).	14068	4.56	1.42	2.684	7.62
flood risk severity	Binary variable equal to 1 if the zip code has high flood risk exposure (FSF flood score ≥ 6), and 0 otherwise.	13246	0.87	0.34	0	1
flood experience	Binary variable equal to 1 if the zip code has recorded NFIP flood loss claims, and 0 otherwise.	14068	0.31	0.46	0	1
household income	Binary variable equal to 1 if the zip code's median household income is above the citywide median, and 0 otherwise.	14068	0.25	0.43	0	1
education attainment	Binary variable equal to 1 if the share of residents with a bachelor's degree or higher is above the citywide median, and 0 otherwise.	14068	0.49	0.50	0	1

(Source: Author)

3.3.2 Statistical models

This study employs an Interrupted Time Series (ITS) framework to examine how housing prices evolve in response to changes in the flood risk information and disclosure environment. ITS is well suited for evaluating policy or information interventions that occur at identifiable points in time and allows researchers to assess both immediate and longer-term shifts in outcome trends following such interventions. In this study, ITS is used to examine whether housing price dynamics change following a sequence of flood risk-related information and policy interventions. These interventions include the release of new flood risk data from FSF and the implementation of enhanced disclosure requirements. By modeling these intervention points within a time-series framework, ITS allows the analysis to evaluate whether housing prices exhibit immediate level changes, changes in long-term trends, or cumulative adjustments following shifts in the flood risk information environment.

ITS offers several advantages for this analysis. First, it enables comparisons between pre- and post-intervention trends in the outcome variable. When evaluating policy or information interventions, ITS can identify immediate effects through level changes at the intervention point, as well as sustained effects through changes in slope over time. Second, ITS models are widely used in public policy and program evaluation to assess the impacts of interventions implemented at clearly defined points in time (Rossi et al., 2019). Because the interventions examined in this study affect the entire housing market simultaneously, ITS provides a practical approach for assessing whether observable shifts in housing prices coincide with changes in the flood risk information environment. Thirdly, ITS is well suited to analyzing policy environments in which multiple interventions occur sequentially. By incorporating multiple intervention points within the same model, the analysis can evaluate how housing markets respond to a series of information and policy changes rather than to a single isolated event. Recent research has applied ITS methods to housing market outcomes in response to policy interventions. For example, Schaefer and Panagiotoglou (2024) combine ITS and hedonic pricing approaches to examine the effects of harm reduction sites on housing prices while controlling for neighborhood socioeconomic characteristics.

Before conducting the analysis, several key assumptions of ITS are considered. First, a sufficient number of observations before and after each intervention is necessary to establish a stable

baseline trend and to distinguish structural changes from random fluctuations. Adequate post-intervention observations are also required to assess both immediate and longer-term effects. Second, ITS assumes that no major confounding events occur at the same time as the intervention that could independently affect the outcome variable. While it is not always possible to fully rule out contemporaneous events, this study incorporates relevant control variables and sensitivity checks to reduce the risk of confounding influences. The following section outlines the empirical specification used to model housing price dynamics in response to multiple flood risk-related interventions.

(1) Interrupted Time Series for Multiple Interventions

A combined ITS model is used to incorporate all interventions simultaneously. Because these interventions occur sequentially over time, estimating them within a single model helps avoid attributing market changes to any single intervention when housing price dynamics may reflect the cumulative evolution of the flood-risk information environment. The five interventions, summarized in Table 6, correspond to the release of newly available flood risk information at different points in time and to regulatory changes affecting flood risk disclosure. For each intervention, the time series of monthly median housing prices is analyzed while controlling for pre-existing trends and potential confounding factors. Dummy variables are included to account for major structural shocks, such as the COVID-19 pandemic. To further capture variation in housing supply and market activity, new-construction data from NYC building permit records are incorporated. These variables help account for short-term fluctuations in housing market dynamics that may not be captured by the underlying time trend. In addition, time fixed effects and location (zip code) fixed effects are included to control for broader temporal influences and unobserved, time-invariant neighborhood characteristics that may affect housing prices.

This combined ITS specification allows the analysis to examine whether the effects of multiple information and policy interventions overlap, interact, or accumulate over time. A relaxed fixed-effects model incorporating zip code, year, and month-of-year effects is used to estimate both the immediate percentage change in housing prices at each intervention point and any subsequent changes in the monthly growth rate following the intervention. A key objective of this analysis is to assess whether earlier interventions condition the impact of subsequent disclosures, thereby

providing insight into the cumulative influence of climate risk information on housing prices. The combined ITS model for multiple interventions can be expressed as follows:

$$y_t = \beta_0 + \beta_1 Time_t + \sum_{i=1}^5 (\beta_{2i} D_{it} + \beta_{3i} (Time_t \times D_{it})) + \gamma X_t + \epsilon_t$$

where:

- y_t represents log of median housing sale price at time t
- $Time_t$ is the continuous time variable representing months since the start of the dataset
- D_{it} is a binary indicator for intervention i , equal to 0 before the intervention and 1 after the intervention. In this study, five interventions correspond to major flood risk information releases and disclosure policy changes
- $(Time_t \times D_{it})$ is an interaction term that captures changes in the time trend following each intervention
- X_t is a vector of control variables, including macroeconomic conditions, housing supply indicators, and structural shock indicators (e.g., the COVID-19 pandemic)
- ϵ_t is the error term

β_0 represents the baseline housing price level at the beginning of the time series, and β_1 captures the underlying pre-intervention trend in housing prices. The key interest coefficients: β_{2i} measures the immediate level change in housing prices associated with intervention i , and β_{3i} represents the change in the monthly price trend following intervention i . γ represents the coefficients associated with the control variables.

Table 6. Key Temporal Intervention Variables in Chapter 3

Variable	Intervention
D_1	FSF model release, June 2020
D_2	Realtor.com disclosure, Aug 2020
D_3	Redfin disclosure, Feb 2021
D_4	Zillow disclosure, Sep 2024
D_5	NY State disclosure law, Mar 2024

(Source: Author)

(2) Sub-market and Subgroup Analysis

To further examine heterogeneity in housing market responses, this study conducts subgroup analyses across different housing submarkets. These analyses explore whether the impacts of evolving flood-risk information and disclosure interventions vary across locations with different risk profiles and socioeconomic characteristics. Specifically, the combined ITS model is estimated separately across several housing submarkets defined by flood risk severity, prior hazard exposure, household income levels, and educational attainment. This approach allows the analysis to assess whether certain communities or market segments are more sensitive to changes in flood-risk transparency. To evaluate heterogeneous responses, the analyses described above are repeated for the following subgroups:

- Risk severity: high-flood-risk vs. low-flood-risk zip codes
- Hazard exposure: flood-experienced areas vs. non-flood-experienced zip codes
- Household income: higher-income vs. lower-income zip codes
- Education level: zip codes with high vs. low educational attainment rates

These subgroup analyses will help reveal whether housing market responses vary by location, risk exposure, or social and economic conditions.

3.4 Results

3.4.1 Combined ITS for Multiple Interventions

Housing markets are exposed to multiple, overlapping sources of flood risk information over time rather than a single isolated disclosure event. To account for the cumulative and potentially interacting effects of sequential interventions, this study estimates combined ITS models that incorporate multiple intervention indicators simultaneously. Table 7 presents two combined ITS specifications. The first model includes four market-based information interventions associated with the release and integration of flood risk information by FSF across major real estate platforms ($D_1 - D_4$). The second specification extends the model by incorporating the New York State flood-risk disclosure law (D_5). Both models include zip-code and monthly fixed effects to control for spatial heterogeneity and seasonal variation in housing markets. Given the research focus on both immediate price adjustments and longer-term trend changes, the primary

specification employs a relaxed fixed-effects (FE) model that includes zip-code, year, and month-of-year fixed effects. This specification allows the analysis to identify both level shifts and changes in price growth trends following each intervention while controlling for time-invariant neighborhood characteristics and broader temporal fluctuations in housing markets.

The first set of results evaluates the release of FSF's flood-risk data and its gradual integration into major real estate platforms ($D_1 - D_4$). Model 3.1 reports the combined ITS results for these market-based information interventions in New York City. The coefficients associated with the four intervention indicators, including FSF's model launch (D_1), Realtor.com's integration (D_2), Redfin's adoption (D_3), and Zillow's adoption (D_4), show generally modest and mostly statistically insignificant immediate effects on logged median housing prices. Realtor.com's integration of FSF flood-risk scores (D_2) is associated with a temporary increase in housing prices of approximately 9%. In contrast, the remaining intervention indicators show small and negative coefficients, suggesting that the initial availability of flood-risk information alone did not produce abrupt repricing in the housing market. These results indicate that the introduction of private-sector flood-risk information improved transparency but did not immediately alter buyers' willingness to pay for flood-exposed properties. One possible explanation is that awareness and interpretation of newly available risk information may diffuse gradually among market participants.

More noticeable effects appear in the post-intervention trend coefficients. The negative and statistically significant coefficient for slope D_1 , indicates a slowdown in housing price growth following the release of the FSF flood-risk model in June 2020. In contrast, slope D_2 (0.087) is positive and highly significant, suggesting a rebound in price growth following Realtor.com's integration of the flood-risk data, coinciding with the early post-lockdown housing market surge. Subsequent slope coefficients alternate in sign, with slope D_3 negative and slope D_4 positive. This pattern suggests a sequence of short-term adjustments and partial recoveries as flood-risk information gradually diffused across multiple real estate platforms.

On the other hand, Model 3.2 extends the analysis by incorporating the New York State flood risk disclosure law (D_5). The baseline time trend remains positive and statistically significant, indicating continued underlying housing price growth over the study period. The policy

intervention indicator (post D_5) is negative but statistically insignificant (-0.012), indicating no immediate price decline following the implementation of the disclosure law in March 2024. Similarly, the slope coefficient associated with D_5 is small and statistically insignificant, suggesting that the regulatory disclosure requirement did not substantially alter price trajectories once flood-risk information had already become widely available through real estate platforms. Interestingly, the slope coefficient for D_4 becomes larger and more statistically significant in the policy-inclusive model, suggesting that later expansions of flood-risk information through digital platforms may have continued to shape housing market expectations even as regulatory disclosure requirements were introduced.

The control variables behave largely as expected. Building permits are positive and highly significant, indicating that neighborhoods experiencing higher levels of new construction also exhibit stronger housing price growth. The mortgage-rate coefficient is negative and statistically significant, consistent with declining housing affordability during periods of higher borrowing costs.

Overall, the combined ITS results indicate that the sequence of flood risk information interventions was associated with modest adjustments in housing price growth trends rather than abrupt price declines. The gradual integration of flood-risk information across real estate platforms appears to have moderated housing price growth over time, while the subsequent regulatory disclosure requirement produced little additional short-term market response. These findings suggest that flood risk information diffuses gradually through housing markets as buyers, sellers, and intermediaries incorporate new information into decision-making processes. Rather than triggering immediate repricing, the evolving flood risk information environment appears to influence housing market dynamics through incremental adjustments in price growth expectations.

Table 7. Combined ITS Model Results

<i>Dependent variable:</i>		
Log Median Sale Price		
	Relaxed FE (D ₁ -D ₄)	Relaxed FE (D ₁ -D ₅)
	Model 3.1	Model 3.2
time	0.002*** (0.001)	0.002*** (0.001)
post D ₁	-0.018 (0.026)	-0.021 (0.026)
post D ₂	0.096* (0.051)	0.096* (0.051)
post D ₃	-0.044* (0.024)	-0.048** (0.024)
post D ₄	-0.014 (0.021)	0.001 (0.027)
post D ₅		-0.012 (0.022)
slope D ₁	-0.074** (0.031)	-0.075** (0.031)
slope D ₂	0.087*** (0.032)	0.088*** (0.032)
slope D ₃	-0.017** (0.007)	-0.016** (0.007)
slope D ₄	0.018* (0.010)	0.022** (0.011)
slope D ₅		-0.004 (0.005)
permits	0.001*** (0.0002)	0.001*** (0.0002)
new units	-0.00000 (0.00001)	-0.00000 (0.00001)
unemployment rate	0.0003 (0.001)	0.0005 (0.001)
mortgage rate	-0.014** (0.006)	-0.016** (0.007)

constant	13.413*** (0.052)	13.419*** (0.052)
<hr/>		
Observations	14,068	14,068
R ²	0.602	0.602
Adjusted R ²	0.597	0.597
Residual Std. Error	0.229 (df = 13899)	0.229 (df = 13897)
F Statistic	125.215*** (df = 168; 13899)	123.751*** (df = 170; 13897)

Note:

*p<0.1; **p<0.05; ***p<0.01

Both models include zip and year-month fixed effects.

3.4.2 Sub-market and Subgroup Analysis

In order to see if the previous results have different results or variations under different levels of flooding conditions or socio-economic settings. This study conducted a couple of sub-market and sub-group analyses by incorporating flood information and socio-demographic indicators into combined ITS models.

3.4.3.1 Flood Risk Severity

Table 8 presents the results of the combined interrupted time series models estimated for zip codes with high flood risk (FSF score ≥ 6). These models examine whether housing price dynamics in more flood-prone submarkets respond differently to the evolving flood-risk information and disclosure environment. All specifications include zip-code and year-month fixed effects, as well as macroeconomic and housing market controls. Across both models, the baseline time trend is positive and statistically significant, indicating that median housing prices in high-risk zip codes continued to increase over time. The immediate level effects associated with the disclosure interventions are generally small and mostly statistically insignificant. Among the intervention indicators, only *post D₃* (Redfin's integration of flood-risk information) is statistically significant in Model 3.4, indicating a modest immediate price decline following this platform adoption. The remaining disclosure events do not produce statistically significant level shifts in housing prices.

More substantial adjustments appear in the post-intervention trend coefficients. The coefficient for *slope D₁* is negative and statistically significant, suggesting that housing price growth slowed following the initial release of the FSF flood-risk model in June 2020. In contrast, *slope D₂* is positive and statistically significant, indicating a rebound in price growth following Realtor.com's integration of flood-risk scores. The coefficient for *slope D₃* is again negative and significant, suggesting a subsequent moderation in price growth after Redfin adopted the flood-risk information. By contrast, *slope D₄* and *slope D₅* are statistically insignificant, indicating that the later expansion of flood-risk information through Zillow and the introduction of the state-level disclosure law did not produce meaningful changes in price trends within high-risk zip codes. Additionally, the control variables behave largely as expected. Building permits are positive and highly significant, indicating that neighborhoods with higher levels of construction activity tend to experience stronger housing price growth. Mortgage rates are negative and

statistically significant, consistent with weaker housing demand during periods of higher borrowing costs. Other controls, including new housing units and unemployment rates, are not statistically significant in these specifications.

In summary, the results suggest that in high-risk housing submarkets, the evolving flood-risk information environment was associated with gradual adjustments in housing price growth, rather than abrupt price declines. Early private-sector flood-risk disclosures appear to have moderated price growth trends over time, while later platform integrations and the state disclosure law generated little additional short-term response.

Table 8. Sub-Market Differences by Flood Risk Severity

	<i>Dependent variable:</i>	
	Log Median Sale Price	
	Relaxed FE (D ₁ -D ₄) Model 3.3	Relaxed FE (D ₁ -D ₅) Model 3.4
time	0.003*** (0.001)	0.003*** (0.001)
post D ₁	-0.016 (0.030)	-0.018 (0.031)
post D ₂	0.089 (0.060)	0.090 (0.060)
post D ₃	-0.045 (0.028)	-0.049* (0.028)
post D ₄	-0.012 (0.025)	-0.001 (0.032)
post D ₅		-0.014 (0.025)
slope D ₁	-0.078** (0.036)	-0.078** (0.036)
slope D ₂	0.091** (0.037)	0.092** (0.037)
slope D ₃	-0.017** (0.008)	-0.016** (0.008)
slope D ₄	0.018	0.021

	(0.011)	(0.013)
slope D ₅		-0.003 (0.006)
permits	0.002*** (0.0003)	0.002*** (0.0003)
new units	-0.00001 (0.00001)	-0.00001 (0.00001)
unemployment rate	0.0002 (0.002)	0.0003 (0.002)
mortgage rate	-0.016** (0.007)	-0.018** (0.008)
constant	13.445*** (0.058)	13.451*** (0.058)
Observations	11,500	11,500
R ²	0.584	0.584
Adjusted R ²	0.578	0.578
Residual Std. Error	0.240 (df = 11356)	0.240 (df = 11354)
F Statistic	111.294*** (df = 143; 11356)	109.759*** (df = 145; 11354)

Note:

*p<0.1; **p<0.05; ***p<0.01

All models include zip and year-month fixed effects.

3.4.3.2 Flood Experience

Table 9 presents the results of the combined ITS models estimated for zip codes with prior flood experience. These models examine whether housing price dynamics in flood-experienced submarkets respond differently to the evolving flood-risk information and disclosure environment. All specifications include zip-code and year-month fixed effects, along with macroeconomic and housing market controls. Across both models, the baseline time trend is positive and statistically significant, indicating that median housing prices in flood-experienced zip codes continued to increase over time. The immediate level effects associated with the disclosure interventions are generally small and statistically insignificant. None of the intervention indicators produce statistically significant immediate changes in housing prices. These results suggest that flood-experienced areas did not exhibit abrupt repricing when new flood-risk information became available.

More noticeable adjustments appear in the post-intervention trend coefficients. The coefficient for *slope D₂* is positive and weakly significant ($p < 0.1$), indicating a modest acceleration in housing price growth following Realtor.com's integration of flood-risk information. In addition, *slope D₄* is positive and statistically significant in both models, suggesting a moderate increase in price growth following Zillow's adoption of flood risk information. By contrast, the remaining trend coefficients are statistically insignificant, indicating no clear trend shifts following these interventions. The control variables behave largely as expected. Mortgage rates are negative and statistically significant, indicating weaker housing price growth during periods of higher borrowing costs. Other controls, including building permits, new housing units, and unemployment rates, are not statistically significant in these models.

Overall, the results suggest that housing markets in flood-experienced zip codes did not exhibit strong immediate price reactions to the disclosure of flood risk information or to the implementation of the state-level disclosure law. Instead, the effects appear primarily through modest adjustments in housing price growth trends following certain platform-based disclosures. These findings indicate that in areas already familiar with flooding, the expansion of formal flood risk information may reinforce existing market expectations rather than triggering abrupt price corrections.

Table 9. Sub-Market Differences by Flood Experience

	<i>Dependent variable:</i>	
	Log Median Sale Price	
	Relaxed FE (D ₁ -D ₄) Model 3.5	Relaxed FE (D ₁ -D ₅) Model 3.6
time	0.005*** (0.001)	0.005*** (0.001)
post D ₁	-0.004 (0.043)	-0.002 (0.043)
post D ₂	0.117 (0.084)	0.116 (0.084)
post D ₃	0.005 (0.040)	0.008 (0.040)
post D ₄	-0.042 (0.035)	-0.057 (0.045)
post D ₅		-0.003 (0.036)
slope D ₁	-0.081 (0.050)	-0.081 (0.050)
slope D ₂	0.091* (0.052)	0.090* (0.052)
slope D ₃	-0.013 (0.012)	-0.013 (0.012)
slope D ₄	0.037** (0.016)	0.032* (0.018)
slope D ₅		0.005 (0.009)
permits	0.0004 (0.0004)	0.0004 (0.0004)
new units	0.00001 (0.00001)	0.00001 (0.00001)
unemployment rate	0.001 (0.002)	0.001 (0.002)
mortgage rate	-0.023** (0.010)	-0.021* (0.011)

constant	12.821*** (0.051)	12.817*** (0.051)
Observations	4,365	4,365
R ²	0.628	0.628
Adjusted R ²	0.622	0.622
Residual Std. Error	0.212 (df = 4291)	0.212 (df = 4289)
F Statistic	99.377*** (df = 73; 4291)	96.694*** (df = 75; 4289)

Note:

*p<0.1; **p<0.05; ***p<0.01

All models include zip and year-month fixed effects.

3.4.3.3 Household Income Level

Table 10 presents the results of the combined ITS models estimated for zip codes with high household income. These models examine whether housing price dynamics in higher-income submarkets respond differently to the evolving flood-risk information and disclosure environment. All specifications include zip-code and year-month fixed effects, along with macroeconomic and housing-market controls. Across both models, the baseline time trend is positive and weakly statistically significant, indicating that housing prices in high-income zip codes continued to increase gradually over time. The immediate level effects associated with the disclosure interventions are generally small and statistically insignificant. None of the intervention indicators produce statistically significant immediate shifts in housing prices within high-income submarkets. These results suggest that the disclosure of flood-risk information did not trigger abrupt repricing in higher-income areas.

Similarly, the post-intervention trend coefficients show limited evidence of systematic changes in price growth following the disclosure events. The slope coefficients associated with the early private-sector disclosures (*slope D₁*, *slope D₂*, and *slope D₃*) are not statistically significant, indicating no clear trend adjustments following these interventions. The coefficients for *slope D₄* and *slope D₅* are also statistically insignificant, suggesting that the later expansion of flood-risk information through Zillow and the implementation of the state-level disclosure law did not produce measurable changes in housing price growth trends in high-income zip codes. The control variables provide some evidence consistent with broader housing market dynamics. Mortgage rates are negative and statistically significant, indicating weaker housing price growth during periods of higher borrowing costs. Building permits show a small negative and

statistically significant coefficient, suggesting that increased construction activity may be associated with modest downward pressure on housing prices within these higher-income areas.

In summary, the results suggest that housing markets in high-income zip codes exhibited limited sensitivity to the sequence of flood-risk information disclosures and regulatory interventions. Neither the platform-based disclosures nor the state-level disclosure law produced statistically significant immediate price adjustments or sustained changes in price growth trends. These findings indicate that housing price dynamics in higher-income submarkets may be influenced more strongly by broader housing demand, location amenities, and macroeconomic conditions than by newly disclosed flood-risk information alone.

Table 10. Sub-Market Differences by Household Income

	<i>Dependent variable:</i>	
	Log Median Sale Price	
	Relaxed FE (D ₁ -D ₄) Model 3.7	Relaxed FE (D ₁ -D ₅) Model 3.8
time	0.002* (0.001)	0.002* (0.001)
post D ₁	-0.003 (0.065)	-0.010 (0.065)
post D ₂	0.130 (0.127)	0.132 (0.127)
post D ₃	-0.077 (0.058)	-0.085 (0.059)
post D ₄	-0.025 (0.053)	0.023 (0.068)
post D ₅		0.006 (0.054)
slope D ₁	-0.082 (0.076)	-0.083 (0.076)
slope D ₂	0.084 (0.078)	0.086 (0.078)
slope D ₃	-0.004 (0.018)	-0.004 (0.018)

slope D ₄	0.008 (0.024)	0.023 (0.028)
slope D ₅		-0.014 (0.013)
permits	-0.001** (0.001)	-0.001** (0.001)
new units	0.00000 (0.00002)	0.00000 (0.00002)
unemployment rate	0.001 (0.004)	0.001 (0.004)
mortgage rate	-0.037** (0.016)	-0.041** (0.016)
constant	13.498*** (0.076)	13.512*** (0.077)
Observations	3,481	3,481
R ²	0.475	0.475
Adjusted R ²	0.464	0.464
Residual Std. Error	0.284 (df = 3414)	0.284 (df = 3412)
F Statistic	46.736*** (df = 66; 3414)	45.375*** (df = 68; 3412)

Note: *p<0.1; **p<0.05; ***p<0.01
All models include zip and year-month fixed effects.

3.4.3.4 Educational Attainment level

Table 11 reports the results of the combined ITS models estimated for housing markets located in zip codes with higher educational attainment. These models examine whether housing price dynamics in more highly educated neighborhoods respond differently to the evolving flood-risk information and disclosure environment. All specifications include zip-code and year-month fixed effects, along with macroeconomic and housing-market controls. Across both models, the baseline time trend is positive but not statistically significant, indicating that housing price growth in highly educated zip codes did not exhibit a distinct underlying trend during the study period after controlling for fixed effects and other factors. The immediate level effects associated with the disclosure interventions are generally small, with the exception of *post D₂*, which is positive and statistically significant in both specifications. This result suggests that housing prices in highly educated zip codes experienced a modest immediate increase following

Realtor.com's integration of flood-risk information. The remaining intervention indicators do not produce statistically significant immediate price shifts.

More substantial adjustments appear in the post-intervention trend coefficients. The coefficient for *slope D₁* is negative and highly significant, indicating that housing price growth slowed following the initial release of the FSF flood-risk model. In contrast, *slope D₂* is positive and statistically significant, suggesting a rebound in housing price growth after Realtor.com integrated flood-risk information into its listings. These two early interventions therefore appear to have produced alternating adjustments in price trends within highly educated neighborhoods. The later interventions show more mixed results. *Slope D₃* is not statistically significant, indicating no clear trend change following Redfin's adoption of flood-risk information. However, *slope D₄* becomes positive and statistically significant in the policy-inclusive specification, suggesting a moderate increase in housing price growth following Zillow's integration of flood-risk data. In contrast, *slope D₅* is negative and statistically significant, indicating a modest slowdown in housing price growth after the implementation of the New York State flood disclosure law. The control variables behave largely as expected. Mortgage rates are negative and statistically significant across both models, indicating weaker housing price growth during periods of higher borrowing costs.

Overall, the results suggest that housing markets in highly educated zip codes experienced some adjustments in price growth trends following early flood risk information disclosures, particularly during the initial expansion of platform-based risk information. However, these adjustments appear to reflect gradual changes in price growth dynamics rather than abrupt price corrections. Later interventions, including Zillow's integration of flood-risk information and the state-level disclosure law, produce more limited or mixed effects, indicating that the influence of flood risk transparency may have become more diffuse as information spread more broadly across the housing market.

Table 11. Sub-Market Differences by Education Level

	<i>Dependent variable:</i>	
	Log Median Sale Price	
	Relaxed FE (D ₁ -D ₄) Model 3.9	Relaxed FE (D ₁ -D ₅) Model 3.10
time	0.001 (0.001)	0.001 (0.001)
post D ₁	0.007 (0.044)	-0.002 (0.044)
post D ₂	0.245*** (0.086)	0.248*** (0.086)
post D ₃	-0.055 (0.039)	-0.064 (0.040)
post D ₄	-0.016 (0.036)	0.047 (0.045)
post D ₅		0.016 (0.036)
slope D ₁	-0.145*** (0.051)	-0.146*** (0.051)
slope D ₂	0.150*** (0.052)	0.153*** (0.052)
slope D ₃	-0.010 (0.012)	-0.009 (0.012)
slope D ₄	0.021 (0.016)	0.040** (0.018)
slope D ₅		-0.019** (0.009)
permits	-0.0004 (0.0004)	-0.0004 (0.0004)
new units	0.00001 (0.00001)	0.00001 (0.00001)
unemployment rate	-0.001 (0.002)	-0.0005 (0.002)
mortgage rate	-0.021** (0.010)	-0.028** (0.011)

constant	13.471*** (0.070)	13.491*** (0.071)
<hr/>		
Observations	6,918	6,918
R ²	0.460	0.460
Adjusted R ²	0.452	0.452
Residual Std. Error	0.266 (df = 6817)	0.266 (df = 6815)
F Statistic	57.983*** (df = 100; 6817)	56.928*** (df = 102; 6815)

Note:

*p<0.1; **p<0.05; ***p<0.01

All models include zip and year-month fixed effects.

3.5 Discussion

This empirical study examined whether critical temporal interventions related to flood-risk disclosure, both market-driven initiatives and mandated policy-driven regulations, produced measurable effects on housing market dynamics in NYC. The findings contribute new insights into how flood-risk information disclosure, depending on its timing, institutional origin, and regulatory framing, shapes housing sale prices over time.

The first key insight is that flood-risk disclosures introduced by private real estate platforms produced modest but observable adjustments in housing price trends, although most immediate price effects were statistically insignificant. In particular, the integration of flood risk information on platforms, such as Redfin (February 2021) and Zillow (September 2024), was associated with changes in post-intervention housing price growth patterns, rather than abrupt price declines. These results suggest that platform-based disclosures may gradually influence market expectations regarding flood vulnerability.

These patterns align with the broader literature on information salience and hazard communication: even when voluntary, accessible, platform-based disclosures can influence buyer behavior, particularly when integrated into widely used housing search platforms where prospective buyers gather information during the home search process. Importantly, these newly available flood risk scores, provided by third-party climate service and analytics organizations and embedded directly into digital listing interfaces, may shape housing market perceptions even when they are not derived from FEMA maps or official government risk assessments.

In contrast, the mandatory state-level disclosure law implemented in March 2024 generated limited immediate market responses and no clear sustained changes in price trends in the combined ITS models. This finding suggests that once flood risk information has already diffused through digital real estate platforms and other informal channels, the marginal effect of additional regulatory disclosure may be limited. This asymmetry highlights an important distinction between information availability and information institutionalization: markets may begin to adjust once risk becomes visible to buyers, even before formal regulatory mandates require disclosure in real estate transactions.

Secondly, the combined ITS models revealed that the sequence of market-based disclosures contributed to gradual adjustments in housing price growth trajectories, while later policy-based disclosures produced diminishing marginal effects once earlier interventions had already shaped market expectations. These dynamics underscore the importance of temporal sequencing in policy design. Voluntary disclosures introduced through digital platforms may serve as early signals that increase transparency and awareness in housing markets. However, when regulatory mandates are introduced after risk information has already become widely accessible, their incremental influence on market outcomes may be limited unless they introduce substantially new information or enforcement mechanisms. Using NYC as a case study, this analysis contributes to broader theories of regulatory layering, information diffusion, and market adaptation in the context of climate risk governance. As climate risk data becomes increasingly accessible through both public and private sources, housing markets may progressively internalize such information into pricing behavior and investment decisions.

Last but not least, the submarket analysis uncovered important heterogeneities in how different communities respond to flood-risk information. In high-risk zip codes, housing prices continued to increase over time but exhibited slower growth rates, suggesting a gradual adjustment process as flood vulnerability becomes more widely recognized. This pattern may reflect increasing buyer sensitivity to flood exposure, evolving insurance costs, or differences in local infrastructure and resilience investments. Similarly, zip code areas with prior NFIP flood-loss experience exhibited slower price growth even before major disclosure interventions occurred. This pattern suggests that the lived experience of past flooding may already function as an informal signal of environmental risk, influencing housing market behavior independently of formal disclosure policies. In such contexts, local experience and community knowledge may partially substitute for formal information disclosure.

Income-based stratification also revealed meaningful patterns. While high-income neighborhoods continued to command relatively high housing prices, the combined ITS models showed limited evidence that these areas responded strongly to flood-risk disclosure interventions. Instead, housing price dynamics in higher-income neighborhoods appear to be influenced more strongly by broader housing demand, location amenities, and macroeconomic conditions than by newly disclosed flood-risk information. Similarly, zip codes with higher

levels of educational attainment exhibited modest adjustments in price growth following early disclosure events but showed mixed or limited responses to later interventions. This pattern may suggest that highly educated homebuyers are more capable of incorporating environmental risk information into decision-making early in the information diffusion process, reducing the marginal impact of subsequent disclosures. These subgroup findings suggest that social and spatial characteristics, such as risk exposure, income, education, and prior disaster experience, mediate how housing markets respond to climate-risk information. These factors shape both the accessibility of risk information and the capacity of households to interpret and act upon it, leading to uneven patterns of market adjustment across neighborhoods.

This study offers several policy implications for policymakers, planners, and real estate stakeholders. First, it demonstrates that expanding access to climate-risk information, whether through public regulations or private data platforms, can gradually influence housing market expectations. Second, the findings suggest that voluntary disclosures embedded in widely used digital platforms may play an increasingly important role in shaping how homebuyers perceive environmental risk. Third, the results highlight the importance of accounting for submarket heterogeneity when designing disclosure policies and mitigation strategies, particularly in cities characterized by diverse socioeconomic and hazard exposure profiles. More broadly, these findings point to the need for coordinated climate risk communication strategies that integrate public regulatory frameworks with private-sector information platforms, ensuring that risk information is both transparent and consistently communicated across housing market actors.

Future Research and Limitations

Several limitations and avenues for future research should be noted. First, the analysis does not explicitly account for lagged behavioral responses, such as delayed reactions by homebuyers or sellers that may unfold months or years after information disclosures occur. Future research could apply distributed lag models or cumulative impact frameworks to capture these temporal dynamics more fully. Second, while the ITS approach is well suited for evaluating temporal policy interventions, it relies on the assumption that pre-intervention trends provide an appropriate counterfactual for post-intervention outcomes. Although the models include extensive controls and fixed effects, future studies could complement this approach with difference-in-differences, ARIMA, or synthetic control methods to strengthen causal inference.

Additionally, although the March 2024 enactment of New York State’s flood-risk disclosure law represents a clear informational intervention, several other housing-related policy discussions and announcements occurred in NYC around the same period. These include the City Council’s March 2024 vote to extend the Rent Stabilization Law, the Adams administration’s announcement of a workforce housing investment initiative, and early public discussion of zoning text amendments aimed at facilitating residential development and office-to-residential conversions. Importantly, these contemporaneous events primarily relate to rental regulation, long-term housing supply, or development finance, and were either continuations of existing policy regimes or proposals without immediate binding effects on owner-occupied housing transactions. Third, the models do not fully capture potential spatial spillover effects, such as shifts in housing demand from higher-risk to nearby lower-risk areas. Nor do they incorporate qualitative dimensions of buyer decision-making, including perceptions of flood risk, trust in risk data sources, and interactions with insurance markets. Mixed-method approaches, including homebuyer surveys or interviews, could provide valuable insights into how environmental risk information influences housing market behavior.

Chapter 4. The Role of Community-Level Flood Mitigation Activities in Shaping Housing Prices

4.1 Introduction

Flooding poses an increasingly serious challenge to urban safety, economic stability, and public finance in U.S. cities. As climate change intensifies precipitation patterns and sea-level rise, flood hazards threaten not only individual properties but also broader urban systems, including transportation networks, utilities, and public services (Gourevitch et al., 2023; U.S. Global Change Research Program, 2023). These disruptions can generate cascading economic effects through housing market depreciation, infrastructure shutdowns, reduced municipal tax revenues, and increased public expenditures for disaster response and recovery. As a result, local governments face growing pressure to proactively manage flood risk, even as uncertainty about future flood exposure continues to increase (Beckett, 2021).

For example, the case of 2012's Hurricane Sandy in New York City (NYC) illustrates the scale and stakes of urban flood risk management. Hurricane Sandy, one of the costliest disasters in U.S. history, caused widespread flooding and marked a turning point in the city's approach to post-disaster recovery and climate adaptation, catalyzing sustained investments in resilience and risk mitigation. In the years following Sandy, NYC has invested more than \$17 billion in post-disaster recovery and resilience initiatives, including coastal protection, drainage improvements, and community-based flood mitigation (NYC, 2026). The city established the Mayor's Office of Climate and Environmental Justice (MOCEJ) to coordinate long-term resilience efforts on behalf of all New Yorkers and has expanded its flood risk management framework to encompass land-use planning, infrastructure investment, public information, and financial support mechanisms (NYCEM, 2025). These investments reflect a growing recognition that flood risk threatens not only physical safety but also the economic foundations of the city, including property markets and fiscal stability.

At the household level, flood risk is also increasingly salient in housing market decisions. Housing represents the largest asset for most households, and changes in property prices directly affect household wealth, financial security, and mobility. Flood risk exposure can impose

multiple risks on homeowners, including property damage, higher insurance costs, mortgage distress, and long-term depreciation, all of which are amplified under climate change. Housing sale prices provide a direct and market-based indicator of how homebuyers and homesellers perceive and internalize flood risk, as they reflect realized transactions rather than appraised or hypothetical values (Gaca, 2018). Prior research shows that properties exposed to flood risk tend to experience fewer transactions and lower prices relative to comparable properties in lower-risk areas (Bernstein et al., 2018; Harrison et al., 2001). More broadly, climate-related risks can reduce the desirability of certain locations, alter market expectations, and reshape patterns of demand and investment in urban housing markets (Palacios, 2023).

While both governments and households care deeply about the relationship between flood risk and housing prices, the physical flood exposure of a given property is largely fixed in the short to medium term. In this context, public flood-mitigation interventions serve as a critical mechanism through which flood risk may be managed, perceived, and potentially priced differently across housing markets. Community-level mitigation activities, such as drainage improvements, green infrastructure, and floodplain management, are intended to reduce damage and enhance resilience, but they may also shape how homebuyers interpret and respond to flood risk when making housing decisions.

Despite the substantial scale of public investment in flood mitigation, surprisingly little empirical work to date has examined how these interventions interact with flood risk in housing markets. Existing studies tend to focus either on the capitalization of flood risk itself or on broad policy programs, such as Federal Emergency Management Agency (FEMA)'s Community Rating System, often at coarse spatial scales. Much less is known about whether, and how, localized, city-managed mitigation projects are associated with housing prices, or whether different types of mitigation activities moderate the relationship between flood risk and housing prices. In particular, it remains unclear which mitigation strategies homebuyers perceive as credible protective measures, and which may instead function as signals of underlying vulnerability.

This study addresses this gap by examining how flood risk and community-level flood mitigation activities are jointly associated with housing prices in NYC. Using recent flood-risk data, detailed property transactions, and spatially explicit information on city-managed mitigation

projects, this study evaluates whether mitigation investments are associated with higher housing prices on average and whether they moderate the housing-market penalty associated with flood risk. By focusing on mitigation type and interaction effects, this chapter provides new evidence on the nuanced ways in which public adaptation investments are reflected, sometimes positively, sometimes negatively, in urban housing markets.

4.2 Literature Review

4.2.1 Flood Mitigation, Flood Risk, and Housing Prices

Growing uncertainty surrounding flood risk has led households, local governments, and financial institutions to increasingly evaluate the economic benefits of flood-mitigation investments (Kelly & Molina, 2023). A large interdisciplinary literature, from urban planning, public policy, ecology, and disaster management, documents that early flood mitigation can generate both short-term risk reduction and long-term adaptive benefits (Keeler et al., 2018). Flood mitigation strategies are commonly categorized into green infrastructure or nature-based solutions (e.g., wetlands, bioswales), grey infrastructure (e.g., drainage systems, levees, floodwalls), and regulatory or non-structural measures (e.g., floodplain management, zoning, and building codes) (International Federation of Red Cross and Red Crescent Societies, 2022; Alves et al., 2019; Prudencio & Null, 2018; Lennon et al., 2014).

A substantial body of research evaluates the economic effectiveness of flood mitigation, primarily in terms of reductions in flood damage and losses. Studies find that open space preservation and wetlands conservation significantly reduce flood-related property losses (Sadiq et al., 2019; Tyler et al., 2019; Calil et al., 2015), while compact development patterns are associated with lower flood damage (Brody et al., 2013). Structural flood protection measures have been shown to reduce expected flood losses, particularly in high-risk areas (Highfield & Brody, 2013), and parcel-level non-structural mitigation measures, such as elevation and retrofitting, can substantially reduce insured losses (Cano Pecharroman & Hahn, 2024; Highfield et al., 2014). However, these studies primarily focus on damage reduction, rather than on how mitigation is reflected in housing market outcomes.

Empirical evidence linking flood mitigation to housing prices is comparatively limited and mixed, with studies finding positive capitalization effects in some contexts, negligible or delayed effects in others, and outcomes that vary by the type of mitigation, spatial scale, and time horizon examined. Early studies examined coastal amenities, including flood exposure, while largely overlooking flood mitigation interventions, including drainage systems, stormwater and green infrastructure, structural defenses (e.g., levees and seawalls), and non-structural planning or regulatory measures (Bin et al., 2008; Pompe, 1999). Kelly and Molina (2023) show that proximity to flood-adaptation infrastructure is associated with increases in housing prices shortly after implementation. Kim (2020) finds positive capitalization effects of green infrastructure and building elevation in MDC and NYC. In contrast, Irwin et al. (2017) document housing price declines near certain green infrastructure projects in suburban contexts, while Hoover et al. (2020) find no statistically significant relationship. These mixed findings suggest that mitigation does not operate as a uniform price-enhancing amenity and that context and mitigation type matter.

Parallel to this literature, a growing body of research examines how flood risk information is capitalized into housing prices. Most studies rely on FEMA flood maps to estimate flood exposure (Hino & Burke, 2021; Bernstein et al., 2018; Bin et al., 2008). However, FEMA maps have been criticized for limitations related to accuracy, spatial resolution, and forward-looking relevance (CFPB, 2025; Urban Institute, 2024; Guin, 2023). Recently, scholars have begun to use First Street Foundation (FSF) flood risk data, which provide advanced methods and property-level risk score assessments. FSF data have been used to estimate national housing overvaluation due to unpriced flood risk (Gourevitch et al., 2023) and to assess long-term exposure of residential and infrastructure assets (Porter et al., 2021, 2022). Comparative studies highlight substantial differences between FEMA and FSF risk estimates. Specifically, FSF identifies a larger share of properties in noncoastal and lower-income neighborhoods as facing elevated pluvial flood hazards, whereas FEMA's flood maps tend to concentrate higher flood risk in coastal and relatively higher-income areas. These methodological differences have important implications for property valuation, insurance coverage, and the distributional consequences of flood risk disclosure (Ding et al., 2024; Galster et al., 2024). Despite this progress, few studies use FSF data to examine housing price responses, and even fewer link FSF-based flood risk to mitigation investments.

Critically, although flood risk and flood mitigation are often studied separately, research rarely examines how mitigation alters the relationship between flood risk and housing prices. A small number of recent studies have begun to explore this interaction. Fonner et al. (2023) find that floodplain restoration reduces perceived flood risk and increases housing prices by approximately 5%. Mutlu et al. (2023) show that green infrastructure can both reduce flood-risk discounts and generate housing price premiums of 5-11%. However, most existing studies focus on whether mitigation is capitalized into housing prices on average, rather than on whether mitigation moderates the marginal price penalty associated with flood risk itself.

4.2.2 Homebuyer Perceptions, Risk Signaling, and Mitigation Interpretation

Housing markets respond not only to objective flood risk, but also to how risk and mitigation are perceived by homebuyers. Flood risk is often intangible, uncertain, and probabilistic, making perceptions and information central to pricing decisions. During the home-buying process, cognitive limitations may lead homebuyers to rely more on perceived than on objective flood risk, with such perceptual biases reflected in housing price discounts (Shi et al., 2024). Housing prices, therefore, serve as a revealed-preference proxy for households' interpretation of flood risk and mitigation (Kim et al., 2020). Survey and empirical studies also show that flood risk awareness is associated with housing price discounts, particularly among households with prior flood experience (Seo et al., 2021). Risk perception and responsiveness vary by age, location, and socioeconomic background (Monaghan et al., 2016) and are shaped by flood insurance programs, disclosure requirements, and communication strategies (Filatova et al., 2011). Recent research has further examined how the presentation of flood risk, along with inconsistent flood-risk communication, can lead homebuyers to underestimate flood exposure, which defined as the physical susceptibility of a property to flooding based on its location and hydrological conditions, particularly for properties in high-risk areas (Sheldon et al., 2025; Oyetunji et al., 2025).

Importantly, mitigation measures may influence housing prices through informational and signaling channels, in addition to physical protection. Homebuyers may interpret flood mitigation infrastructure either as credible evidence of reduced risk or as a signal of underlying vulnerability. Survey-based research indicates that residents and real estate professionals do not uniformly perceive green infrastructure as value-enhancing (Williams et al., 2019), and recent

evidence from Florida suggests that many residents do not expect future flood risk to affect housing prices (Palm & Bolsen, 2023). These findings highlight substantial heterogeneity in how mitigation is understood and valued.

Studies that explicitly examine the visibility and interpretation of mitigation activities support this dual mechanism. Jauregui et al. (2023) find that homebuyers are willing to pay price premiums for properties near newly constructed green infrastructure, but that these premiums decline as infrastructure ages. Boatwright et al. (2014) show that visible flood-protection features, such as reinforced street edges, are associated with higher housing prices. More broadly, homebuyers' level of trust in mitigation effectiveness, environmental beliefs, and prior experience with flooding shape willingness to pay for flood protection (Verlynde et al., 2019). Recent work tracking homebuyers through the home search process further demonstrates that homebuyers prefer properties with effective and visible mitigation measures, such as elevation or flood-resistant materials, and are willing to pay premiums for them (Sheldon et al., 2025).

Despite growing interest in flood risk and adaptation, several gaps remain. First, there is limited use of forward-looking, high-resolution flood risk data, such as FSF risk scores, to study housing price responses at the city level, particularly in dense urban environments. Second, existing studies rarely examine heterogeneity across mitigation types, leaving unanswered which public investments are most effective from a housing market perspective. Third, and most importantly, the literature largely overlooks whether mitigation investments moderate the marginal price effect of flood risk, rather than merely shifting average prices. As a result, we know little about whether mitigation reduces, amplifies, or leaves buyers' sensitivity to flood risk unchanged.

This study addresses these gaps by combining parcel-level housing transactions in NYC with FSF flood-risk data and detailed, city-managed flood-mitigation investments. By explicitly modeling interactions between flood risk and mitigation activities, the analysis moves beyond average capitalization effects to examine how different types of mitigation alter the flood-risk discount itself. In doing so, this research contributes to the literature by highlighting the dual role of mitigation as both physical protection and an informational signal, offering new insights into how public adaptation investments are interpreted and priced in urban housing markets.

4.2.3 Research Hypotheses

This study addresses the following research question: *Do community-level flood-mitigation activities reduce the adverse effects of flood risk on housing prices?* To answer this question, the study adopts a property-level analytical framework that quantifies the effect of flood risk on housing prices and examines whether public mitigation activities moderate this relationship. The analysis is guided by three sub-questions:

- What is the relationship between flood risk and housing prices in NYC?
- How are local flood mitigation investments associated with the relationship between flood risk and housing prices?
- Does the association between flood risk and housing prices differ across types of flood mitigation activities?

A central assumption underlying this study is that community-level flood mitigation activities influence housing market outcomes primarily through the perceptions and then subsequent choices made by home buyers and sellers. For flood mitigation measures to be reflected in housing prices, market participants must at least partially recognize their presence and interpret them, accurately or not, as signals of reduced risk or enhanced resilience, though awareness and interpretation are likely to vary across buyers, sellers, and market contexts. This awareness can arise through several channels: First, real estate disclosures and online property listings increasingly reference resilience features or nearby infrastructure upgrades, particularly in flood-prone areas. According to the National Association of Realtors (2024), approximately 43% of homebuyers begin their housing search online, increasing the likelihood that visible or advertised mitigation improvements shape decision-making. Secondly, flood insurance programs provide an additional informational channel through which flood risk is conveyed to homebuyers. In the United States, properties located in high flood-risk areas, specifically within FEMA's Special Flood Hazard Areas (SFHAs), are required to carry flood insurance in order to obtain federally backed mortgages and to participate in the National Flood Insurance Program (HUD Exchange, 2026; Tobin & Calfee, 2005). This requirement serves as a salient signal of flood risk, prompting homebuyers to explicitly consider flood exposure and weigh the trade-offs between flood insurance costs and housing prices when purchasing. Third, NYC's commitment to open data

and transparency is important. The city publicly provides detailed flood maps and infrastructure investment records, which are accessible to real estate professionals, researchers, and prospective homeowners alike. This accessibility enhances public awareness of both flood risk and mitigation activities. Finally, neighborhood reputation and lived experience matter. Research has shown that some homebuyers prefer to receive flood risk information from their communities (Feldman et al., 2016). In communities that have experienced repeated flooding, the successful implementation of visible mitigation projects, such as green infrastructure, drainage improvements, or protective barriers, may gradually shift perceptions and reduce perceived risk over time. Even without formal announcements, these changes can become capitalized into housing prices through repeated market interactions.

4.3 Data & Method

4.3.1 Data Collection and Processing

This study aims to quantify the impact of flood risk on housing sale prices at the property scale, and to examine whether community-level flood mitigation activities moderate the relationship between flood risk and housing prices. To achieve this, the analysis integrates multiple data sources, including NYC housing sale transactions, flood risk information from the FSF, socio-economic characteristics from the U.S. Census Bureau, and local housing market and macroeconomic indicators from NYC Planning.

4.3.1.1 Housing Sale Price Data

Housing transaction data are primarily drawn from the NYC rolling sales and historical sales records, which provide detailed, parcel-level information on residential property transactions. These data are used to quantify the housing market impacts of flood risk and flood mitigation measures. Additional details on this data source and preprocessing procedures are provided in 3.3.1 Data Collection and Processing in Chapter 3.

The housing transaction dataset includes sale dates and sale prices, as well as property characteristics such as gross square footage, year built, and building class. For the purposes of this study, housing transactions between January 1, 2016, and December 31, 2024, are used. The sample is further restricted to Building Class Category 1, which includes residential properties such as one- to three-family dwellings and condominiums. Properties classified as vacant land or

other non-residential categories are excluded from the analysis. Consistent with standard practice in hedonic housing price analyses and with the approach adopted in Study 2, transactions with implausibly low sale prices, defined as those below \$10,000, are excluded from the analysis (Goodman & Thibodeau, 2008; Bernstein et al., 2019). This threshold reflects a commonly used rule of thumb in real estate research and is justified on practical grounds, as such transactions rarely represent arm's-length market sales. Instead, they typically correspond to family transfers, estate inheritances, divorce settlements, cooperative share transfers, data entry errors, or nominal transactions recorded for legal or administrative purposes rather than market valuation (Kenton, 2025; Baldauf et al., 2020).

To further improve robustness and limit the influence of extreme values, outliers in housing prices are identified and removed using the interquartile range (IQR) method. Specifically, observations falling below the first quartile minus 1.5 times the IQR ($Q1 - 1.5 \times IQR$) or above the third quartile plus 1.5 times the IQR ($Q3 + 1.5 \times IQR$) are excluded. This IQR-based trimming is the preferred approach because it is a standard, data-driven method that adapts to skewed housing price distributions without imposing arbitrary cutoffs and preserves most transactions while removing extremely high or low values that may reflect data errors or highly atypical market behavior. After cleaning for missing sale prices and applying these filters, the final housing sales dataset contains 190,162 transactions.

4.3.1.2 Flood Risk Factor

Flood risk information is obtained from the FSF, which provides aggregated flood risk scores at the zip code level across the United States. Each zip code is assigned a flood risk score ranging from 1 to 10, with higher values indicating greater flood exposure. Scores of 1 indicate minimal flood risk, scores of 10 indicate extreme risk, and zip codes with scores above 6 are classified as high risk and are shown in red on the map. This study uses FSF's average flood risk score in NYC, which reflects current flood exposure under a 100-year return period scenario at the zip code level.

To reduce non-essential multicollinearity in models that include interaction terms, the average flood risk measure is mean-centered by subtracting the citywide mean flood risk from each zip code's score. This transformation does not alter the substantive interpretation of the flood risk

variable but allows regression coefficients, particularly interaction effects, to be interpreted relative to the average level of flood risk across NYC.

The spatial distribution of average flood risk across NYC zip codes is illustrated in Figure 15. Zip codes with flood risk scores greater than 6 are classified as high risk and are shown in red on the map. Because flood risk is aggregated at the zip code level, this measure may be subject to the Modifiable Areal Unit Problem (MAUP). Zip codes are administrative boundaries rather than environmentally homogeneous units, and sharp contrasts in average flood risk across adjacent zip codes may partly reflect boundary definitions rather than true discontinuities in flood exposure. Accordingly, the flood risk measure in this study captures neighborhood-scale flood risk context rather than property-specific risk.

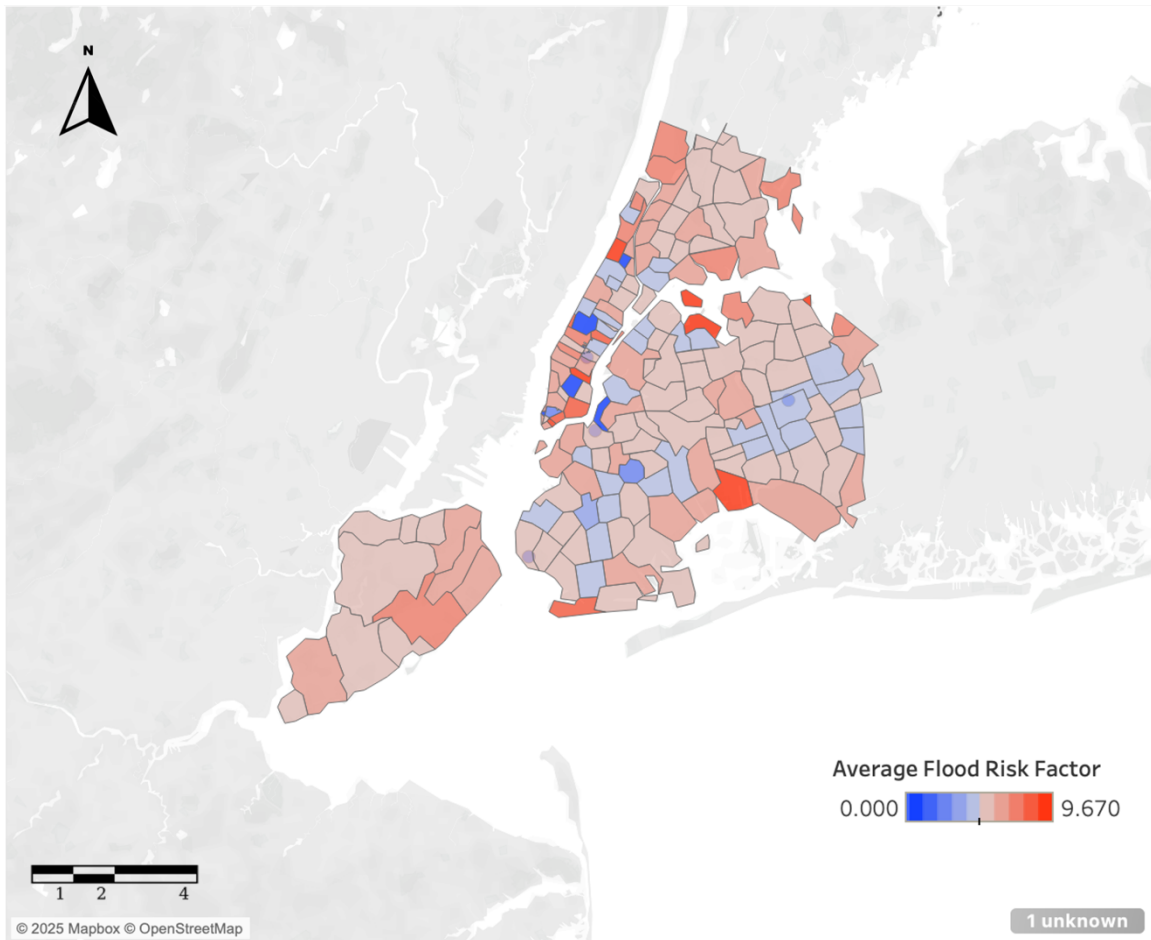


Figure 15. NYC FSF Flood Risk Map
(Source: Author)

4.3.1.3 Flood Mitigation Activities

This study uses two primary data sources to capture community-level flood-mitigation activities: the NYC Mitigation Actions Database and the Green Infrastructure (GI) Database from NYC Open Data. The NYC Mitigation Actions Database contains 965 existing and under-construction hazard-mitigation and climate-adaptation projects in NYC. These projects are designed to reduce hazard exposure, address climate-related risks, or prevent potential economic losses. The completion dates of these mitigation actions range from 2013 to 2025, which aligns well with the study period of 2016-2024. To focus on interventions directly related to flooding, this study excludes projects unrelated to flood hazards, resulting in a subset of 484 flood-specific mitigation projects for analysis. The geographic coordinates (latitude and longitude) of each project are converted to zip codes using the OpenStreetMap Nominatim API to facilitate spatial integration with housing transaction data.

In addition, this study incorporates NYC's GI database, maintained by the Department of Environmental Protection. This dataset provides detailed information on stormwater management infrastructure constructed on streets, sidewalks, and other impervious surfaces. Key variables include project location, construction status, installation date, infrastructure type, and physical features. As of the most recent update on June 10, 2025, 13,950 out of 14,345 GI units (97%) were reported as constructed, indicating broad implementation of GI projects across the city.

Integrating these two flood-mitigation datasets with property-transaction data requires several additional data-processing steps. First, duplicate projects in the GI database are identified and removed so that mitigation activities are treated at the project level rather than the asset level. Projects sharing the same geographic location (latitude and longitude) and construction year are considered duplicates, and 117 records are removed. After this deduplication step, the GI database and the NYC Mitigation Actions Database are merged, and no further duplication is detected. This study then develops a mitigation project codebook based on FEMA's Community Rating System (CRS) framework, supplemented by the classification criteria proposed by Kim (2020). Each project is assigned to a category based on its primary objective and dominant intervention mechanism, as described in the project description provided in the datasets. When projects include multiple components, classification is determined by the main task conducted

and the core function of the investment. To ensure analytical clarity and avoid double-counting, each project is assigned to one and only one mitigation category, making the categories mutually exclusive by construction. While some projects may include complementary features (for example, green infrastructure embedded within a broader drainage upgrade), assigning a single primary category allows for consistent aggregation across space and time and facilitates interpretable comparisons across mitigation types in the regression analysis.

Using this framework, all mitigation projects are categorized into nine types: green infrastructure, construction reinforcement, drainage improvement, reconstruction and new critical facilities, equipment retrofitting, warning systems, information and mapping, education and community outreach, floodplain management, and grey infrastructure. Among these categories, green infrastructure represents the largest share of projects.

In contrast, grey infrastructure, warning systems, information and mapping, and education and community outreach each include fewer than one project in the dataset. Floodplain management projects primarily consist of planning- and policy-oriented interventions, such as strategic planning, mitigation program evaluation, property relocation, or regulatory compliance activities, that operate at a citywide scale rather than at the zip-code level. Because this study focuses on NYC-regulated, localized mitigation interventions that can plausibly vary across neighborhoods, and to avoid introducing selection bias or cherry-picking by supplementing the data with additional external sources, these project types are excluded from subsequent analyses. Detailed definitions and descriptions of all mitigation categories are provided in Table 12.

Table 12. NYC Flood Mitigation Activities Category Codebook

Mitigation activities type	Description	Total count	Percentage
Green infrastructure	This category includes nature-based and low-impact interventions designed to manage stormwater, reduce runoff, and enhance natural flood absorption. Activities include stormwater management projects; restoration of wetlands, lagoons, salt marshes, and coastal green spaces; beach nourishment; open space preservation; pavement subgrade upgrades; and building-scale measures such as blue roofs, green roofs, rooftop farms, detention systems, drywells, and stormwater system improvements.	13971	96.69
Equipment retrofitting	This category pertains to upgrades to building systems that enhance operational resilience during flood events, including the installation or retrofitting of on-site emergency power generators, electrical wiring and cable upgrades, pump installations, and related mechanical or electrical equipment improvements.	204	1.41
Drainage improvement	Measures that enhance the performance and reliability of drainage systems to prevent water backflow and localized flooding. Examples include erosion-control projects, installation of electronic check valves, floodgate upgrades, and interim flood-protection measures such as HESCO barriers, Tiger Dams, and flood logs.	185	1.28
Construction reinforcement	Structural and infrastructural enhancements aimed at strengthening existing assets against flood impacts. Activities include infrastructure upgrades, service building repairs, elevation of buildings and critical components, and reinforcement of transportation and utility infrastructure, such as elevating roadways.	41	0.28
Reconstruction and new critical facility	Development or replacement of facilities intended to maintain essential services during and after flood events. This category includes reconstruction of damaged assets and provision of new critical facilities, such as emergency shelters and resilience hubs, designed to support future flood preparedness and response.	39	0.27
Floodplain management	Planning- and policy-oriented interventions that reduce long-term exposure to flood risk. Activities include floodplain management planning, evaluation of mitigation programs, property acquisition and relocation, and implementation of flood protection	8	0.06

	strategies consistent with regulatory and hazard mitigation frameworks.		
Grey infrastructure	Large-scale engineered structures designed to physically control or block floodwaters. Examples include the construction or reinforcement of levees, dams, seawalls, wharves, and other hard-infrastructure flood defenses.	1	0.01
Warning system, information, and mapping	Information-based tools that improve flood preparedness, awareness, and decision-making. This category covers flood mapping updates, map information services, alarm and warning systems, hazard and risk disclosure initiatives, flood protection guidance, technical assistance, and flood data collection, maintenance, and dissemination.	1	0.01
Education and community outreach	Programs that strengthen community awareness, preparedness, and engagement related to flood risk. Activities include public education campaigns, community outreach projects, stakeholder workshops, and resident-focused capacity-building initiatives.	0	0.00

(Source: Author)

To capture variation in the intensity, timing, and spatial distribution of flood mitigation activities, this study aggregates mitigation projects into a zip code-year panel dataset and merges it with property transaction records. For each housing sale, mitigation variables are constructed as three-year cumulative counts of project types within the corresponding zip code. Specifically, for a property transaction occurring in year t , this study sums the number of completed mitigation projects of each category in years t , $t - 1$, and $t - 2$. For example, a transaction in 2020 is associated with the total number of drainage improvement projects completed in 2020, 2019, and 2018.

Mitigation exposure is operationalized using a three-year cumulative window for substantive and empirical reasons, rather than for sample size considerations. Prior research indicates that housing market responses to flood mitigation investments are time-limited and tend to be strongest shortly after project completion. A three-year window, therefore, captures the period during which mitigation investments are most likely to influence buyer perceptions and pricing decisions. This temporal framing is consistent with behavioral evidence showing that recent infrastructure investments are more salient to homebuyers and more likely to enter their information sets than older, normalized interventions (Jauregui et al., 2023). In addition, this

study conducts robustness checks using alternative aggregation windows, including five-year cumulative measures and “ever-built” indicators. The three-year cumulative specification yields the most stable and interpretable associations between mitigation activities and housing prices, whereas longer windows tend to dilute effects by pooling projects with heterogeneous timing and relevance.

4.3.1.4 Socio-economic Variables

In addition to flood risk and mitigation measures, this study incorporates several control variables to account for other factors that influence housing prices. These controls help isolate the specific effects of flood risk and mitigation activities by adjusting for broader economic, demographic, and social conditions that also shape housing market outcomes.

The socio-economic control variables are primarily drawn from the 2018 and 2023 ACS 5-Year Estimates provided by the U.S. Census Bureau. To align socio-demographic conditions with housing transaction timing, transactions occurring between 2016 and 2018 are matched with ACS 2018 estimates, while transactions from 2019 through 2024 are matched with ACS 2023 estimates. This approach ensures that neighborhood socio-economic characteristics reflect conditions proximate to the timing of each housing sale, while avoiding excessive interpolation across ACS release periods.

These variables include the percentage of white residents, median household income (in thousands of dollars), the percentage of the population with a bachelor’s degree or higher, and the fraction of renter-occupied households in each zip code. These controls capture underlying socio-economic conditions that may shape housing market dynamics and influence how flood risk and mitigation information is capitalized into property values (Baldauf et al., 2020; Miller & Pinter, 2022).

The analysis also incorporates locational fixed effects to control for time-invariant neighborhood characteristics and to account for unobserved spatial heterogeneity. Local place identifiers (*PO_NAME*) are used to control for persistent, time-invariant differences across geographic areas, such as access to amenities, historical development patterns, and neighborhood reputation, that are not fully captured by observable covariates.

To control for citywide and regional economic conditions, this study includes the number of new residential units, monthly unemployment rates, and a set of COVID-period indicators that capture major macroeconomic shocks and housing market disruptions common across locations. Data on new residential units are obtained from the NYC Department of City Planning, while unemployment rates come from the Bureau of Labor Statistics' Local Area Unemployment Statistics (LAUS). These variables are widely used in housing market studies to account for macroeconomic fluctuations that influence housing demand and pricing (Kim, 2020; Mueller et al., 2009).

All macroeconomic indicators are aggregated at the monthly borough level, where boroughs are NYC's five primary administrative divisions: Manhattan, Brooklyn, Queens, the Bronx, and Staten Island. Aggregating to the borough scale allows these indicators to vary over time while remaining consistent with the timing of individual housing transactions. Including these factors helps ensure that the estimated effects of flood risk and mitigation are not conflated with broader patterns of socio-economic sorting or neighborhood stratification. Table 13 presents descriptive statistics for the key variables used in the empirical analysis, including housing price indicators, macroeconomic controls, and flood-risk related variables.

Table 13. Descriptive Statistics for Variables used in Chapter 4

Variable	Measurement	Obs	Mean	SD	Min	Max
housing price	Residential property sale price (USD) recorded at the transaction level	190162	731637	336382	10000	1710000
gross square feet	Total floor area in square feet for the transacted property	185414	1814.3	801.9	0.0	31393.0
year built	Year in which the property was originally constructed	188832	1934.4	152.0	0.0	2024.0
flood risk	Average flood risk score in each zip code	184444	5.46	0.76	0.00	9.67
Green infrastructure		190162	24.70	88.24	0.00	923.00
Drainage improvement		190162	0.01	0.11	0.00	1.00
Construction reinforcement	Three-year cumulative count of flood mitigation projects completed in each zip code.	190162	0.03	0.24	0.00	3.00
Equipment retrofitting		190162	0.06	0.33	0.00	8.00
Reconstruction and new critical facility		190162	0.02	0.14	0.00	2.00
unemployment rate	Unemployment rate (%) representing local labor market conditions at the time of sale.	190162	6.09	3.02	3.80	21.50
income	Median household income (USD) at the zip-code level	184421	79267	22230	21149	182614
white	Share of residents identified as non-Hispanic White at the zip code level	184426	0.40	0.27	0.02	0.94
bachelor or more	Share of residents aged 25 or older with a bachelor's degree or higher at the zip code level	184426	0.32	0.10	0.05	0.85
renter	Share of occupied housing units that are renter-occupied at the zip code level	184421	0.48	0.21	0.14	0.97
Variable	Description					
COVID-19 period	Categorical variable capturing pandemic-related market phases: 0 = pre-COVID (before Feb 2020); 1 = Mar - May 2020; 2 = Jun - Dec 2020; 3 = Jan - Jun 2021; 4 = Jul 2021 - Feb 2022; 5 = Mar - Dec 2022; 6 = Jan 2023 - Dec 2024.					
building class	Property classification at the time of sale, indicating structural type and use (e.g., A1–A10: single-family homes; B: two-family dwellings; C: walk-up apartments; R: condominiums; S: mixed-use buildings).					

(Source: Author)

4.3.2 Statistical models

This study employs cross-sectional multivariate regression as the primary empirical strategy to assess whether local flood mitigation activities moderate the relationship between flood risk and housing prices (Stock, 2020; Gelman & Hill, 2006). The analysis follows a three-step modeling approach designed to progressively address the research questions and evaluate the robustness of the results.

(1) Hedonic OLS Model between Flood risk and Housing Price

Building on the standard hedonic pricing framework, this study first estimates a series of ordinary least squares (OLS) regressions to examine the association between flood risk and housing sale prices. In these baseline specifications, housing prices are modeled as a function of parcel-level flood risk and a set of property structural characteristics, including gross square footage, year built, and building class.

To better isolate the effect of flood risk on housing outcomes, the models progressively incorporate additional time-varying and location-specific controls. These include macroeconomic and housing market indicators, as well as socio-demographic characteristics measured at the zip-code level. Together, these controls account for broader economic conditions and neighborhood characteristics that may influence housing demand and pricing.

In terms of empirical strategy, locational fixed effects are introduced in later model specifications to capture unobserved, time-invariant neighborhood attributes, such as access to amenities, historical development patterns, and persistent differences in housing market conditions. By comparing housing transactions within the same geographic area, these fixed effects help reduce bias arising from omitted local characteristics and allow for a more conservative estimate of the flood-risk capitalization effect. The baseline hedonic model can be expressed as follows:

$$\log(\text{Price}) = \beta_0 + \beta_1 \text{Flood Risk}_i + \chi_i' \alpha + N_i' \gamma + \epsilon_i$$

Where:

- $\log(\text{Price}_i)$ represents the natural log of housing prices for the transaction
- Flood Risk_i is the measure of flood risk for zip code i

- X_i is a vector of property characteristics (e.g., area size, building age)
- N_i is the locational fixed effects
- ϵ_i is the error term

To assess whether the OLS assumptions are reasonably satisfied, several diagnostic checks are conducted. First, this study examines pairwise correlations among control variables. Strong correlations (e.g., greater than 0.8 or less than -0.8) may indicate multicollinearity and should be reviewed carefully; if redundancy is detected, one of the correlated variables may be excluded from the model. Second, variance inflation factors (VIFs) are calculated to further assess multicollinearity, with particular attention to ensuring that VIF values for key explanatory variables remain below the conventional threshold of 10. In addition, given the hierarchical structure of the data and the likelihood of correlated observations within the same zip code, standard errors are clustered at the zip-code level. This approach accounts for within-area correlation and improves the reliability of statistical inference, particularly given the mismatch in spatial scales between the dependent variable (property-level transactions) and several independent variables (zip-code-level measures). Finally, residual diagnostics are used to evaluate model robustness. Linearity is assessed through residual plots, and heteroskedasticity is tested using the Breusch-Pagan test. Together, these diagnostic procedures help ensure that the estimated coefficients are robust and that inferences drawn from the OLS models are appropriate.

(2) Model with Flood Mitigation Activities

Building on the baseline hedonic results, this study next incorporates community-level flood mitigation activities to examine whether these interventions are directly associated with housing prices, conditional on flood risk and other covariates. Including mitigation measures allows the analysis to assess whether localized adaptation investments are capitalized into housing prices as amenities or, alternatively, function as signals of underlying flood vulnerability.

Specifically, this specification adds measures of cumulative flood-mitigation activities at the zip code level to the regression model. These variables capture recent mitigation efforts that may influence buyer perceptions, insurance costs, or expected future damage. If mitigation investments are perceived as effective risk-reducing measures, their coefficients are expected to be positive. Conversely, if mitigation projects primarily signal heightened flood exposure or

ongoing vulnerability, their coefficients may be negative. The empirical model with flood mitigation measures is specified as follows:

$$\log(\text{Price}) = \beta_0 + \beta_1 \text{Flood Risk}_i + \beta_2 \text{Mitigation Measures}_i + \chi_i' \alpha + N_i' \gamma + \epsilon_i$$

Where:

- *Mitigation Measures_i* is the number of flooding mitigation activities at zip code i

(3) Model with Interaction Term

To directly test whether flood mitigation activities moderate the relationship between flood risk and housing prices, this study further introduces interaction terms between flood risk and mitigation measures, *FloodRisk* × *Mitigation Measures*. These specifications allow the marginal effect of flood risk on housing prices to vary with the presence and intensity of mitigation activities, rather than assuming a uniform flood-risk discount across all locations.

By including interaction terms, the model examines whether mitigation investments attenuate or amplify the price penalty associated with flood risk. A positive coefficient on the interaction term indicates that mitigation moderates the negative effect of flood risk on housing prices; that is, the flood-risk discount is smaller in communities with more mitigation activity. In contrast, a negative interaction coefficient indicates that mitigation investments intensify the flood-risk penalty, consistent with a risk-signaling or heightened-awareness mechanism. This interaction framework captures average marginal effects across the full distribution of flood-risk levels and provides insight into how different types of mitigation shape market responses to environmental risk. The interaction model is specified as follows:

$$\log(\text{Price}) = \beta_0 + \beta_1 \text{Flood Risk}_i + \beta_2 \text{Mitigation Measures}_i + \beta_3 (\text{FloodRisk}_i \times \text{Mitigation Measure}_i) + \chi_i' \alpha + N_i' \gamma + \epsilon_i$$

Where:

- *FloodRisk_i × Mitigation Measure_i* is an interaction term to explore how the relationship between flood risk and housing prices is moderated by mitigation activities.

4.4 Results

4.4.1 Hedonic OLS Model between Flood Risk and Housing Price

Table 14 presents estimates from hedonic OLS models examining the relationship between parcel-level flood risk and housing sale prices in NYC between 2016 and 2024. The models are estimated sequentially, progressively incorporating (1) property structural characteristics and local housing market and macroeconomic indicators, (2) neighborhood sociodemographic characteristics, and (3) neighborhood fixed effects. Model fit improves substantially as controls are added, with the adjusted R squared increasing from 0.007 in the baseline specification (Model 4.1) to 0.246 in Model 4.3, and further to 0.313 in the fixed-effects specification (Model 4.4). This pattern underscores the importance of persistent, place-based factors in explaining housing price variation across NYC.

Across all specifications, the key variable of interest, flood risk, is consistently negative and statistically significant. The estimated coefficients range from -0.066 in the baseline model to -0.043 in the fixed-effects model. Given the log-linear specification, these estimates imply that a one-point increase in the flood-risk score (on a 0-10 scale) above the NYC average is associated with housing sale prices approximately 4.3% to 6.6% lower, holding other factors constant. The magnitude of the flood-risk discount declines after controlling for neighborhood socioeconomic characteristics and fixed effects, suggesting that part of the raw price penalty reflects underlying neighborhood attributes correlated with flood exposure. However, even after controlling for neighborhood fixed effects that absorb average housing price differences across areas, flood risk remains negatively and statistically significantly associated with housing sale prices. These findings are consistent with the study hypothesis and with prior literature documenting the capitalization of environmental risk into housing prices, even in contexts where climate risk information is imperfect or unevenly disclosed.

Models 4.2 through 4.4 include property structural characteristics, local housing market conditions, neighborhood sociodemographic factors, and locational fixed effects to ensure that the estimated flood-risk effects are not confounded by standard determinants of housing prices. These control variables behave largely as expected and improve overall model fit. Property size is consistently and positively associated with housing sale prices, while building age shows a

small discount effect that becomes negligible once neighborhood fixed effects are included. Also, the local housing market and macroeconomic indicators exhibit intuitive relationships. New residential construction is positively associated with housing sale prices, likely reflecting concentration in high-demand areas rather than causal supply effects. Higher unemployment rates are associated with lower housing sale prices, consistent with reduced purchasing power during weaker labor-market conditions. COVID-period indicators capture temporary market disruptions and subsequent recovery phases.

Neighborhood sociodemographic characteristics further explain variation in housing prices. Higher shares of white residents and renters are positively associated with higher prices, reflecting long-standing spatial inequalities, investor activity, and multifamily concentration in higher-value neighborhoods. Finally, the inclusion of neighborhood fixed effects captures substantial, persistent spatial heterogeneity in housing prices across NYC, reinforcing that location remains one of the strongest determinants of housing value.

In sum, the hedonic OLS results provide strong and robust evidence that flood risk is capitalized into housing prices in NYC. Across all specifications, a one-point increase in flood risk is associated with a 4% to 7% reduction in sale prices, even after controlling for detailed property characteristics, macroeconomic conditions, neighborhood demographics, and location fixed effects. These findings underscore the economic relevance of flood-risk information and highlight how environmental risk interacts with deeply entrenched spatial inequalities in urban housing markets.

Table 14. Hedonic OLS Models of Flood Risk on Housing Price

	<i>Dependent variable:</i>			
	Log of Housing Price			
	Baseline	Property Characteristics and Economic indicator included	Socio-demographic variables included	Location fixed effects
	Model 4.1	Model 4.2	Model 4.3	Model 4.4
flood risk	-0.066*** (0.002)	-0.042*** (0.002)	-0.062*** (0.002)	-0.043*** (0.002)
gross square feet		0.0002*** (0.00000)	0.0002*** (0.00000)	0.0002*** (0.00000)
year built		-0.0001*** (0.00001)	-0.0001*** (0.00001)	0.00001* (0.00001)
new units		0.0001*** (0.00000)	0.0001*** (0.00000)	0.00004*** (0.00000)
unemployment rate		-0.018*** (0.001)	-0.018*** (0.001)	-0.019*** (0.001)
covid period_1		0.204*** (0.006)	0.184*** (0.005)	0.172*** (0.005)
covid period_2		-0.187*** (0.009)	-0.166*** (0.008)	-0.184*** (0.008)
covid period_3		0.126*** (0.008)	0.127*** (0.008)	0.115*** (0.007)
covid period_4		-0.029*** (0.007)	-0.031*** (0.006)	-0.034*** (0.006)
covid period_5		0.039*** (0.006)	0.037*** (0.006)	0.021*** (0.005)
covid period_6		0.016*** (0.005)	0.016*** (0.005)	0.015*** (0.005)
white			0.222*** (0.006)	0.583*** (0.010)
income			-0.00000*** (0.00000)	0.00000*** (0.00000)

bachelor or more	1.367*** (0.018)	0.384*** (0.026)
renter	0.226*** (0.011)	0.338*** (0.014)
PO name_Bayside		0.185*** (0.016)
PO name_Bellerose		0.025 (0.020)
PO name_Bronx		-0.205*** (0.013)
PO name_Brooklyn		0.046*** (0.012)
PO name_Cambria Heights		-0.096*** (0.020)
PO name_College Point		0.319*** (0.019)
PO name_Corona		0.179*** (0.019)
PO name_East Elmhurst		0.205*** (0.017)
PO name_Elmhurst		0.376*** (0.020)
PO name_Flushing		0.371*** (0.014)
PO name_Forest Hills		0.227*** (0.019)
PO name_Fresh Meadows		0.279*** (0.016)
PO name_Hollis		0.118*** (0.019)
PO name_Howard Beach		-0.078*** (0.020)
PO name_Jackson Heights		0.286*** (0.030)
PO name_Jamaica		-0.028*

	(0.014)
PO name_Kew Gardens	-0.072** (0.033)
PO name_Little Neck	0.227*** (0.019)
PO name_Long Island City	0.091** (0.043)
PO name_Maspeth	-0.012 (0.018)
PO name_Middle Village	-0.044*** (0.017)
PO name_New York	-0.012 (0.034)
PO name_Oakland Gardens	0.286*** (0.019)
PO name_Ozone Park	-0.034** (0.016)
PO name_Queens Village	0.015 (0.017)
PO name_Rego Park	0.181*** (0.023)
PO name_Richmond Hill	-0.072*** (0.019)
PO name_Ridgewood	-0.160*** (0.016)
PO name_Rosedale	0.032* (0.018)
PO name_Saint Albans	-0.015 (0.017)
PO name_South Ozone Park	0.086*** (0.017)
PO name_South Richmond Hill	0.048*** (0.019)
PO name_Springfield Gardens	0.004 (0.017)

PO name_ Staten Island				-0.300*** (0.014)
PO name_ Sunnyside				0.220*** (0.033)
PO name_ Whitestone				0.228*** (0.017)
PO name_ Woodhaven				-0.014 (0.017)
PO name_ Woodside				0.184*** (0.019)
Constant	13.377*** (0.001)	13.508*** (0.023)	12.926*** (0.025)	12.667*** (0.031)
Observations	184,444	179,694	179,671	179,671
R ²	0.007	0.172	0.247	0.313
Adjusted R ²	0.007	0.172	0.246	0.313
Residual Std. Error	0.582 (df = 184442)	0.532 (df = 179662)	0.508 (df = 179635)	0.485 (df = 179597)
F Statistic	1,360.437*** (df = 1; 184442)	1,206.495*** (df = 31; 179662)	1,679.329*** (df = 35; 179635)	1,121.835*** (df = 73; 179597)
<i>Note:</i>	*p<0.1; **p<0.05; ***p<0.01 Controls for property types omitted for brevity.			

4.4.2 Main Effects: Flood Risk and Mitigation Activities

Table 15 reports hedonic OLS estimates of the relationship between flood risk, city-managed flood mitigation activities, and housing sale prices in NYC between 2016 and 2024. The analysis examines whether and how localized flood-mitigation investments are associated with housing prices, and how these associations evolve as property, market, and locational characteristics are progressively controlled for. Model 4.5 includes flood risk and mitigation measures alongside property characteristics and local economic indicators. Model 4.6 further incorporates neighborhood sociodemographic characteristics, while Model 4.7 adds interaction terms between flood risk and mitigation activities. Model fit improves substantially across specifications, with the adjusted R squared increasing from 0.174 to 0.316, indicating that neighborhood context explains a large share of housing price variation.

Across all specifications, flood risk remains negatively and statistically significantly associated with housing prices. Because flood risk is mean-centered, the coefficient reflects the effect of flood risk at the average level of mitigation exposure. In Model 4.6, a one-point increase in flood risk relative to the citywide mean is associated with a 4.7% lower sale price, controlling for property characteristics, market conditions, and neighborhood sociodemographic factors. This magnitude is consistent across specifications, providing further evidence that flood risk is systematically capitalized into housing prices in NYC once observable characteristics are controlled for.

Turning to mitigation activities, the estimated main effects vary substantially by project type, consistent with the non-random spatial targeting of mitigation investments. Drainage improvements are positively and statistically significantly associated with housing prices across all specifications. In Model 4.6, each additional drainage project completed within the prior three years in a given zip code is associated with an approximately 10.5% increase in sale prices, conditional on controls. Similarly, reconstruction and new critical facilities show a robust positive association, corresponding to an approximately 11.0% price premium. These results suggest that large-scale, visible investments in flood-resilient infrastructure are positively valued by homebuyers, on average, potentially because they signal long-term public commitment to neighborhood protection.

In contrast, other mitigation categories are associated with negative or weak price effects. Construction reinforcement becomes negative and statistically significant once sociodemographic controls are included, indicating that such projects may be concentrated in areas with persistent vulnerabilities that outweigh perceived benefits. Equipment retrofitting shows a negative association in Model 4.6, though the magnitude is relatively small, approximately -2.6%. Green infrastructure, the most prevalent mitigation category citywide, is associated with a statistically significant but negligible price discount, approximately -0.01% per additional project. While green infrastructure is central to NYC's flood adaptation strategy, these results suggest that homebuyers may not perceive such interventions as materially reducing flood risk in housing market valuations, particularly for severe flooding threats, or may not view them as a strong substitute for more traditional flood protection measures.

Table 15. Effect of Mitigation Activities on the Relationship Between Flood Risk and Housing Prices

	<i>Dependent variable:</i>		
	Log of Housing Price		
	Property char. & local econ. Indicators added	Socio-demogr. factors added	Interaction Model
	Model 4.5	Model 4.6	Model 4.7
flood risk	-0.047*** (0.002)	-0.047*** (0.002)	-0.049*** (0.002)
drainage improvement	0.141*** (0.012)	0.105*** (0.011)	0.143*** (0.014)
green infrastructure	-0.0001*** (0.00001)	-0.0001*** (0.00001)	-0.0001*** (0.00001)
construction reinforcement	0.016*** (0.006)	-0.044*** (0.005)	-0.072*** (0.006)
equipment retrofitting	-0.007 (0.004)	-0.026*** (0.004)	-0.005 (0.005)
reconstruction and new critical facility	0.129*** (0.009)	0.110*** (0.008)	0.123*** (0.010)
gross square feet	0.0002*** (0.00000)	0.0002*** (0.00000)	0.0002*** (0.00000)
year built	-0.0001*** (0.00001)	0.00002** (0.00001)	0.00002** (0.00001)
new units	0.0001*** (0.00000)	0.00004*** (0.00000)	0.00004*** (0.00000)
unemployment rate	-0.018*** (0.001)	-0.019*** (0.001)	-0.019*** (0.001)
Covid period_1	0.205*** (0.006)	0.176*** (0.005)	0.178*** (0.005)
Covid period_2	-0.180*** (0.009)	-0.186*** (0.008)	-0.185*** (0.008)
Covid period_3	0.130*** (0.008)	0.117*** (0.007)	0.118*** (0.007)
Covid period_4	-0.032*** (0.007)	-0.037*** (0.006)	-0.037*** (0.006)

Covid period_5	0.038*** (0.006)	0.020*** (0.005)	0.020*** (0.005)
Covid period_6	0.018*** (0.005)	0.015*** (0.005)	0.016*** (0.005)
white		0.570*** (0.010)	0.573*** (0.010)
income		0.00000*** (0.00000)	0.00000*** (0.00000)
bachelor or more		0.437*** (0.026)	0.450*** (0.027)
renter		0.302*** (0.015)	0.289*** (0.015)
flood risk: drainage improvement			-0.074*** (0.020)
flood risk: green infrastructure			0.0003*** (0.00003)
flood risk: construction reinforcement			0.044*** (0.008)
flood risk: equipment retrofitting			-0.014*** (0.004)
flood risk: reconstruction and new critical facility			-0.023** (0.009)
Constant	13.499*** (0.023)	12.700*** (0.031)	12.713*** (0.031)
Observations	179,694	179,671	179,671
R ²	0.174	0.315	0.316
Adjusted R ²	0.174	0.315	0.315
Residual Std. Error	0.531 (df = 179657)	0.484 (df = 179592)	0.484 (df = 179587)
F Statistic	1,051.771*** (df = 36; 179657)	1,058.694*** (df = 78; 179592)	998.190*** (df = 83; 179587)

Note:

* p<0.1; ** p<0.05; *** p<0.01

Coefficients of property types and neighborhood fixed effects are omitted for brevity.

4.4.3 Moderation Analysis: OLS Model with Interaction Terms

Model 4.7 examines whether different types of flood mitigation activities moderate the relationship between flood risk and housing prices, revealing substantial heterogeneity across mitigation types. The model introduces interaction terms between mean-centered flood risk and each mitigation category. Because flood risk is mean-centered, the interaction coefficients indicate how mitigation activities alter the marginal effect of flood risk relative to its average level across the city, relative to its average level across the city.

Two notable exceptions emerge. Firstly, some mitigation activities exhibit positive moderation effects, partially reducing homebuyers' sensitivity to flood risk. Green infrastructure shows a positive and statistically significant interaction with flood risk, although the magnitude is small. The coefficient indicates that green infrastructure reduces the marginal flood-risk price penalty by approximately 0.03% points per risk unit. While economically modest, this result suggests that green infrastructure may slightly attenuate homebuyers' sensitivity to flood exposure, even if it does not substantially increase average housing prices.

Construction reinforcement also demonstrates a positive and statistically significant interaction with flood risk, indicating a partial protective effect. Zip-code areas with construction reinforcement experience a smaller flood-risk price penalty compared to areas without such investments. However, this moderation effect is not large enough, on average, to fully offset the baseline flood-risk discount, suggesting that while reinforcement investments reduce homebuyer sensitivity to flood risk, they do not eliminate it.

In contrast, some mitigation activities intensify the flood-risk penalty, amplifying rather than mitigating buyer concerns. The interaction between flood risk and drainage improvements is negative and statistically significant. The estimated coefficient (-0.074) implies that in zip codes with drainage projects, the flood-risk price discount increases by approximately 7.4% points per one-point increase in flood risk. Consequently, with one additional drainage project, the marginal flood-risk effect increases from roughly -4.9% to -12.3% per risk unit. Although drainage improvements are associated with higher housing prices on average, the interaction results indicate that they do not reduce homebuyers' sensitivity to flood risk. Instead, drainage investments appear to heighten flood-risk capitalization. This pattern is consistent with a risk-

signaling interpretation, whereby drainage projects draw attention to underlying flood vulnerability or reflect a history of flooding that increases buyer awareness, even while providing baseline infrastructure benefits. Other interaction terms, including equipment retrofitting, and reconstruction or new critical facilities, are statistically significant but do not consistently offset flood risk in a way that suggests strong protective housing price capitalization. These interactions remain negative, indicating that such interventions may coexist with heightened perceived vulnerability rather than mitigating it.

Overall, the moderation analysis highlights that flood mitigation investments influence housing market responses to flood risk through multiple and contrasting mechanisms. Some mitigation activities, such as green infrastructure and construction reinforcement, modestly reduce the housing market penalty associated with flood risk, while others, most notably drainage improvements, intensify it. These findings suggest that flood mitigation is not uniformly capitalized as protection in housing markets. Instead, its moderating effect depends on mitigation type, visibility, and perceived effectiveness. How mitigation activities are perceived by buyers, either as credible protective measures or as signals of underlying exposure, underscore the role of homebuyer perceptions and risk signaling in shaping how climate adaptation investments are reflected in housing prices.

4.5 Discussion

This study offers several important insights into how flood risk and flood mitigation activities are reflected in housing prices. First, using newly available flood-risk information from FSF, this study provides strong evidence that flood risk is negatively capitalized into housing prices in NYC, consistent with and extending prior research. Across all model specifications, higher flood risk is associated with lower housing prices, even after accounting for detailed property characteristics, macroeconomic factors, socioeconomic conditions, and neighborhood fixed effects. In practical terms, a one-point increase in the flood-risk score is associated with an estimated 4% to 8% reduction in housing prices, depending on the specification. These magnitudes closely align with findings from prior meta-analyses and empirical studies (e.g., Beltrán et al., 2018), reinforcing the conclusion that flood risk represents an economically meaningful dimension of housing market valuation. Importantly, the persistence of this

relationship after controlling for neighborhood fixed effects suggests that flood risk matters beyond broad spatial sorting patterns and is systematically incorporated into housing prices within local markets.

Second, the analysis demonstrates that some types of flood mitigation activities are meaningfully associated with housing prices, while others are not. The main-effects models indicate that visible and structurally oriented mitigation investments, such as drainage improvements and reconstruction or construction of new critical facilities, are positively associated with housing prices once location-specific characteristics are controlled for. These patterns suggest that homebuyers may value mitigation investments that are tangible, durable, and clearly linked to flood protection. In contrast, other mitigation activities are associated with price discounts. These measures may be less visible to homebuyers or may primarily function as regulatory or administrative tools rather than as perceived improvements to neighborhood safety or resilience.

Third, the interaction models reveal that some mitigation activities genuinely moderate the relationship between flood risk and housing prices, while others amplify flood-risk penalties. The interaction analysis shows that mitigation does not uniformly reduce the negative price effects of flood risk. Green infrastructure and construction reinforcement exhibit positive moderation effects, indicating that these interventions modestly reduce homebuyers' sensitivity to flood risk. Although the magnitude of these moderation effects is small, their statistical significance suggests that certain mitigation strategies can partially attenuate flood-risk capitalization.

In contrast, drainage improvements display a negative moderation effect: in areas with drainage projects, the marginal price penalty associated with flood risk is larger, not smaller. This pattern is consistent with a risk-signaling interpretation, whereby drainage investments draw attention to underlying flood vulnerability or reflect a history of flooding that heightens buyer awareness. These findings underscore that mitigation investments operate not only through physical risk reduction, but also through informational or behavioral channels that shape how homebuyers interpret and respond to flood risk.

Taken together, these results highlight that flood mitigation investments play heterogeneous roles in housing markets, functioning at times as protection and at other times as signals of risk.

Mitigation activities influence housing prices in nuanced and sometimes counterintuitive ways, depending on their visibility, perceived effectiveness, and the context in which they are deployed. This complexity suggests that adaptation policies may have unintended distributional or market effects if homebuyer perceptions are not carefully considered alongside engineering objectives.

Several limitations of this study point to important directions for future research. First, the analysis relies on hedonic OLS models that identify robust associations but do not establish causal effects. Flood mitigation projects are not randomly assigned; they are often targeted toward areas with higher flood exposure, prior flood damage, or aging infrastructure. Although extensive controls and neighborhood fixed effects mitigate some sources of bias, unobserved factors, such as past flood events, insurance market conditions, or political prioritization, may still influence the estimated relationships. Accordingly, the mitigation results should be interpreted as reflecting housing market responses correlated with mitigation presence, rather than definitive causal impacts.

Second, there is a mismatch in spatial scale between the outcome and several explanatory variables. Housing transactions are measured at the parcel level, while mitigation activities and some socioeconomic characteristics are aggregated at the zip-code level. Although mitigation projects include geographic coordinates, this study is unable to precisely measure distance-based exposure between individual properties and specific mitigation assets. This aggregation may obscure within-zip-code heterogeneity and attenuate estimated effects. Future research could improve spatial precision by linking transactions to mitigation exposure using distance-based measures, such as project density or investment amounts within a defined radius of each property, while acknowledging challenges posed by linear or corridor-based projects.

Third, data limitations constrain the set of housing characteristics included in the models. A substantial number of transactions are excluded due to missing structural attributes, and several important features commonly used in hedonic analyses, such as bedrooms, bathrooms, renovation quality, amenities, and views, are not available in NYC Open Data. In addition, mitigation measures are captured primarily as project counts rather than by scale, cost, or engineering capacity. Incorporating richer property data and more detailed mitigation attributes

(e.g., investment amounts, asset size, or protective capacity) would enable future research to better distinguish between symbolic and substantive mitigation. Future work could reduce MAUP concerns by using finer spatial units or distance-based measures.

Finally, this study infers homebuyer perceptions indirectly through observed price responses. While the results strongly suggest that informational and behavioral mechanisms play a central role in how flood risk and mitigation are capitalized, the analysis cannot directly observe buyer beliefs or awareness. Future research could integrate transaction data with surveys, interviews, or experimental methods to more directly examine how homebuyers interpret different types of mitigation and how those interpretations shape willingness to pay.

In sum, this research demonstrates that flood risk is economically meaningful in urban housing markets and that flood mitigation investments influence prices in complex and differentiated ways.

By using updated flood-risk data and detailed local mitigation information for NYC, the study highlights the dual role of mitigation as both protection and signal. These findings provide a foundation for future work that more tightly integrates engineering effectiveness, spatial targeting, and behavioral responses in the evaluation of climate adaptation policies.

Chapter 5. Conclusion

5.1 Synthesis of Findings and Broader Implications for Households and Developers

Bringing together the three chapters, this dissertation demonstrates how flood risk information, market disclosure mechanisms, and public mitigation investments interact to shape housing market outcomes under climate change. Across different analytical scales and methods, the findings collectively highlight that housing markets are neither fully efficient nor fully unresponsive in responding to flood risk. Instead, market responses reflect a dynamic process in which information salience, institutional context, and perceived protection from climate hazards jointly influence how households and developers evaluate risk–return trade-offs in residential real estate.

The first takeaway is that housing functions as both a physical shelter and a financial asset, and climate risk forces households to reconcile these dual roles. Evidence from Chapter 2 shows that home buyers and sellers do respond to climate-related hazards and risks, particularly when hazard information becomes salient through actual events and public-driven risk disclosure, but that these responses involve trade-offs rather than uniform avoidance. In a high-demand, supply-constrained market such as New York City, households appear willing to accept some level of flood exposure in exchange for location advantages, neighborhood amenities, or housing affordability. This suggests that flood risk is increasingly incorporated into price negotiations and housing choices rather than treated as a binary constraint. In this sense, climate risk reshapes how housing value is assessed rather than determining whether markets function at all.

Second, the analysis underscores the importance of information asymmetry and market awareness in shaping housing market responses to climate risk. Chapter 3 shows that the disclosure of flood risk information influences housing market dynamics primarily through gradual adjustments in price growth trends rather than abrupt price shocks. The combined interrupted time series analysis indicates that most disclosure interventions, including those introduced through major real estate platforms, did not trigger immediate repricing of housing assets. Instead, the integration of flood risk information into widely used digital platforms

appears to have contributed to incremental shifts in housing price trajectories over time. These findings suggest that flood risk disclosure operates through a process of information diffusion, where newly available climate risk information gradually becomes incorporated into the expectations and decision-making processes of market participants. As digital real estate platforms increasingly serve as primary information gateways for prospective homebuyers, they may play a growing role in shaping how environmental risk is perceived and evaluated during housing search and transaction processes.

The results from Chapter 3 also indicate that policy-driven disclosure mandates may have diminishing marginal effects once risk information has already circulated through market channels. By the time the New York State flood risk disclosure law was implemented in March 2024, much of the relevant flood risk information had already become accessible through private-sector platforms and climate analytics tools. As a result, the regulatory disclosure requirement did not produce strong additional price responses in the housing market. These findings highlight an important distinction between information availability and information institutionalization. Housing markets may begin to incorporate climate risk into pricing once information becomes visible and salient to buyers, even before formal regulations require disclosure during property transactions. These results suggest that climate-risk disclosure policies may be most effective when they complement existing information channels and improve the clarity, credibility, and accessibility of risk communication, rather than relying solely on formal regulatory mandates.

Third, this dissertation highlights that flood mitigation is not automatically capitalized into housing prices. Chapter 4 demonstrates that the price effects of mitigation investments depend on whether their benefits are visible, credible, and perceived as durable by market participants. Some forms of mitigation appear to offset flood-risk penalties, whereas others show limited or no effect, suggesting that not all mitigation investments are equally legible to homebuyers or sufficient to meaningfully reduce perceived risk. Importantly, mitigation outcomes, such as neighborhood-scale green infrastructure upgrades or retrofitting programs, also intersect with existing spatial and social inequalities, implying that flood mitigation can either reinforce or alleviate uneven exposure depending on how investments are designed, communicated, and implemented.

The submarket analyses in Chapter 3 further illustrate that housing market responses to climate risk are not uniform across neighborhoods. Areas with higher flood exposure, prior flood experience, or distinct socioeconomic characteristics exhibit different patterns of price adjustment over time. In some high-risk neighborhoods, housing prices continued to increase but at slower growth rates, suggesting a gradual process of risk awareness and market adjustment rather than abrupt price corrections. Similarly, differences across income and education levels indicate that social and spatial contexts influence how households interpret and respond to newly disclosed environmental risks.

Taken together, these findings carry important implications for developers and private-sector real estate actors. If flood risk meaningfully influences housing price dynamics over time, then investments in resilience, particularly in areas with visible and well-communicated mitigation measures, may help preserve long-term asset value. Developers and investors may increasingly view climate-resilient infrastructure not simply as a regulatory burden, but as a risk-management strategy that protects long-term property values in climate-exposed markets.

At the same time, insurers and mortgage lenders should recognize that flood risk and mitigation investments influence property values beyond traditional underwriting thresholds. As climate risk becomes more salient in housing markets, declining or more volatile property values in high-risk areas may affect collateral quality, alter loss-given-default estimates, and reshape risk-based pricing in mortgage and insurance markets. These dynamics highlight the need for financial institutions to integrate climate risk considerations more systematically into lending, underwriting, and asset valuation frameworks.

5.2 Implications for Urban Planning and Climate Policy Implementation

Beyond market behavior and actors in the residential real estate market, this dissertation offers several insights for urban planners and policymakers tasked with governing development and flood mitigation under increasing climate risk. A central implication is the need to confront the flood risk trade-off between safety and housing development more explicitly in urban governance. This trade-off refers to the tension between accommodating housing growth and economic development, often in high demand but high-risk locations, and ensuring long-term safety and resilience for residents in the face of intensifying climate hazards. In practice, urban governments frequently permit or incentivize development in flood-prone areas to meet housing supply targets, expand tax bases, or support economic competitiveness, while relying on mitigation measures or post-disaster recovery to manage risk *ex post*. Cities such as New York face acute pressure to expand housing supply, often in areas exposed to current and future flood hazards. The findings of this dissertation suggest that climate resilience policy must move beyond project-based mitigation toward a more integrated approach that aligns land-use planning, housing production, and long-term risk reduction. Instruments such as state-level buyout programs, zoning and development restrictions in high-risk areas, resilience-oriented redevelopment standards, and building retrofitting programs all play a role in shaping where, and under what conditions, urban growth should occur.

The results also highlight the growing relevance of urban stormwater flooding beyond traditionally defined flood zones. As climate change intensifies precipitation patterns, flooding is increasingly occurring in areas previously considered low risk, including inland and upland neighborhoods, as observed in cities such as Seattle (Weisend, 2026). This trend has implications not only for dense urban cores but also for suburban and rural communities experiencing new forms of climate-related hazard exposure. Planning frameworks that rely primarily on historical flood maps may therefore underestimate future risk, reinforcing the need for adaptive, forward-looking risk assessments that account for changing hydrological conditions.

A third policy implication concerns the shift from climate risk disclosure to climate risk communication. While mandatory disclosure policies remain important, the findings of this

dissertation suggest that the effectiveness of climate risk information ultimately depends on trust, clarity, and interpretability. The availability of flood risk information, particularly when integrated into widely used digital real estate platforms, can gradually influence housing market dynamics even in the absence of strong immediate price responses. Mandatory disclosure establishes a baseline of transparency, but its influence on market behavior depends on how risk information is framed, explained, and incorporated into decision-making processes by households and market intermediaries. Research suggests that persuasive strategies alone are insufficient; sustained, transparent communication is essential for building public support for climate action (Voelkel et al., 2026). At the same time, as federal scientific capacity and regulatory support fluctuate, academic institutions, local governments, and private climate service providers may increasingly serve as trusted intermediaries in communicating climate risk. However, recent controversies surrounding the accuracy of private climate risk models and concerns about potential market impacts have generated political resistance and implementation setbacks (Crawford, 2025). The decision by platforms such as Zillow to scale back the visibility of flood risk scores illustrates the fragility of climate risk communication in housing markets (Brown, 2025; Roston, 2025). In this context, community-based initiatives may play a complementary role. Programs such as real-time flood monitoring networks and neighborhood-scale data platforms, exemplified by NYC FloodNet, demonstrate how localized, transparent information can support both household decision-making and public planning (NYC et al., 2026). These initiatives help translate abstract risk metrics into lived experience, making climate risk more legible and actionable at the community level.

Importantly, this dissertation also emphasizes that policy design must account for human behavior and perception. Housing prices function not only as economic indicators but also as signals of risk and preference. Risk information is filtered through cognitive biases, including status quo bias and reliance on prior experience, meaning that more data does not automatically lead to better decisions. Participatory planning approaches, community-based adaptation programs, and resident-centered initiatives, such as housing resilience grants and citizen-science flood monitoring, can help bridge the gap between technical risk assessments and everyday decision-making. By engaging residents directly, planners can improve both the legitimacy and effectiveness of adaptation policies. In particular, planners may benefit from integrating climate

risk information more systematically into routine planning processes such as comprehensive plans, zoning updates, capital investment planning, and housing policy design. Embedding climate risk considerations within these institutional frameworks can help ensure that adaptation strategies are implemented proactively rather than reactively.

Finally, the findings point to several avenues for future research and policy experimentation. Urban planning is increasingly recognized as essential for addressing multi-hazard risk, yet the social and behavioral dimensions of risk perception remain underexplored in multi-hazard research (Kwon et al., 2026). As additional climate-risk data, such as wildfire and extreme-heat metrics, become widely available, future studies could examine how different hazards are capitalized through distinct price mechanisms. Other promising directions include conducting natural field experiments, in collaboration with social media and real estate platforms, to study how climate risk information circulates and influences behavior (Fairweather et al., 2023), as well as research on rental markets, climate-induced displacement, and climate gentrification.

More broadly, this dissertation concludes that resilience-oriented public investment, transparent risk communication, and equity-framed planning are mutually reinforcing rather than competing objectives. Cities that proactively integrate these dimensions will be better positioned to manage the intertwined challenges of climate change, housing affordability, and social equity in the decades ahead.

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Appendix A: Systematic Literature Review List

Publication Year	Author	Title
2018	Peng, Binbin; Song, Jie	A Case Study of Preliminary Cost-Benefit Analysis of Building Levees to Mitigate the Joint Effects of Sea Level Rise and Storm Surge
2018	McCoy, Shawn J.; Zhao, Xiaoxi	A City under Water: A Geospatial Analysis of Storm Damage, Changing Risk Perceptions, and Investment in Residential Housing
2017	Sealy, Kathleen Sullivan; Strobl, Eric	A hurricane loss risk assessment of coastal properties in the caribbean: Evidence from the Bahamas
2022	Li, Zhuoxun; Wang, Liangxu; Shen, Ju; Ma, Qiang; Du, Shiqiang	A Method for Assessing Flood Vulnerability Based on Vulnerability Curves and Online Data of Residential Buildings-A Case Study of Shanghai
2020	Herr, Vincent; Kochanski, Adam K.; Miller, Van V.; McCrea, Rich; O'Brien, Dan; Mandel, Jan	A method for estimating the socioeconomic impact of Earth observations in wildland fire suppression decisions
2024	Xu, Junbing; Zhu, Minling; Zhan, Shaoguo	A neglected climate risk: The price effect of urban waterlogging
2020	Zulkarnain, Siti Hafisah; Tsujimura, Maki; Yuzir, Muhamad Ali; Razali, Muhammad Najib; Tarmidi, Zakri	A review of climate change (floods) and economic attributes response to residential property value in Malaysia
2022	Koo, Kang Mo; Liang, Jian	A view to die for? Housing value, wildfire risk, and environmental amenities
2023	Kelly, David L.; Molina, Renato	Adaptation Infrastructure and Its Effects on Property Values in the Face of Climate Risk
2019	Walsh, Patrick; Griffiths, Charles; Guignet, Dennis; Klemick, Heather	Adaptation, Sea Level Rise, and Property Prices in the Chesapeake Bay Watershed
2017	Kim, Jeongseob; Park, Junsung; Yoon, D. K.; Cho, Gi-Hyong	Amenity or hazard? The effects of landslide hazard on property value in Woomyeon Nature Park area, Korea
2013	Ou-Yang, Chieh; Kunreuther, Howard; Michel-Kerjan, Erwann	An Economic Analysis of Climate Adaptations to Hurricane Risk in St. Lucia
2020	Chandra-Putra, Handi; Andrews, Clinton J.	An integrated model of real estate market responses to coastal flooding
2022	Craig, Michael	An Overview of Flood Risk to the Housing Finance Ecosystem
2014	Bivand, Roger S.; Gomez-Rubio, Virgilio; Rue, Harvard	Approximate Bayesian inference for spatial econometrics models
2024	Tavor, Tchai	Assessing the financial impacts of significant wildfires on US capital markets: sectoral analysis
2023	Livy, Mitchell R.	Assessing the housing price capitalization of non-destructive flooding events
2014	Eves, Chris; Wilkinson, Sara	Assessing the immediate and short-term impact of flooding on residential property participant behaviour
2022	Shi, Longzhong; Chen, Bo; Chen, Xuan; Chen, Zhuo	Assessing the impact of wildfires on property values in wildland-urban intermix and interface in Colorado: A hedonic approach
2022	Wang, Haoying	Boundary discontinuity, unobserved spatial heterogeneity, and flood risk analysis: application to a rural housing market

2006	Carbone, JC; Hallstrom, DG; Smith, VK	Can natural experiments measure behavioral responses to environmental risks?
2023	Fonner, Robert; Izon, German; Feist, Blake E.; Barnas, Katie	Capitalization of reduced flood risk into housing values following a floodplain restoration investment
2023	Mutlu, Asli; Roy, Debraj; Filatova, Tatiana	Capitalized value of evolving flood risks discount and nature-based solution premiums on property prices
2020	Livy, Mitchell R.	Catastrophe capitalization: Estimating the capitalization of extreme natural events across type and reoccurrence
2024	Hennighausen, Hannah; James, Alexander	Catastrophic fires, human displacement, and real estate prices in California
2013	Bin, Okmyung; Landry, Craig E.	Changes in implicit flood risk premiums: Empirical evidence from the housing market
2021	Giglio, Stefano; Maggiori, Matteo; Rao, Krishna; Stroebel, Johannes; Weber, Andreas	Climate Change and Long-Run Discount Rates: Evidence from Real Estate
2024	Dong, Hongwei	Climate change and real estate markets: An empirical study of the impacts of wildfires on home values in California
2023	Anderegg, William R. L.; Collins, Timothy; Grineski, Sara; Nicholls, Sarah; Nolte, Christoph	Climate change greatly escalates forest disturbance risks to US property values
2022	Li, Han; Grant, Richard J.	Climate gentrification in Miami: A real climate change-minded investment practice?
2018	Keenan, Jesse M.; Hill, Thomas; Gumber, Anurag	Climate gentrification: from theory to empiricism in Miami-Dade County, Florida
2023	Thompson, Joshua J.; Wilby, Robert L.; Hillier, John K.; Connell, Richenda; Saville, Geoffrey R.	Climate Gentrification: Valuing Perceived Climate Risks in Property Prices
2020	Gibson, Matthew; Mullins, Jamie T.	Climate Risk and Beliefs in New York Floodplains
2021	Clayton, Jim; Devaney, Steven; Sayce, Sarah; Van de Wetering, Jorn	Climate Risk and Real Estate Prices: What Do We Know?
2024	Shi, Song; Bangura, Mustapha; Ghosh, Sumita	Cognitive limits of perceived flood risk on residential property values
2019	Bernstein, Asaf; Gustafson, Matthew T.; Lewis, Ryan	Disaster on the horizon: The price effect of sea level rise
2024	Sariffuddin, S.; Samsura, D. Ary A.; van der Krabben, Erwin; Setiyono, Budi; Pradoto, Wisnu	Distressed property and spillover effect: A study of property price response to coastal flood risk
2009	Mueller, Julie; Loomis, John; Gonzalez-Caban, Armando	Do Repeated Wildfires Change Homebuyers' Demand for Homes in High-Risk Areas? A Hedonic Analysis of the Short and Long-Term Effects of Repeated Wildfires on House Prices in Southern California
2008	Pope, Jaren C.	Do Seller Disclosures Affect Property Values? Buyer Information and the Hedonic Model
2020	Baldauf, Markus; Garlappi, Lorenzo; Yannelis, Constantine	Does Climate Change Affect Real Estate Prices? Only If You Believe In It

2020	Coulson, N. Edward; McCoy, Shawn J.; McDonough, Ian K.	Economic diversification and the resiliency hypothesis: Evidence from the impact of natural disasters on regional housing values
2024	Peter, Nkolika J.; Okagbue, Hilary I.; Adelowo, Mofetoluwa G.; Samuel, Olugbemisola W.; Iroham, Chukwuemeka O.; Nto, Sunday E.	Effects of climate change on residential properties in Wemabod Estate, Ikeja, Lagos State, Nigeria
2004	Bin, Okmyung; Polasky, Stephen	Effects of Flood Hazards on Property Values: Evidence before and after Hurricane Floyd
2001	Harrison, David M.; Smersh, Greg T.; Schwartz, Arthur L.	Environmental Determinants of Housing Prices: The Impact of Flood Zone Status
2022	Paudel, Jayash	Environmental Disasters and Property Values: Evidence from Nepal's Forest Fires
2007	Michael, Jeffrey A.	Episodic flooding and the cost of sea-level rise
2022	Mostafiz, Rubayet Bin; Friedland, Carol J.; Rohli, Robert V.; Bushra, Nazla	Estimating Future Residential Property Risk Associated with Wildfires in Louisiana, U.S.A.
2018	McAlpine, Steven A.; Porter, Jeremy R.	Estimating Recent Local Impacts of Sea-Level Rise on Current Real-Estate Losses: A Housing Market Case Study in Miami-Dade, Florida
2021	Dube, Jean; AbdelHalim, Maha; Devaux, Nicolas	Evaluating the Impact of Floods on Housing Price Using a Spatial Matching Difference-In-Differences (SM-DID) Approach
2024	Conlisk, Erin; Butsic, Van; Syphard, Alexandra D.; Evans, Sam; Jennings, Megan	Evidence of increasing wildfire damage with decreasing property price in Southern California fires
2024	Donou-Adonsou, Ficawoyi; Ryan, Alexander J.	Financial impacts of climate change
2023	Chongwilaikasaem, Sukampon; Chalermyanont, Tanit	Flood hazards and housing prices: a spatial regression analysis for Hat Yai, Songkhla, Thailand
2010	McKenzie, Russell; Levendis, John	Flood Hazards and Urban Housing Markets: The Effects of Katrina on New Orleans
2019	Zhang, Lei; Leonard, Tammy	Flood Hazards Impact on Neighborhood House Prices
2016	Zhang, Lei	Flood hazards impact on neighborhood house prices: A spatial quantile regression analysis
2008	Bin, Okmyung; Kruse, Jamie Brown; Landry, Craig E.	Flood Hazards, Insurance Rates, and Amenities: Evidence from the Coastal Housing Market
2022	Nguyen, Hong Thi Bich; Miller, Norman G.; Pham, Nam Khanh; Truong, Hiep Thanh	Flood risk and buyer search behavior in Ho Chi Minh City
2022	Miller, Ryan G.; Pinter, Nicholas	Flood risk and residential real-estate prices: Evidence from three US counties
2019	Bakkensen, Laura A.; Ding, Xiaozhou; Ma, Lala	Flood Risk and Salience: New Evidence from the Sunshine State
2011	Pryce, Gwilym; Chen, Yu	Flood risk and the consequences for housing of a changing climate: An international perspective

2021	Seo, Jungseok; Oh, Jihun; Kim, Jeongseob	Flood risk awareness and property values: evidences from Seoul, South Korea
2024	Dubos-Paillard, Edwige; Lavaine, Emmanuelle; Millock, Katrin	Flood Risk Information Release: Evidence from Housing Markets Around Paris
2016	Rajapaksa, Darshana; Wilson, Clevo; Managi, Shunsuke; Hoang, Vincent; Lee, Boon	Flood Risk Information, Actual Floods and Property Values: A Quasi-Experimental Analysis
2020	Hennighausen, Hannah; Suter, Jordan F.	Flood Risk Perception in the Housing Market and the Impact of a Major Flood Event
2013	Turnbull, Geoffrey K.; Zahirovic-Herbert, Velma; Mothorpe, Chris	Flooding and Liquidity on the Bayou: The Capitalization of Flood Risk into House Value and Ease-of-Sale
2009	Daniel, Vanessa E.; Florax, Raymond J. G. M.; Rietveld, Piet	Flooding risk and housing values: An economic assessment of environmental hazard
2016	Rabassa, Mariano Javier; Zoloa, Juan Ignacio	Flooding risks and housing markets: a spatial hedonic analysis for La Plata City
2016	Meldrum, James R.	Floodplain Price Impacts by Property Type in Boulder County, Colorado: Condominiums Versus Standalone Properties
2001	Shultz, SD; Fridgen, PM	Floodplains and housing values: Implications for flood mitigation projects
2009	Daniel, Vanessa E.; Florax, Raymond J.G.M.; Rietveld, Piet	Floods and Residential Property Values: A Hedonic Price Analysis for the Netherlands
2013	Atreya, Ajita; Ferreira, Susana; Kriesel, Warren	Forgetting the Flood? An Analysis of the Flood Risk Discount over Time
2019	Atreya, Ajita; Czajkowski, Jeffrey	Graduated Flood Risks and Property Prices in Galveston County
2010	Zhang, Yang; Hwang, Seong Nam; Lindell, Michael K.	Hazard Proximity or Risk Perception? Evaluating Effects of Natural and Technological Hazards on Housing Values
2024	Ellen, Ingrid Gould; Meltzer, Rachel	Heterogeneity in the recovery of local real estate markets after extreme events: The case of Hurricane Sandy
2020	Yi, Donggyu; Choi, Hyundo	Housing Market Response to New Flood Risk Information and the Impact on Poor Tenant
2016	Votsis, Athanasios; Perrels, Adriaan	Housing Prices and the Public Disclosure of Flood Risk: A Difference-in-Differences Analysis in Finland
2019	Pilla, Francesco; Gharbia, Salem S.; Lyons, Ronan	How do households perceive flood-risk? The impact of flooding on the cost of accommodation in Dublin, Ireland
2021	Inoue, Ryo; Hatori, Kohei	How Does Residential Property Market React to Flood Risk in Flood-Prone Regions? A Case Study in Nagoya City
2021	Chiang Hsieh, Lin-Han	How Does the Effect Fade over Distance? An Inquiry into the Decay Pattern of Distance Effect on Property Values in the Case of Taipei, Taiwan
2022	Kim, Seung Kyum; Hammitt, James K.	Hurricane risk perceptions and housing market responses: the pricing effects of risk-perception factors and hurricane characteristics
2007	Graham, J. Edward; Hall, William W.; Schuhmann, Peter W.	Hurricanes, Catastrophic Risk, and Real Estate Market Recovery
2016	Athukorala, Wasantha; Martin, Wade; Neelawala,	IMPACT OF WILDFIRES AND FLOODS ON PROPERTY VALUES: A BEFORE AND AFTER ANALYSIS

	Prasad; Rajapaksa, Darshana; Wilson, Clevo	
2019	Nicholls, Sarah	Impacts of environmental disturbances on housing prices: A review of the hedonic pricing literature
2020	Beck, Jason; Lin, Meimei	Impacts of Sea Level Rise on Real Estate Prices in Coastal Georgia
2018	Beltran, Allan; Maddison, David; Elliott, Robert J. R.	Is Flood Risk Capitalised Into Property Values?
2018	Jung, Eunah; Yoon, Heeyeun	Is Flood Risk Capitalized into Real Estate Market Value? A Mahalanobis-Metric Matching Approach to the Housing Market in Gyeonggi, South Korea
2021	Hsieh, Lin -Han Chiang	Is it the flood, or the disclosure? An inquiry to the impact of flood risk on residential housing prices
2020	Murfin, Justin; Spiegel, Matthew	Is the Risk of Sea Level Rise Capitalized in Residential Real Estate?
2010	Kousky, Carolyn	Learning from Extreme Events: Risk Perceptions after the Flood
2007	Ewing, Bradley T.; Kruse, Jamie B.; Wang, Yongsheng	Local housing price index analysis in wind-disaster-prone areas
2005	Hallstrom, DG; Smith, VK	Market responses to hurricanes
2020	Apergis, Nicholas	Natural Disasters and Housing Prices: Fresh Evidence from a Global Country Sample
2019	Bosker, Maarten; Marlet, Gerard; Garretsen, Harry; van Woerkens, Clemens	Nether Lands: Evidence on the Price and Perception of Rare Natural Disasters
2009	Salter, Sean P.; King, Ernest W.	Price Adjustment and Liquidity in a Residential Real Estate Market with an Accelerated Information Cascade
2022	Nguyen, Quyen; Thorsnes, Paul; Diaz-Rainey, Ivan; Moore, Antoni; Cox, Simon; Stirk-Wang, Leon	Price recovery after the flood: risk to residential property values from climate change-related flooding
2021	Fuerst, Franz; Warren-Myers, Georgia	Pricing climate risk: Are flooding and sea level rise risk capitalised in Australian residential property?
2024	Shen, Shuli	Resilience and sustainability: Engineering solutions in disaster-affected real estate markets
2018	Ortega, Francesc; Taspinar, Suleyman	Rising sea levels and sinking property values: Hurricane Sandy and New York's housing market
2023	Tyndall, Justin	Sea Level Rise and Home Prices: Evidence from Long Island
2023	Tarui, Nori; Urbanski, Seth; Lam, Quang Loc; Coffman, Makena; Newfield, Conrad	Sea level rise risk interactions with coastal property values: a case study of O'ahu, Hawai'i
2023	Dogan, Can; Hattapoglu, Mustafa; Hoxha, Indrit	Short-run effects of hurricanes on the housing markets: evidence from Florida
2019	Johnston, Robert J.; Moeltner, Klaus	Special Flood Hazard Effects on Coastal and Interior Home Values: One Size Does Not Fit All
2021	Cohen, Jeffrey P.; Barr, Jason; Kim, Eon	Storm surges, informational shocks, and the price of urban real estate: An application to the case of Hurricane Sandy*
2019	Shr, Yau-Huo (Jimmy); Zipp, Katherine Y.	The Aftermath of Flood Zone Remapping: The Asymmetric Impact of Flood Maps on Housing Prices
2022	Fletcher, Cameron S.; Ganegodage, K. Renuka; Hildenbrand, Marian D.; Rambaldi, Alicia N.	The behaviour of property prices when affected by infrequent floods
2008	Vigdor, Jacob	The Economic Aftermath of Hurricane Katrina

2020	Kim, Seung Kyum	The Economic Effects of Climate Change Adaptation Measures: Evidence from Miami-Dade County and New York City
2022	Shu, Evelyn G.; Porter, Jeremy R.; Wilson, Bradley; Bauer, Mark; Pope, Mariah L.	The Economic Impact of Flood Zone Designations on Residential Property Valuation in Miami-Dade County
2011	Kellenberg, Derek; Mobarak, A. Mushfiq	The Economics of Natural Disasters
2024	Menendez, Patricia; Barcena, Maria Jesus; Gonzalez, Maria Cristina; Tusell, Fernando	The effect of flood risk on house prices in the Basque Country
2022	Wei, Fang; Zhao, Lvswang	The Effect of Flood Risk on Residential Land Prices
2021	Hino, Miyuki; Burke, Marshall	The effect of information about climate risk on property values
2020	Boustan, Leah Platt; Kahn, Matthew E.; Rhode, Paul W.; Yanguas, Maria Lucia	The effect of natural disasters on economic activity in US counties: A century of data
2018	Kiel, Katherine A.; Matheson, Victor A.	The effect of natural disasters on housing prices: An examination of the Fourmile Canyon fire
2010	Stetler, Kyle M.; Venn, Tyron J.; Calkin, David E.	The effects of wildfire and environmental amenities on property values in northwest Montana, USA
2023	Fang, Lu; Li, Lingxiao; Yavas, Abdullah	The Impact of Distant Hurricane on Local Housing Markets
2017	Rajapaksa, Darshana; Zhu, Min; Lee, Boon; Hoang, Viet-Ngu; Wilson, Clevo; Managi, Shunsuke	The impact of flood dynamics on property values
2018	Belanger, Philippe; Bourdeau-Brien, Michael	The impact of flood risk on the price of residential properties: the case of England
2018	Bélanger, Philippe; Bourdeau-Brien, Michael; Dumestre, Maxence	The Impact of Flood Zones on Residential Property Prices: The Case of Canada
2011	Pryce, Gwilym; Chen, Yu; Galster, George	The Impact of Floods on House Prices: An Imperfect Information Approach with Myopia and Amnesia
2017	Below, Scott; Beracha, Eli; Skiba, Hilla	The Impact of Hurricanes on the Selling Price of Coastal Residential Real Estate
2023	Haese, Sophie; Hirte, Georg	The impact of unexpected flood events and adaption measures on lot prices
2019	Miller, Norm G.; Gabe, Jeremy; Sklarz, Michael	The Impact of Water front Location on Residential Home Values Considering Flood Risks
2023	Adachi, J. K.; Li, L.	The impact of wildfire on property prices: An analysis of the 2015 Sampson Flat Bushfire in South Australia
2020	Kim, Seung Kyum; Peiser, Richard B.	The implication of the increase in storm frequency and intensity to coastal housing markets
2024	Lisboa, erico Gaspar; Lisboa, Roberto Eduardo Bastos; Bello, Leonardo Augusto Lobato	The influence of urban welfare and flood impact on the real estate market of apartments: the case of Belém city (Brazil)
2021	Catma, Serkan	The Price of Coastal Erosion and Flood Risk: A Hedonic Pricing Approach
2022	Oubennaceur, Khalid; Chokmani, Karem; Lessard, Florence; Gauthier, Yves;	Understanding Flood Risk Perception: A Case Study from Canada

	Baltazar, Catherine; Toussaint, Jean-Patrick	
2023	Gourevitch, Jesse D.; Kousky, Carolyn; Liao, Yanjun (Penny); Nolte, Christoph; Pollack, Adam B.; Porter, Jeremy R.; Weill, Joakim A.	Unpriced climate risk and the potential consequences of overvaluation in US housing markets
2018	Mueller, Julie M.; Lima, Ryan E.; Springer, Abraham E.; Schiefer, Erik	Using Matching Methods to Estimate Impacts of Wildfire and Postwildfire Flooding on House Prices
2019	Athukorala, Wasantha; Martin, Wade; Wilson, Clevo; Rajapaksa, Darshana	Valuing bushfire risk to homeowners: Hedonic property values study in Queensland, Australia
2024	Contat, Justin; Hopkins, Carrie; Mejia, Luis; Suandi, Matthew	When climate meets real estate: A survey of the literature
2020	Filippova, Olga; Nguyen, Cuong; Noy, Ilan; Rehm, Michael	Who Cares? Future Sea Level Rise and House Prices
2007	Donovan, Geoffrey H.; Champ, Patricia A.; Butry, David T.	Wildfire Risk and Housing Prices: A Case Study from Colorado Springs
2018	McCoy, Shawn J.; Walsh, Randall P.	Wildfire risk, salience & housing demand

Appendix B: Coding Protocol and Codebook

Category	sub-Category	Item/ examples
Hazard type	flooding	
Hazard type	hurricane / storm	
Hazard type	landslide	
Hazard type	multiple hazards	
Hazard type	sea level rise	
Hazard type	wildfire	
Journal publication	Real estate & housing markets	<i>Real Estate Economics, Housing Studies, Journal of Housing Economics</i>
Journal publication	Economics (General & Applied)	<i>Journal of Urban Economics, Regional Science and Urban Economics</i>
Journal publication	Urban Planning & Regional Studies	<i>Journal of Planning Education and Research, Urban Studies</i>
Journal publication	Public Policy & Governance	<i>Policy Studies Journal, World Development, Energy Policy</i>
Journal publication	Finance & Financial Economics	<i>Journal of Finance, Journal of Financial Economics, Real Estate Finance</i>
Journal publication	Environmental & Climate Science	<i>Nature Climate Change, Environmental Research Letters, Climatic Change</i>
Method	Econometric methods	Hedonic pricing regression
Method	Econometric methods	Repeat-sales regression
Method	Econometric methods	Panel regression
Method	Econometric methods	Linear mixed-effects model
Method	Econometric methods	Logistic regression
Method	Econometric methods	ARMA model
Method	Econometric methods	Bayesian inference
Method	Econometric methods	Structural equation model (PLS)

Method	Quasi-experimental designs	Difference-in-differences (DiD)
Method	Quasi-experimental designs	Dynamic DiD (event study)
Method	Quasi-experimental designs	Staggered DiD
Method	Quasi-experimental designs	Triple differences (DDD)
Method	Quasi-experimental designs	Regression discontinuity design (RDD)
Method	Quasi-experimental designs	DiD panel regression
Method	Quasi-experimental designs	DiD with spatial dependence
Method	Quasi-experimental designs	DiD with matching (PSM / NN)
Method	Quasi-experimental designs	DiD + DDD (triple differences)
Method	Spatial methods	Spatial Lag Model (SLM)
Method	Spatial methods	Spatial autoregressive (SAR) model
Method	Spatial methods	Spatial error (SEM) model
Method	Spatial methods	Spatial Durbin (SDM) model
Method	Spatial methods	Geographically weighted regression (GWR)
Method	Spatial methods	Spatial quantile regression
Method	Spatial methods	Spatial exposure & projection analysis
Method	Reviews & commentary	Systematic literature review
Method	Reviews & commentary	Narrative literature review
Method	Reviews & commentary	Conceptual commentary
Method	Social science methods	Cost-benefit analysis
Method	Social science methods	Logistic regression

Method	Social science methods	Vulnerability assessment
Method	Social science methods	Risk loss analysis
Method	Social science methods	Loss valuation
Method	Social science methods	Catastrophic risk simulation
Method	Social science methods	Integrated agent-based modeling
Method	Social science methods	Bayesian inference
Method	Social science methods	Linear mixed-effects regression / LMM
Method	Social science methods	ARMA model
Method	Social science methods	Stated preference methods
Method	Social science methods	Meta-analysis
Method	Social science methods	Survey research with descriptive statistical analysis
Method	Social science methods	Geospatial wildfire risk modeling
Method	Social science methods	Repeat-sales price regression
Method	Social science methods	Agent-based modeling