# A Program Treading Water: Measuring the Effect of Changes in National Flood Insurance Program Premiums on Houston Housing Markets


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**Abstract**

This research investigates how well housing markets reflect the risk of flooding, especially as risks are exacerbated by development, environmental changes, and climate change. In particular, how do flood insurance premiums affect property values? I focus on counties along the Texan Gulf Coast, clustered around the Houston area. To evaluate fluctuations in property values in response to flood risk, I run a difference-in-differences model using repeated home sales data from Zillow's ZTRAX and rates increases generated by the 2012 and 2014 National Flood Insurance Program policy changes. The preliminary results show a lag in the response of house prices by 4 months after premium hikes were implemented. On average, home values, as measured through repeated home sales, declined by 4-6% when flood insurance premium rates are adjusted to reflect full flood risks.



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# 1 Introduction

Extensive flooding in the greater Houston area, brought about by unprecedented levels of rainfall following Hurricane Harvey, reignited a national policy debate on the effectiveness of flood insurance. In particular, the subsidized premiums and sizeable insurance payout to repeated claimants drew attention to the insolvency of the National Flood Insurance Program (NFIP). More than its fiscal soundness, policymakers, economists, and urban planners are concerned about the NFIP's ability to signal flood risk correctly. Being able to signal flood risk would push homebuyers to consider living in areas that are less flood-prone, and it would decrease the total cost of flooding damages in the future. Without actuarially fair premiums and a good understanding of homeowner behavior, the NFIP would not do its job of averting avoidable damages in the next big flood.

My research question asks how the house market responds to these signals of flood risk. How do increases in flood insurance premiums change property values? What does that tell us about how the homeowner internalizes flood risk? If homeowners do internalize flood risks, would people make housing decisions differently? These and other questions on risk information, time and uncertainty, and homeowner expectations test the impact of flood insurance design on disaster preparedness and consumer welfare. As climate change remolds coastlines and heightens the probabilities of storms, the ability of a federal flood insurance program that is flexible and nimble enough to anticipate these changes becomes even more crucial.

In this study, I use a repeat sales, difference-in-differences model to identify the impact of variations in flood insurance rates on home prices in Harris and Fort Bend counties. I focus on the shift from subsidized to full risk insurance premiums generated by two legislative reforms for the NFIP, the Biggert-Waters Flood Insurance Reform Act of 2012 and the Homeowner Flood Insurance Affordability Act (HFIAA) of 2014. Both of these legislations had the mission of eliminating subsidies for houses built before the communities throughout the US adopted the Flood Insurance Rate Maps (FIRMs), but they raised the rates in different ways. The HFIAA14 was passed to amend the design of rate increases mandated by BW12.

The paper is divided into five sections. Section 1 introduces the National Flood Insurance Program and its legislative history. I provide a brief literature review. Section 2 delves into the methods of analysis, first developing a theory of the effect of premiums on property values and then specifying the model. Section 3 presents the data. Section 4 analyzes the results, and section 5 concludes.

## 1.1 National Flood Insurance Program & Recent Policy Changes

The National Flood Insurance Program (NFIP) was instituted in 1968 by Congress. Administered by the Federal Emergency Management Agency (FEMA), the NFIP provides low-cost flood insurance, distributes flood risk maps, and sets minimum building and zoning codes in flood-prone areas. As of 2017, the NFIP covers about 5.1 million properties worth more than \$1.25 trillion in the US. Figure 1 shows the increase in policy take-up of the NFIP over time. Despite the growth in volume, take-up has been concentrated in 30 counties along coastal United States (51% total policies as of July 2017).[1] Most of the counties are in 3 states: Florida, Texas, and Louisiana.

[1] Kousky, Carolyn. "Concentration of Policies in the NFIP." Risk Management and Decision Processes Center, 18 Jan. 2018, riskcenter.wharton.upenn.edu/resilience-lab-notes/concentration/.

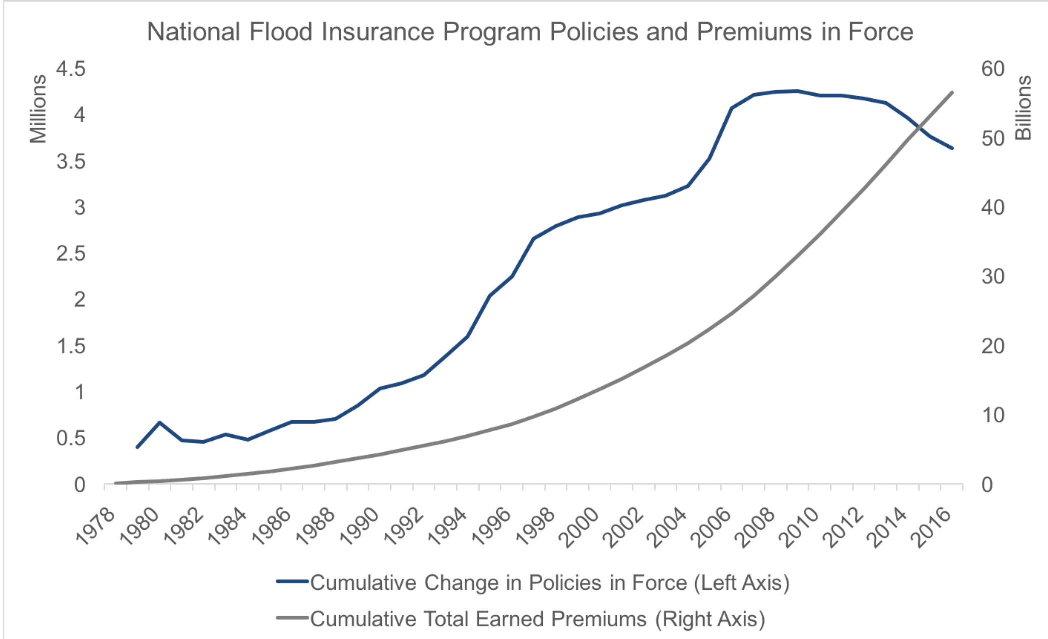


Figure 1: NFIP Policies in Force, total premiums collected

There has been a long history of policy changes reforming the National Flood Insurance Program, often prompted by the gap between claims paid out of the NFIP and the total premiums collected. However, it was not until 2012, building on the national conversation and political momentum generated first by Hurricane Katrina in 2005 and then Hurricane Sandy in 2012, that the Congress amended the premium structure of the NFIP to reflect the full risk of flooding. In fact, the NFIP has been in deficit since 2006.[2] As of 2017, the NFIP owes $24 billion in debt and runs an annual deficit of $1.5 billion.[3]

This paper focuses on the two pieces of NFIP legislation that seek to introduce actuarially fair flood insurance: BW12 and HFIAA14. The first policy change, the Biggert-Waters Flood Insurance Reform Act of 2012 (BW12), corrected flood insurance rates to reflect the full flood risk estimated by FEMA.[4] Congress voted to remove the subsidies embedded in the premiums and raised rates for homebuyers in flood-prone areas. Under constituent pressure, however, the Congress reversed its stance by passing the Homeowner Flood Insurance Affordability Act (HFIAA) in 2014.[5] By modifying and repealing provision of BW12, HFIAA14 delays the increase in premiums to give homeowners a chance to adjust. The goal of the policy was to decrease the financial burden of increased flood insurance premiums without seriously compromising its design to achieve actuarially fair rates.

[2]Michel-Kerjan, Erwann O. “Catastrophe economics: the national flood insurance program.” Journal of Economic Perspectives 24.4 (2010): 165-86.

[3]Stockton, Nick. “The Great Lie of American Flood Risk.” Wired, Conde Nast, 3 June 2017, www.wired.com/2017/03/great-lie-american-flood-risk/.

[4]FEMA. Flood Insurance Reform - Rates and Refunds. www.fema.gov/flood-insurance-reform-rates-and-refunds.

[5]In this paper, I will use HFIAA14 or HFIAA interchangeably. Congress has two versions of the HFIAA bill. The one that is relevant here, the one that got passed, has the nickname HFIAA13 because it was proposed in the House of Representatives in the last quarter of 2013. The bill that the Senate proposed, named HFIAA14, was not the version that became law. The two bills are fairly similar. It is, however, easier to use HFIAA14 for the House of Representative bill to signify that the H.R. HFIAA version got passed into law in 2014.

These policies, once codified into law, pass into the responsibility of FEMA. Through trainings, policy change notices, and the annually updated Flood Insurance Manual, FEMA guides insurance agents to offer revised policies to their clients. The actualization of the policy changes depends on the interactions between the insurance agent and the homeowners. Specially, FEMA offers NFIP insurance through select private insurance agencies, called Write Your Own (WYO) program participants.[6] As a result, the NFIP policies are standardized across varied geographies in the US.

The basic components of the flood insurance program have remained constant over time. As an insurance scheme, the NFIP pools flood risks for houses, collects premiums from all policyholders, and, in the case of flooding, pays out claims for damages up to a certain predetermined limit. By law, properties in the Special Flood Hazard Areas (SFHA) are required to carry flood insurance if the building carries a federally backed mortgage.[7] While the rates vary, the policy coverage stays the same within the same type of property. Figure 2 shows the standardized policy coverage under NFIP by property type. For a residential dwelling, the NFIP has maximum coverage of up to $250,000 in building property damage (structure) and $100,000 in personal property damage (contents). For commercial and condominiums, the maximum building coverage increases to $500,000. While adequate coverage for the structure is mandatory, contents coverage is optional under the SFHA mandatory purchase statute.


Figure 2: NFIP Policy Coverage in the Regular and Emergency Programs

The deductible, a specified amount of money policyholder must pay before receiving a claim payout to prevent moral hazard behavior, varies for different flood insurance policies according to FEMA classifications of the property. Figure 3 shows the minimum deductible required for pre-

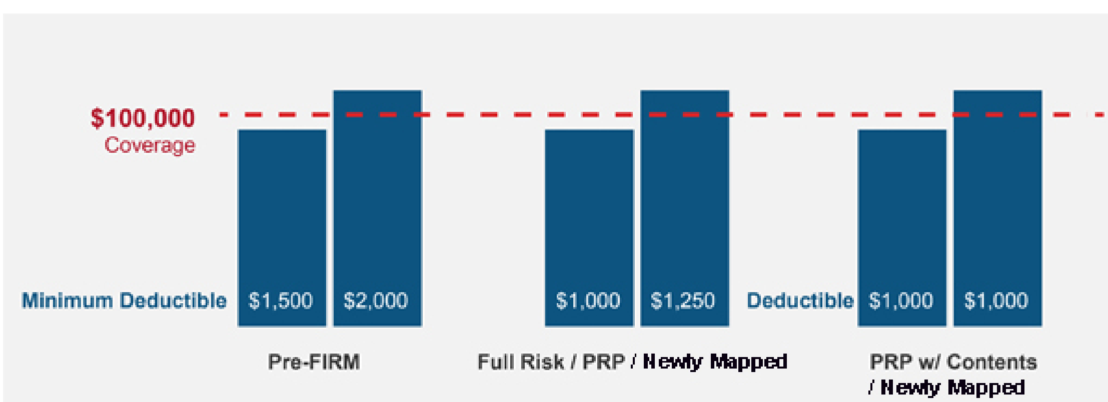


Figure 3: NFIP Deductible Amounts

[6]The Write Your Own Program began in 1983.

[7]The mandatory purchase requirement comes from the Flood Disaster Protection Act of 1973 and the National Flood Insurance Reform Act of 1994

FIRM, Full Risk, PRP, and Newly Mapped properties. The red line signals the coverage threshold. If the coverage is over \$100,000, then the deductible that applies is the bar that the red line crosses for that category. In general, the deductibles vary only according to the amount of coverage the policy provides. These FEMA classifications of property play a major role in the BW12 and HFIAA14 legislations in determining the premium rates.[8]

To act as an efficient incentive for risk avoidance, the NFIP needs to be actuarially fair. The premium rate should equal the expected value of loss or damage from flooding. To assess the expected value of loss, FEMA conducts flood hazard mapping of the floodplains and includes damage functions from historical flood events.[9] The information, from base flood elevation (BFE) assessments to proximity to nearby waterways, is then compiled together in the Flood Insurance Rate Map (FIRM). The FIRM becomes effective once the community adopts it. Insurance agents can then extrapolate the flood risk embedded in the FIRM to calculate the premium specific to each property from the rates outlined in the NFIP.

Before the 2012 reforms, the premiums for pre-FIRM houses were set below the expected risk of flood damage, in effect subsidizing pre-FIRM houses. As Figure 4 indicates, properties built before FIRMs are produced did not have access to flood hazard information. Only the properties built after FIRM panels were available were able to adhere to the proper safe building standards. The subsidies for pre-FIRM properties on average are 40 percent to 45 percent of the full-risk premium.[10] As a result, pre-FIRM classifications became central in guiding the policy changes outlined in BW12. The baseline cutoff for pre-FIRM properties is December 31, 1974. However, as FIRMs take time — the initial assessment and adoption dates varied across different parts of the US — the FIRM dates vary across different communities. FEMA uses the later of the two dates, 1974 or the local FIRM adoption date, to determine pre-FIRM status.

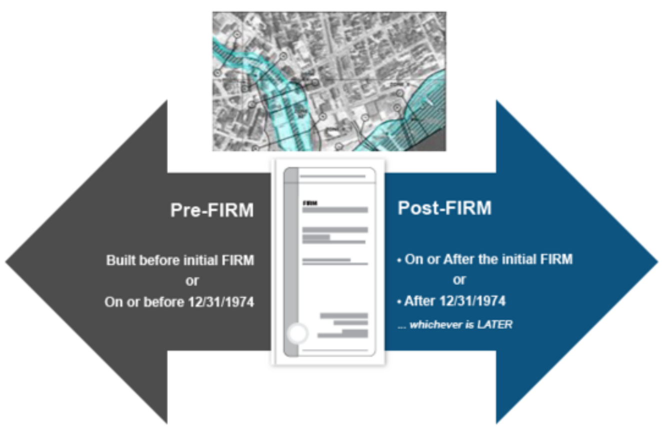


Figure 4: Pre-Firm Designation Under FEMA NFIP Classifications

[8]This is especially true in the context of grandfathering, where the property would keep its subsidized rates after a reassessment of flood risk or a redrawing of flood zones in FIRM panels. These properties are referred to as “Newly Mapped.”

[9]In the US, FEMA works with local governments to send out surveyors. However, drones are a promising source of innovation in flood risk assessment. A World Bank team pioneering drones in flood risk reduction has demonstrated success in Dar es Salaam. Soesilo, Denise. “Flood Mapping for Disaster Risk Reduction: Obtaining High-Resolution Imagery to Map and Model Flood Risks in Dar Es Salaam.” World Bank and Humanitarian OpenStreetMap Team, Mar. 2015.

[10]Government Accountability Office. “Flood Insurance: Public Policy Goals Provide a Framework for Reform.” U.S. GAO, 11 Mar. 2011, www.gao.gov/products/GAO-11-429T.

The Biggert-Waters Flood Insurance Reform Act of 2012 removes subsidized flood insurance policies for pre-FIRM structures to reflect full flood risks. According to new reports, the rate increase mandated by BW12 affects up to 1 million subsidized properties in Special Flood Hazard Areas.[11] Homeowners saw an immediate jump in flood insurance premium rates to the full risk premium when the changes were implemented in 2013.

Berated for BW12's insensitivity on the affordability of flood insurance and witnessing the uproar in the housing market, Congress modified the policy to give homeowners more time to adjust. With the passage of HFIAA14, NFIP gave refunds to homeowners who paid higher premiums under BW12, capped the rate increases at 18% per year, and imposed annual surcharges and a Reserve Fund payment. HFIAA also includes a more in-depth discussion of grandfathering and the Newly Mapped Procedure. Both of these measures moderate rate increases for specific FEMA classified properties.[12] Nonetheless, HFIAA14 remained steadfast on eliminating pre-FIRM subsidies. Though the rate increases were moderated by short-term adjustments, the long-term effect of HFIAA14 is clear. Rates will increase gradually to achieve full risk rates. The following section describes the rate hikes in detail.

### 1.1.1 NFIP Rate Hikes

To pinpoint temporal variation in rates, it is important to understand how NFIP rates are determined and how BW12 and HFIAA14 changed the rate structure. BW12 immediately raised rates, upon policy take-up or renewal, for all pre-FIRM structure to the full risk rate. HFIAA14 gave refunds for homeowners whose policies were impacted by BW12 and committed to a scheduled rate increase of up to 18% each year for individual policyholders until the full risk rate is reached. Figure 5 gives a conceptual diagram of what the rate increases look like. Each year, the rates are adjusted for all types of properties and risk profiles according to the actuary formula. Thus, the de-trended diagram gives a good framework to evaluate the removal of flood insurance rate subsidies specific to the NFIP policies.

Issued by FEMA twice a year, the NFIP Flood Insurance Manuals guide the WYO companies in the issuance of policies.[13] The document contains detailed instructions on the design of individual policies and outlines the variations within different FEMA property sub-classifications. The archive of the NFIP Flood Insurance Manuals allows for longitudinal mapping of insurance rates stretching back to 2005, in the form of annual rates per $100 of coverage. Coverage is broken down into basic and additional coverage, purchased at different rates (Appendix 6.2). For a residential property, $250,000 in total coverage consists of $60,000 in basic coverage and $190,000 in additional coverage. The premiums are then formulaically derived from the rates, coverage needed, deductible factor, and applicable discounts. Explicitly, BW12 and HFIAA14 adjust the rates. However, because the premiums are directly derived from the rates, holding coverage, deductible, and discounts constant, BW12 and HFIAA14 translate flood risk into rates, then into premiums without a loss of generality. For a one-story, single family residence, the removal of subsidies might result in a 20% increase in

[11] Olorunnipa, Toluse. "Flood Insurance Price Increases Affecting Home Sales." Insurance Journal, 25 Oct. 2013, www.insurancejournal.com/news/national/2013/10/24/309110.htm.

[12] For example, the Newly Mapped Procedure gives properties that were newly mapped into a SFHA a one year of grace period, under which the flood insurance rate is identical to a Preferred Risk Policy (PRP) premium. After the first year, the rates transition with the same 18% annually capped increase to the full flood risk rate.

[13] FEMA. *Flood Insurance Manual.* https://www.fema.gov/media-library/assets/documents/133846

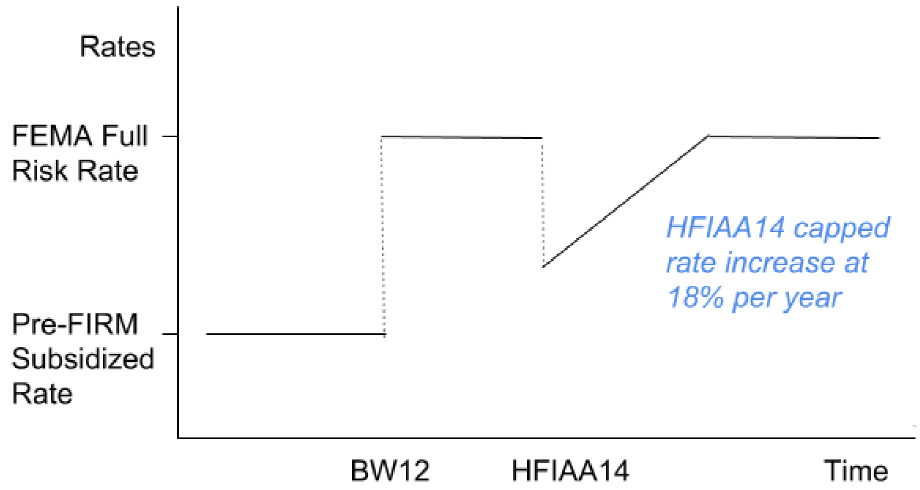


Figure 5: De-trended NFIP rates

premiums. In specific cases, the change in premiums could be much greater or smaller. They all equate to the full risk rates determined by FEMA.

The rates for flood insurance ranges widely. The minimum rate was \$0.16 per \$100 of basic limits building coverage as of 2011.[14] As of 2017, the rate hovers around \$0.24 per \$100 of basic limits. There is not an official maximum rate. Higher rates correspond to houses with increasingly negative Base Flood Elevations (BFE). For example, as of 2017, a single residence property with one floor in zone A, with a BFE marking of -15 feet, would incur a rate of \$14.65 per \$100 of basic limits building coverage.[15] In determining these rates, FEMA relies on an actuarial formula presented in Appendix 6.2 incorporating surveyed flood risk and average historical losses within each risk-based category. If we require a precise definition of actuary fairness, historical losses are aggregated at the risk-based categories level and do not reflect property-level risks. However, without more sophisticated hazard modeling, the current actuary formula will do.

Two sets of dates for BW12 and HFIAA14 are relevant. The first set of dates contains the legislation passage date, which are July 6, 2012 for BW12 and March 21, 2014 for HFIAA14. If the housing market holds rational expectations, the agents and homeowners might anticipate the rate changes embedded in the passage of these legislations. The second set of dates are markers for time allotted for implementation. BW12 started implementation January 1, 2013 and is supposed to actualize the bulk of rate changes by October 1, 2013. HFIAA14 started implementation April 1, 2015, and the gradual increase will stop when the policy for a certain property reaches full risk rates. Figure 6 gives a broad overview of the timeline of NFIP changes between 2012 and 2015 that are relevant to this study.

After the passage of BW12, the housing market held much uncertainty as regulators and insurance agents transitioned to the new rates regime. In macro theory, when there is high uncertainty,

[14]The minimum rate takes into consideration the maximum flood level that might damage a building located in a SFHA and recognizes a minimum price associated with the risk transfer in the presence of adverse selection and the uncertainty of risk elevation in the NFIP.
Hayes, Thomas L., Andrew Neal. "Actuarial Rate Review." Washington, DC: Federal Emergency Management Agency (2011).

[15]FEMA. *Flood Insurance Manual.* (2017). https://www.fema.gov/media-library/assets/documents/133846

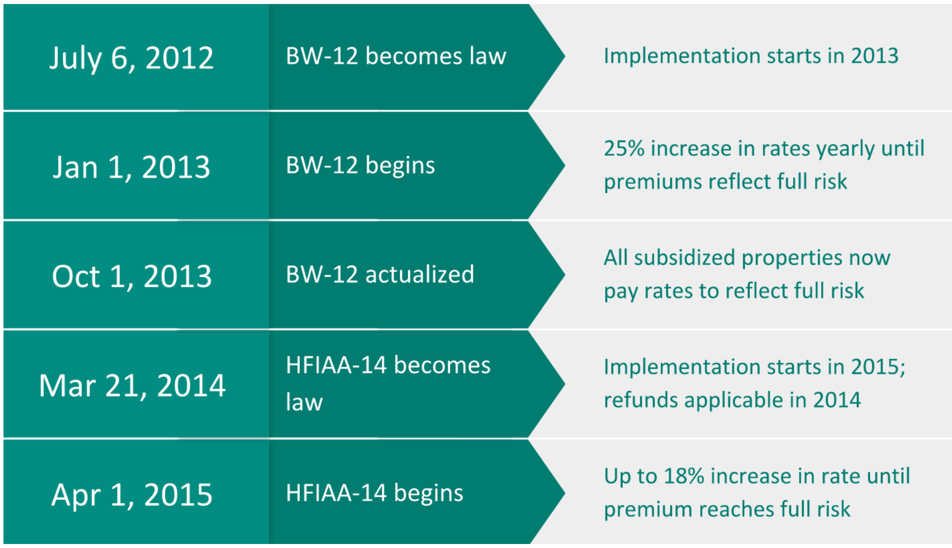


Figure 6: Timeline of NFIP Legislation

trades occur with lower volume. As a result, we would expect to see a lower volume of houses sold. Nevertheless, unless there are isolated instances of noncompliance, the implementation dates signify the start of rate increases. Thus, starting in January 1, 2013 for example, banks could not close on sales of a subset of pre-FIRM properties without properly priced flood insurance. If the home buyer does not purchase it, the bank financing the mortgage is compelled to do so on their behalf. Exhibits that catalog rate increases for FEMA sub-classifications of properties over time can be found in Appendix 6.1.

High transaction costs with delays characterize housing markets. News reports and testimonies have documented the destabilizing effects BW12 had on the housing market, which raises concerns about lagged effects.[16] First, there is a built-in policy implementation lag of 6-12 months for BW12 and HFIAA14. This lag is clearly identified. Second, there is inherent lag in the housing market as it internalizes exogenous shock. Simulation exercises using impulse response models demonstrate this lag with macro shocks, and the select hedonic disamenity studies demonstrate this lag with environmental factors.[17] Last, flood insurance policy renewals occur throughout the year, presenting a lag for a small portion of the houses in flood-prone regions. All three lags accumulate the delays in when policy signals get relayed to the average homeowner.

## 1.2 Literature

This research not only reflects the current debate but also builds on varied literature on flood insurance and housing market dynamics. In the economics literature, flood insurance studies fall into two categories: risk studies and premium studies. Most flood insurance studies are risk studies,

[16] Stockton, Nick. “The Great Lie of American Flood Risk.” Wired, Conde Nast, 3 June 2017, www.wired.com/2017/03/great-lie-american-flood-risk/.

[17] Iacoviello, Matteo, and Stefano Neri. ”Housing market spillovers: evidence from an estimated DSGE model.” American Economic Journal: Macroeconomics 2.2 (2010): 125-64.; Hwang, Min, and John M. Quigley. ”Economic fundamentals in local housing markets: evidence from US metropolitan regions.” Journal of regional science 46.3 (2006): 425-453.; Clayton, Jim, Norman Miller, and Liang Peng. ”Price-volume correlation in the housing market: causality and co-movements.” The Journal of Real Estate Finance and Economics 40.1 (2010): 14-40.

which means they focus on the effect of the actual or perceived risk of flooding. Premiums studies are rare; few, if any, directly measure the change in home values in response to the marginal increase in flood insurance rates. This paper contributes to an understudied space to open up a different set of discussion on the capitalization of flood risk. As a result, whereas one cannot control the occurrence of hurricanes or risk perception, the consequences of capitalizing risk via insurance rates can be measured. The design of the NFIP program can be, subsequently, adjusted through policy.

Studies on home values utilize two main methods of analysis, hedonic analysis and repeat sales. In a hedonic analysis, the price of the whole reflects the sum of individual parts of the house, as well as its features and neighborhood amenities. This method requires an accurate construction of how each feature is related to each other, and it is difficult to conduct. Flood risk studies use hedonic models of home values to understand the channel through which risk informs prices, often specifying an implicit price or premium for flood risk.[18]

The most prominent site-based risk study is Bin et al. (2008), a paper that utilizes geospatial software, coupled with hedonic analysis, to determine if location within a flood zone lowers house value.[19] They find that insurance premiums do convey risk information to homeowners. Building on their previous work, Bin and Landry (2013) examine property prices in Pitt County, North Carolina before and after two hurricanes in the area.[20] They find significant price differentials after major flooding events: a 5.7% decrease after Hurricane Fran and 8.8% decrease after Hurricane Floyd. This led the authors to conclude that actual events could cause a large loss if properties are not insured. In other words, homebuyers internalize risk after flood events.

Overall, however, results on flood risk and house prices are mixed. A meta-analysis done by Daniel et al. (2009) of 19 studies and 117 point estimates shows that the implicit price for a house located in the 100-year flood plain vary considerably, from -52% to +58%.[21] Atreya and Czajkowski (2016) found that studies do not adequately address people's desire to live in beach-front property; hedonic analysis needs to further delineate between the positive and negative amenities of living near a coast.[22] Indeed, there remains room for further improvements on research design in this area.

Turning away from hedonic models, Kousky (2010) uses a repeat sales study to examine prices for houses between the Mississippi and Missouri rivers in Missouri and found that prices declined after the 1993 flood for houses in the 500-year floodplains.[23] Repeat sales studies avoid having to specify the relationship between different amenities and characteristics of a house (Bailey, Muth

[18] Palmquist, Raymond B. "Property value models." *Handbook of environmental economics* 2 (2005): 763-819.

[19] Bin, Okmyung, Jamie Brown Kruse, and Craig E. Landry. "Flood hazards, insurance rates, and amenities: Evidence from the coastal housing market." Journal of Risk and Insurance 75.1 (2008): 63-82.

[20] Bin, Okmyung, and Craig E. Landry. "Changes in implicit flood risk premiums: Empirical evidence from the housing market." Journal of Environmental Economics and management 65.3 (2013): 361-376.

[21] Daniel, V., Florax, R., Rietveld, P., 2009. Flooding Risk and Housing Values: An Economic Assessment of Environmental Hazard. Ecological Economics 69:355-365
Chao, Philip T., James L. Floyd, and William Holliday. Empirical Studies of the Effect of Flood Risk on Housing Prices. No. IWR-98-PS-2. Army Engineer Inst for Water Resources Fort Belvoir VA, 1998.

[22] Atreya, Ajita, and Jeffrey Czajkowski. "Graduated flood risks and property prices in Galveston County." Real Estate Economics (2016).

[23] Kousky did not find significant changes in property prices in 100-year floodplains post flooding.
Kousky, Carolyn. "Learning from extreme events: Risk perceptions after the flood." Land Economics 86.3 (2010): 395-422.

and Nourse 1963).[24] The SP Case-Shiller Index is a famous example of a housing market index constructed based on repeat home sales. By comparing the prices of the same house, the repeat sales method controls for cross-sectional variation in house characteristics. Instead, the focus turns to time varying factors, such as housing market trends and shocks. Equation 1 shows the construction of such a model. The log ratio of home prices for home $i$ is dependent on the change in time periods ($D$) and the idiosyncratic error term ($\omega$).

$$log(\frac{P_{t+\tau,i}}{P_{t,i}}) = \sum_{t=1}^{\tau_i} \gamma_t D_t + \omega_{t,i} \ \forall \ i = 1, ..., n \tag{1}$$

These quasi-experimental studies have replicated and supported hedonic studies. Dastrup et al. (2012) test whether the installation of solar panels on a home changes the home prices in a meaningful way.[25] The repeat sales results served as a robustness check on the hedonic results. Carbone et al. (2006) employs the same technique with Hurricane Andrews.[26] Because the hurricane was a "near-miss" for some counties in Florida, this study exploits the gap between flood warnings and actual flooding to analyze the role of the hurricane in informing risk spatially and intertemporally. Carbone et al. similarly find that hedonic and repeat sales results reinforce each other, this time using a modified hedonic framework to check the results of the repeat sales.

Whereas risk studies rely on a change in the perception of flood risk, premium studies offer a more direct channel through which to study on home valuation.[27] Flood risks become actualized as homeowners are compelled to purchase insurance and comply with regulations. Indeed, BW12 and HFIAA14 are natural experiments to see the flood insurance rate jumps. Villar (2015) is the only premium study on the current NFIP program.[28] Using Zillow's Median House Value Index, Villar (2015) finds that BW12 had a negative impact on the median home values in areas with subsidized policies.[29] Yet, the study leaves a few things to be desired. First, because of data constraint, median house values do not allow for specific controls that could pinpoint the property level effects. Second, Villar's work in 2015 did not allow for adequate analysis of HFIAA14. By applying a repeat sales approach to premium studies, my research can explore the effects of increased flood insurance payments on the property level across time. As a result, the comparisons between empirical results and the theoretical expectation of change in individual property values can shed light on how homeowners conceptualize premiums.

Outside of the economics literature, a number of Congressional reports and Treasury studies have outlined various policy pitfalls of the National Flood Insurance Program. The most significant problems are moral hazard in insuring repeatedly flooded homes and the challenge in calibrating

[24] Bailey, Martin J., Richard F. Muth, and Hugh O. Nourse. "A regression method for real estate price index construction." *Journal of the American Statistical Association* 58.304 (1963): 933-942.

[25] Dastrup, Samuel R., et al. "Understanding the Solar Home price premium: Electricity generation and 'Green' social status." European Economic Review 56.5 (2012): 961-973.

[26] Carbone, Jared C., Daniel G. Hallstrom, and V. Kerry Smith. "Can natural experiments measure behavioral responses to environmental risks?." *Environmental and Resource Economics* 33.3 (2006): 273-297.

[27] Risk perception and premiums could be conceptualized as two channels through which flood risk impacts home values.

[28] The NFIP program went through a number of significant changes in the 1990s. Hurricane Katrina also changed the fiscal orientation of the program administrators. Current, in this case then, refers to the NFIP program after 2000.

[29] Villar, Daniel Clark. An analysis of housing values and national flood insurance reform under the Biggert-Waters Act of 2012. Diss. Colorado State University, 2015.

rates for low probability, high impact events.[30] Others call for a redesign of the NFIP.[31] Recommendations include extending the contract of flood insurance from 1 year to 5-10 years, tying the insurance to the property rather than the homeowner, adding home improvement requirements for houses in high risk areas, and supplying low income households with flood insurance vouchers. However, these recommendations do not center the need to equate premiums to risk. Taken at face value, some of the white paper policy recommendations would further subsidize segments of the NFIP policyholders.

The technical literature does not successfully characterize the political economy of the National Flood Insurance Program; these tensions surface only in Congressional hearings and in bureaucracy of local offices. The program changes in the NFIP take on ponderous socioeconomic dimensions when evaluated in this light: certain homeowners are "losing a substantial amount of their entire life equity."[32] A testimony by the NFIP Coordinator of Oregon State Department of Land Conservation and Development Christine Shirley shows that the actual implementation of BW12 was rushed and in disarray. Confusion was prevalent on all levels, from the agents, to the banks, to the community members. Despite FEMA's documented strategy of outreach and re-training, coalitions of bankers, home builders, real estate agents, and insurance companies have asked repeatedly for clearer and faster guidance on implementation.[33] Banks were unable to close on sales from secondary effects of capitalizing the increase in insurance premiums, which caused slight disruptions to the housing market.

Following the abrupt implementation of BW12, housing market uproar, and political inquiry, affordability studies became the focus of the flood insurance literature. The foundation for this series of investigations comes from the National Research Council report (2015) on NFIP affordability. Utilizing microsimulations, the committee is able to model the effects of policy design changes onto property level responses.[34] Findings were divided on whether affordability warranted lower premiums. Kahn and Smith (2017), in a study focused on the Gulf Coast, claimed that reduced rates have little basis in affordability concerns for its justification.[35] On the flip side, the RAND study on the impact of increased rates on New York City shows disproportionate effects on low-income communities when the costs are defined as contributing to the housing burden.[36] They take a step further to project the impact of flood insurance costs forward with additional sea level rise in coastal areas. Rather than viewing the increased premiums as a percentage of property value, the report argues that affordability studies should evaluate rates relative to household income. Again, the report does not directly address the need for full risk rates, instead arguing for heavier subsidies

[30] King, Rawle O. "The national flood insurance program: Status and remaining issues for congress." Congressional Research Service 42850 (2013).

[31] Michel-Kerjan, Erwann, and Howard Kunreuther. "Redesigning flood insurance." Science 333.6041 (2011): 408-409.

[32] Fugate, Craig, Subcommittee on Housing, and Insurance US House of Representatives. "Implementation of the Biggert-Waters Flood Insurance Reform Act of 2012: One Year After Enactment." (2013).

[33] United States, Congress, Cong. House, Committee on Financial Services. "Implementation of the Biggert-Waters Flood Insurance Act of 2012: Protecting Taxpayers and Homeowners" Hearing before the Subcommittee on Housing and Insurance of the Committee on Financial Services, U.S. House of Representatives, November 19, 2013, 113AD. 113th Congress, 1st session, document 113-52.

[34] National Research Council. Affordability of National Flood Insurance Program Premiums. The National Academies Press, 2015.

[35] Kahn, Matthew E., and V. Kerry Smith. The Affordability Goal and Prices in the National Flood Insurance Program. No. w24120. National Bureau of Economic Research, 2017.

[36] Dixon, Lloyd, et al. *The Cost and Affordability of Flood Insurance in New York City.* Santa Monica, CA: RAND Corporation, 2017.

to allow low income households to continue living in flood prone places. The solution should address the risk of living in flood-prone areas in a socioeconomically sensitive manner.

Finally, a number of miscellaneous studies offer additional insight into the nuances of the flood risks in housing markets. Meldrum (2016), a risk study, finds that for Colorado, increases in flood risk only significantly and negatively affected condominiums.[37] Standalone, single-family residences were indifferent to risk premiums. Bakkensen and Barrage (2017) investigates the role of heterogenous beliefs in valuing coastal housing.[38] Preliminary findings indicate that lower fractions of optimistic agents and more accurate flood risk information decrease volatility and overvaluation. Whereas Bakkensen and Barrage (2017) assumes behavioral models of the property owners, some of whom learn about flood risk through Bayesian updating from recent storms, increased flood insurance premiums guarantee the acknowledgement of flood risks.

[37]Meldrum, James R. "Floodplain price impacts by property type in Boulder County, Colorado: Condominiums versus standalone properties." Environmental and Resource Economics 64.4 (2016): 725-750.

[38]Bakkensen, Laura, and Lint Barrage. Heterogeneous Climate Beliefs and US Home Price Dynamics: Going Under Water?. Working Paper, 2017.

# 2 Methods

The difference-in-differences model has been used in a number of previous studies to isolate the effects of public policy. The oft-cited work by Card and Krueger (1993) utilizes the minimum wage increase in New Jersey as a natural experiment to track the policy's effect on employment.[39] The study examined fast food restaurants on the border between New Jersey and Pennsylvania who shared parallel trends in employment and took the difference in the differences of the restaurants' employment levels before and after the policy change. Because only the New Jersey restaurants were influenced, the comparison with the control group in Pennsylvania gave the isolated effect of the wage policy on employment for the treated group.

In the environmental literature, panel data, displaying both time varying and time invariant information, employ diff-in-diff models in a similar manner to elucidate damage or implicit pricing. Mendelsohn et al. (1992) pioneers this methodology in measuring the disamenity from hazardous waste sites on small, open neighborhoods.[40]

$$V_{it} = f(Z_i, X_{it}) + \alpha_i + \varepsilon_{it} \tag{2}$$

By taking the first difference of a hedonic model, shown in Equation 2 where the value ($V_{it}$) of a house is a function of time varying ($X_{it}$) and time invariant ($Z_i$), the time invariant error ($\alpha_i$) drop out, leaving the idiosyncratic error ($\varepsilon_{it}$). The resulting model weighs heavily on time variation. The necessity of correctly identifying the time variation thus lends itself to employing the diff-in-diff model, where intertemporal effects apply only to the treatment group.

The section is organized in the following way: the first part discusses valuation in the housing market, capitalizes flood risk into valuation, and conceptualizes how the NFIP policy changes generate exogenous variation in the market; the second part formalizes and specifies the model.

## 2.1 Housing Market

Because housing occupies a relatively indispensable portion of a consumer's budget, housing necessitates its own market, with home buyers and home sellers as active participants and a series of agents and financiers as intermediaries.[41] The decision to buy or sell a property is facilitated by home prices. Thus, the factors that influence price changes and the mechanisms that allow it are worth examining. The sales price, or asset price, is the capitalized value of the anticipated future services provided by the house.[42] Palmquist (2005) emphasizes that the asset price is fundamentally different from the rental price, which is not capitalized. As a result, changes in macroeconomic conditions would alter asset prices but not the rental price.

A number of structural features characterize housing markets. Because houses are location dependent and immobile, the conditions of a housing market is often tied to the labor market in the

[39] Card, David, and Alan B. Krueger. Minimum wages and employment: A case study of the fast food industry in New Jersey and Pennsylvania. No. w4509. National Bureau of Economic Research, 1993.

[40] Mendelsohn, Robert, et al. "Measuring hazardous waste damages with panel models." *Journal of Environmental Economics and Management* 22.3 (1992): 259-271.

[41] Blank, David M., and Louis Winnick. "The structure of the housing market." The Quarterly Journal of Economics 67.2 (1953): 181-208.

[42] Palmquist, Raymond B. "Property value models." Handbook of environmental economics 2 (2005): 763-819.

area. Real estate is both a consumption and investment good. In the US, housing capital accounts for one third of total capital stock.[43] Housing is seen as an investment in capital that individual household engages in. Like other forms of capital, house values hold and change over long periods of time. Because land is scarce and supply of housing limited, homes tend to appreciate in value over time. The net appreciation, after accounting for depreciation in a home's wear and tear, allows homeowners and homebuyers consider buying property as a long term investment process.

To theorize consumer behavior with a rational actor assumption, at the time of purchase then, the homebuyer has expectations for a discounted flow of value derived from owning the house. The market clearing price of a house is a reflection of the net present value of the house. Whereas consumption goods are consumed in the immediate period, a buyer of a capital asset makes the purchasing decision with a longer time horizon, consisting of multiple periods each with a certain amount of uncertainty. Empirically, Case and Shiller (2012) shows that the average home buyer holds 10 year horizons.[44] However, to simplify the model of home valuation, we assume an infinite stream of rents from the property. The value of the house, then, is a function of the sum of the flow of rents ($R$) minus the per period cost of maintaining the house ($C$), discounted by a factor of $r$, the interest rate (Equation 3).

$$PV = \sum_{t=0}^{\infty}(R-C)e^{-rt} = \frac{R-C}{r} \tag{3}$$

Included in cost $C$ are a number of recurring costs, including insurance premiums. Equation 4 shows the present value of the house discounted by an interest rate ($r$), taxes ($t$), and insurance premiums ($p$).

$$PV = \frac{R}{r+t+p} \tag{4}$$

What happens when the insurance premiums change? How would the present value of the property respond? Assuming a constant discount rate $r$ and tax rate $t$, Equation 5 shows the expected percentage change in present value of the house from a one-time increase in the level of insurance premiums.

$$\Delta PV = \frac{r+t+p_0}{r+t+p_1} - 1 \tag{5}$$

A increase in premiums from $p_0$ to $p_1$ would yield a $\frac{r+t+p_0}{r+t+p_1} - 1$ decrease in the present value of a house. Thus, the amount the home value changes is a function of the relative cost of the premiums with rents and other costs. Suppose $r$=3%, $t$=2%, and $p_0$=1%, an increase of 10% in flood insurance would result in 1.6% decrease in home values.[45] When testing the model empirically, we can also back out the consumer discount rate. If home values decline less than expected, holding taxes constant, it may indicate that consumers have a higher discount rate than the mortgage rate.

What does this look like in the context of NFIP policy changes? The rate increases, mapped out in Figure 5, reflect an elimination of the pre-FIRM subsidies.[46] For a given type of property

[43] Harding, John P., Stuart S. Rosenthal, and C. F. Sirmans. "Depreciation of housing capital, maintenance, and house price inflation: Estimates from a repeat sales model." Journal of urban Economics 61.2 (2007): 193-217.

[44] Case, Karl E., Robert J. Shiller, and Anne Thompson. What have they been thinking? Home buyer behavior in hot and cold markets. No. w18400. National Bureau of Economic Research, 2012.

[45] The discount rate used here is the average mortgage rate at 3% as a placeholder. The average tax rate in Texas is 2%, with metropolitan areas like Houston collecting up to 2.39% in property taxes.

[46] The premiums shown here are for pre-FIRM single-family residences in inland flood zones, zones that start with A designations.

and a given flood risk profile, the increase in premiums are set. What varies across homes are the relative costs of premiums. As a result, for a house valued at \$250,000 in replacement costs, a 20% increase in premiums of a full coverage NFIP policy correspond to a 2.4% decline in home value.[47] For the same amount of coverage and the same increase in premiums, a house valued at \$500,000 in the building replacement cost would only see a 1.28% decline in home value.

| | Premiums as percent of home value | | |
|---|---|---|---|
| Value of home (\$) | Pre-2012 | Post-2015 | Change in home value |
| 2500000 | 0.07% | 0.08% | -0.27% |
| 1250000 | 0.14% | 0.17% | -0.54% |
| 833333 | 0.21% | 0.25% | -0.79% |
| 625000 | 0.27% | 0.33% | -1.04% |
| 500000 | 0.34% | 0.41% | -1.28% |
| 416667 | 0.41% | 0.50% | -1.51% |
| 357143 | 0.48% | 0.58% | -1.74% |
| 312500 | 0.55% | 0.66% | -1.96% |
| 277778 | 0.62% | 0.75% | -2.18% |
| 250000 | 0.68% | 0.83% | -2.38% |

| Premiums (\$/year) | |
|---|---|
| 2011 Premiums | 1710 |
| 2015 Premiums | 2073 |
| % Increase | 21.2% |

Figure 7: Anticipated declines in home value

Whereas Equation 3 models the per year cost of maintaining a house ($C$) as a constant, some costs do vary over time. Equation 6 modifies the cost function to allow for a constant increase or decrease in costs each year. With a small $a$ where $a > 1$, a gradual increase in costs occur over time.

$$PV = \sum_{t=0}^{\infty}(R - aC(t))e^{-rt} = \frac{R - aC(t)}{r} \tag{6}$$

How would the model fully capitalize the rates if the rates increase yearly only up to a certain cap? Equation 7 shows a piecewise function broken up by periods of constant increase initially, followed by periods of full, capped costs. For a homeowner, the full cost of the maintaining the property is still apparent from day one. However, because the costs rise gradually, the capitalization gives a slight discount over time. The higher the discount rate $r$, the more discounted costs for the consumer.

$$PV = \begin{cases} \sum_{t=0}^{\gamma}(R - ac(t))e^{-rt} \\ \sum_{t=\gamma+1}^{\infty}(R - C)e^{-rt} \text{ , where } \gamma = \text{transition year} \end{cases} \tag{7}$$

In both Equations 6 and 7, we're interested in what would happen to the present value of the house if we increased the slope of the increase in premiums from $a = 1$ to $a > 1$. The change would simply be the change in the subsidy offered when $a$ >1 (Equation 9). In other words, home value under

[47] These calculations use the same discount rate and tax rate as the example calculation in the paragraph above ($r$=3%, $t$=2%).

HFIAA14 consists of a discounted net rent path each year, a discounted initial premium, and a discounted new premium path (Equation 8).

$$PV = \frac{R}{r+t} + \frac{1}{p(t)} - p_0 \tag{8}$$

The difference-in-difference takes out the net rent path and the initial premium levels, leaving the effect of new premiums (the change) to the affected property value.

$$\Delta PV = \frac{1}{p(t)} \tag{9}$$

In summary, these equations theorize the channels through which flood insurance premiums could affect home values. Equations 3, 4, and 5 model the effect of a flat flood insurance premium $p$ on home values. Equation 5 gives the prediction that an increase in premium levels could decrease home values through the channel of a one-time jump in capitalized future cost, much like the change mandated by the Biggert-Waters Act of 2012. Equations 6, 7, 8 and 9 present a different scenario. Rather than a constant cost, the cost of flood insurance premium increases by a rate of $a$ each period until it hits a cap (Equation 7). The element of interest in this scenario is no longer the increase in level of insurance premium but rather the rate of increase over time. Equation 9 models the change in home values as a result of this gradually increasing flood insurance premium, which resembles the changes mandated by HFIAA14.

This framework is not perfect. In particular, one aspect of the flood insurance program that the equations could not capture was the limited coverage provided by NFIP, capped at $250,000 for residential property. This coverage signifies the replacement value of the building itself, also known as insurable value.[48] As a result, houses with replacement values over $250,000 receive only partial coverage under standardized NFIP policies. As a result, the the premium rate is a smaller fraction of the value of their house ($p$ is inversely related to the replacement value of the house once over $250,000 threshold). This implies that houses with higher replacement costs are less affected by the rate changes. The absolute per dollar effect is the same, but the effect is a smaller fraction of their property value. This may be a small adjustment considering that most claims are made for partial house damage and not total replacement.

A number of other assumptions are present. The most important of which assumes homogenous, rational consumers who are able to smooth consumption intertemporally. The discount rate ($r$) may be adjusted for consumers with different patience tolerance. However, we are not sure if consumers hold rational expectations. If the assumption is incorrect and consumers hold adaptive expectations, then the present value of property would not factor in the future stream of costs from flood insurance premiums. Instead, the present value calculation would be backwards looking, a derivation of past streams of rent and costs involved in owning the property.[49] Furthermore, transactions data observes the actual reduction in housing price associated with a new buyer. In a market with asymmetrical information, the buyer may only know the observed premium and may not comprehend the expected increase over time mandated by the HFIAA14 rate regime. The discount rate of the new buyer is not known.

[48] The rule of thumb FEMA uses for the replacement cost of a property is usually 80% of the total value of the property.

[49] Chow, Gregory C. "Usefulness of adaptive and rational expectations in economics." Center for Economic Policy Studies, Princeton University, 2011.

## 2.2 Empirical Model

Given the theory on house valuation and NFIP premiums, the basic structure of the empirical strategy is a difference-in-differences model using repeat sales. Since the policy changes occurred between 2012 and 2015, I can use a variety of dates corresponding to BW12 and HFIAA14 passage and implementation to test a number of hypothesis about how the housing market reacts to updated flood information via the NFIP. To tease out the housing market response, I use the variation in flood risk levels that different properties experience. SFHA is a dummy variable that signals 1 if the house is located in a flood-prone area.[50] The SFHA designation, policy periods, and their interaction help explain the difference in the ratios of paired transaction prices between houses in flood zones and ones that are not.

$$log(\frac{P_{t+\tau,i}}{P_{t,i}}) = \alpha + \beta_1(SFHA_i) + \beta_2(Pol\_Period_i) + \beta_3(SFHA_i \times Pol\_Period_i) + \varepsilon_i \tag{10}$$

The interaction term between the NFIP policy treatment period and the SFHA designation, $\beta_3$, is the coefficient of interest in Equation 10. $\beta_3$ would represent the average change in the ratio of high flood risk house prices after the NFIP policy changes. $\beta_1$ signals the baseline difference in the ratio of paired sales prices between houses in flood zones and houses not in the flood zones pre-treatment period (with NFIP subsidy). $\beta_2$ estimates any time varying factors that would contribute to differential rates for house price change for both the treatment and control groups. By running a diff-in-diff, we control for trend effects of $\beta_2$; otherwise, we would have arrived at a biased, "naive" estimator $\beta_2 + \beta_3$.

In this scenario, the diff-in-diff model includes an additional layer of complexity. Whereas other diff-in-diff models compare the average outcomes of each of the four scenarios, before and after treatment and control and treatment group, the unit of comparison in this repeat sales model would compare the *change* in house prices marked by the paired transactions. Thus, the differences are first taken between the change in house prices for SFHA and non-SFHA separately, comparing the houses that have been bought and sold in the treatment period that straddle a policy change versus transactions that do not. The differential effect of the NFIP policy on flood-prone houses and the non-flood prone houses are then compared to isolate the NFIP policy effect on flood-prone houses from the trend effects.

Because BW12 and HFIAA14 were not independent events, this study prefers to incorporate both policies into the same model. Figure 8 shows the conceptual illustration of the model. Rather than proposing individual experiments, the complex diff-in-diff gives the opportunity to account for cross-policy interaction effects. The model is shown in Equation 11. Appendix 6.3 clarifies the period markings for $T1, T2$, and $T3$.

$$\begin{aligned} log(\frac{P_{t+\tau,i}}{P_{t,i}}) = \alpha+\beta_1(SFHA_i)+\beta_2(T1_i)+\beta_3(T2_i)+\beta_4(T3_i)+\beta_5(SFHA_i\times T1_i)+\beta_6(SFHA_i\times T2_i) \\ + \beta_7(SFHA_i \times T3_i) + \varepsilon_i \end{aligned} \tag{11}$$

With the multi-period diff-in-diff, there are 3 effects of interest specific to flood-prone properties. The first, $\beta_5$, demonstrates the change in prices when a pair of repeat sales straddle the BW12

[50] Once again, SFHA designation confers mandatory flood insurance purchase. FEMA's SFHA designation includes three definitions: "100-year floodplain" with 1% annual chance of flood; At least a 26% chance of flooding over a 30-year mortgage; High-risk zones are designated as either A zones or V zones

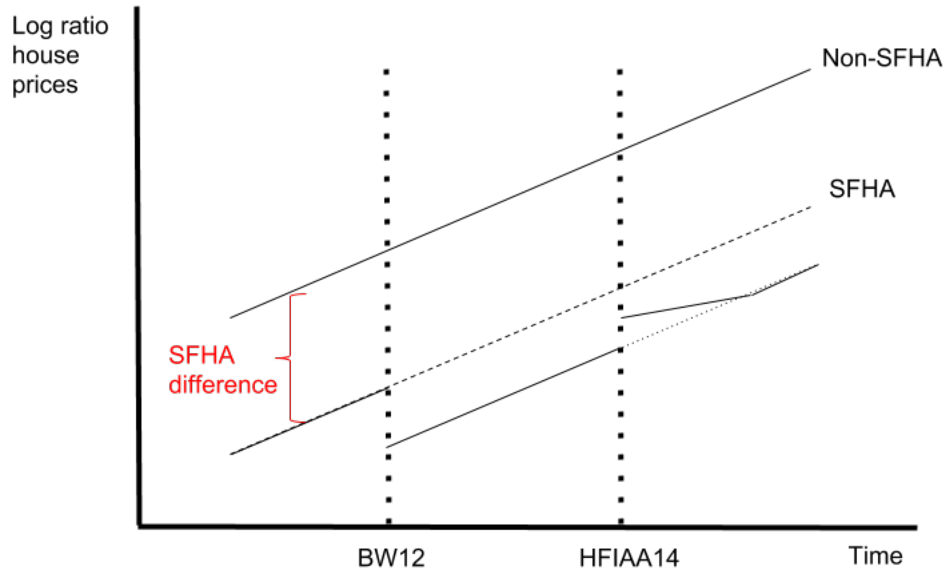


Figure 8: Difference in differences model

policy. I anticipate a drop in house prices for the houses that sell after BW12. The second effect, $\beta_6$, demonstrates the change in prices when a pair of repeat sales directly straddle the HFIAA14 policy. This means that the first sale occurred after BW12 and before HFIAA14 and the second sale occurred after HFIAA14. Conditional on the house experiencing BW12, the $\beta_6$ estimator shows the drop or gain in property value brought about by HFIAA14. $\beta_7$ estimates the third effect, which measures paired transactions that was bought before BW12 and sold after HFIAA14. Because the HFIAA14 sales conditional on BW12 were already controlled for in $T2$, $\beta_7$ estimates the direct effect of HFIAA14 on property values.

What are the parallel effects in the non-SFHA properties and what are the pre-BW12 baseline effects? As in the simple model, $\beta_1$ still signifies the differential house price ratios when NFIP subsidies were in place. $\beta_2, \beta_3,$ and $\beta_4$ represent the differential house price ratios for the control group in the periods bracketing BW12, HFIAA14 conditional on BW12, and HFIAA14, respectively. With interaction terms that make up the diff-in-diff, $\beta_5, \beta_6,$ and $\beta_7$ account for these baseline estimates to isolate the effects for flood-prone properties post-treatment.

### 2.2.1 Predictions

A number of testable predictions emerge from the individual and combined models. The following allude to coefficients in the combined model only, but the predictions apply to corresponding coefficients in the individual models also. The first set is concerned with the direction of price change. BW12 and HFIAA14 both increased rates. If NFIP premiums did factor into the capitalized present value of a property as an annual cost, then $\beta_5$ and $\beta_7$ should both be negative to signify that high flood risk home values have dropped. If homeowners capitalize gradual increases in rates immediately upon implementation, then there should not be heterogenous effects in $\beta_7$ for houses with varying second transaction years post-HFIAA14. However, if the opposite is true, and if houses sold more recently showing larger decreases in home values, then consumers may have adaptive expectations. Similarly, under a rational expectations framework, $\beta_6$ should resemble $\beta_7$: $\beta_6$ should have the same sign, but slightly smaller magnitude, given the time-value discount. If HFIAA14 is not fully capitalized, then $\beta_6$ might be positive from the repeal of BW12 rates.

The second set of predictions examine the severity of the price decline. Given that BW12 increased flood insurance rates to full risk overnight, it is possible that the housing market had a stronger reaction, resulting in a larger $\beta_5$ estimate. However, between BW12 and HFIAA14, there was uncertainty, both on the consumers' side and the regulators' side, as to whether or not the changes in BW12 were permanent. Because of this uncertainty and the lags embedded in the housing and insurance markets, the $\beta_5$ estimate may show little effect. The bulk of present value updating may have occurred after the passage of HFIAA14.

The third set of predictions are not necessarily predictions but a series questions. These are factors that I would test for. First, if there is discrepancy between the $\beta$ estimates and the theoretical predictions of change in property value, it may indicate that the discount rate deviates from the average mortgage rate for individuals or that there are omitted variables/unobservables in the valuation model. Second, the estimates currently do not account for housing and insurance market lag. While it is clear when FEMA implemented the legislative reforms, it is unclear how the enforced premium actually filters through the housing market. On the flip side, how long do the effects last and how long do home values stay depressed? If the adjustment period takes time, then the HFIAA14 estimators may include lasting BW12 effects and may be underestimated. Third, because HFIAA14 includes surcharges for all NFIP policies, including ones that already pay full risk rates, the strength of the HFIAA14 signal might be stronger than the BW12 signal.[51] As a result, the magnitude of the $\beta_6$ and $\beta_7$ estimates may be exaggerated. Finally, as discussed earlier, NFIP coverage extends only to a replacement value of $250,000 for residential properties. As a result, there may be heterogenous, nonlinear effects across property values. All three estimators of interest may be higher for properties under the replacement value threshold.[52]

### 2.2.2 Limitations

The model raises a number of potential concerns, and it is important to consider them one by one to ensure the proper model specification. The major categories to consider are selection, measurement, spillover and theoretical limitations. Endogeneity is the main problem. In cases where bias is unavoidable, it is important to know how the estimates may be biased.

The repeat sales, diff-in-diff model accentuates time variation. As a result, the first areas of concern are selection effects from omitted variables. In the case of flood insurance premium's effect on home values, historic flood events and changes in the flood maps during the time period of interest are two factors that may affect both the premiums and the home values independently. Historic flood events from storms are recorded by NOAA and used in actuary calculations for the NFIP premiums.[53] On the other hand, flood events may have damaged the building, and as a result, the property value declined independently. Changes in flood maps may be an important

[51] The confounding element here is that more houses in SFHA zones take up NFIP insurance, with both subsidized and full risk rates.

[52] Because I do not have the actual replacement value threshold for individual properties, I assume that the replacement value is equal to the value of the building, which is often 80% of the total home value. Later when I test this, I will move this around to test for different possibilities.

[53] Storms and floods that take place between 2012 and 2014 are particularly important to account for. The time period between the most recent storm/flood and the second transaction would give information on how influential weather events are on home sales.

omitted variable as a dummy (ie. whether or not the house is "newly mapped" onto a higher risk flood zone).[54] The model assumes a time invariant SFHA designation. For a small portion of the houses, that may not be true.[55] To address this, I add year and years between transactions as controls.

Second, measurement error may attenuate the estimators, yielding smaller effects than the true estimator. In measuring NFIP policy changes, the strength of the signals and how clearly defined the signals are crucial in preventing bias. First, the bulk of BW12 and HFIAA14 rate increases apply to subsidized pre-FIRM properties. A number of loopholes and discounts via grandfathering and appeals processes, created by program adjustments made since 1968, further cloud the ability to isolate houses affected by the removal of the subsidies. As a result, the model would benefit from data that can isolate pre-FIRM properties. Because the implementation of BW12 was tempered by uncertainty and HFIAA14 was not, the policy signals may be uneven. HFIAA14 may be a more permanent signal. Lags and lasting effects of these policies may contribute to the measurement problem. As a result, I conduct a series of robustness checks across alternative definitions of the timing of the rate hikes to pinpoint the response in the housing market.

The third area of concern is the potential for spillovers. Housing markets in the US are localized; studies often take neighborhoods as the unit of analysis because the houses trend together. If the value of one house increases, the value of the house next door may increase or decrease. If the houses are substitutes for homebuyers, the neighboring house value may increase. If instead, the houses are complements, valuation of the neighboring house will decrease. Thus, it may be important to recognize and control for neighborhood effects in the model. However, flood zones usually encompass the entire neighborhood. Spillover would occur only in a small subset of the dataset where a few houses are elevated while others are not.

Finally, there are a number of theory-imposed limitations. The repeat sales method selects out a substantial portion of the dataset. For one, houses built after HFIAA14's implementation in 2015 are not covered in the dataset. Second, only houses that are old enough to be sold twice are considered. In the two counties surrounding Houston relevant to this study, this selection may only yield samples from the older neighborhoods. In addition, because sales of houses trigger NFIP policy renewals or originations, the transactions dataset cannot reveal information for NFIP policies that have been grandfathered. Repeat sales also cannot control for within house variation over time. These factors may include depreciation of the housing stock or major alterations of the building itself. I do not have observations on home improvements. As a result, uncontrolled for within house variation over time increases noise in the regression outputs. To control for these unobservables, I include time between home sales in the regression to roughly proxy for changes in the condition of the house.

[54] Houston had two major recent updates to its FIRM panels: 2002 and 2017. Individual properties could also conduct its own elevation assessment, output a BFE, and mitigate flood risks. It would be difficult to compile a database of all flood risk changes in a short period of time.

[55] The historical flood maps could be a robustness check on the current effect, as an extension of this project. There are also preliminary maps that project sea level rise impacts. This is another interesting extension.

# 3 Data & Descriptives

## 3.1 Data

The research pulls data from Zillow's ZTRAX database and FEMA flood maps (FIRM panels). ZTRAX is in tabular form whereas FIRM panels are geospatial, accessible through ArcGIS. The FIRM panels have been digitized by FEMA, and they are accessible for most counties in the US via the National Flood Hazard Panel (NFHL).

ZTRAX is a property transactions and attributes database.[56] Appendix 6.4 illustrates its contents and how it is structured. It includes "information from more than 374 million detailed public records across over 2,750 U.S. counties covering more than two decades of deed transfers, mortgages, foreclosures, auctions, property tax delinquencies and more for residential and commercial properties" as well as "assessor data including property characteristics, geographic information, and prior valuations on approximately 200 million parcels in over 3,100 counties." Updated once a quarter, ZTRAX covers property records extending back to the early 1990s, when counties first started to digitize their records.[57]

Observations in the attributes dataset represents individual properties, and observations in the transactions dataset represents individual transactions. They are tied together by the property ID called *importparcelid*. Within each of these two main datasets, there are smaller variable files containing different categories of variables. I use primarily the transactions dataset, where the separate files are connected by a transaction ID, *transid*. Whereas the attributes dataset is cross-sectional, showing samples of houses in different areas, the transactions dataset is an unbalanced panel and shows longitudinal records of transactions for different properties in different areas. Thus, it is possible to identify a range of properties that have sold multiple times and pair the sales.

Property data is complex and messy, and ZTRAX required extensive cleaning. The Main table under Transactions contains the primary record for various events, such as deed transfers, mortgages, foreclosures, etc. PropertyInfo, a separate table under Transactions, provides address and location information as recorded from public records. I extracted and cleaned data from Harris and Fort Bend counties.[58] The sample size for Harris County's transactions data consists of 3,950,138 transactions, of which 3,480,071 are primary records. The sample size for Fort Bend County's transactions data contains 748,671 observations, of which 681,678 are primary records. In total, the original dataset consists of 4,161,749 primary records.

Obtaining a clean set of consumer-to-consumer home sales required extensive filtering on *DataClassStndCode, DocumentTypeStndCode, IntraFamilyTransferFlag, and PropertyUseStndCode*, among others. There were three levels of filtering. The first excludes foreclosure and mortgage documents in *DataClassStndCode,* leaving transactions deeds. The second excludes inheritance, intra-family transfers, and foreclosure ownership transfer deeds because these transactions do not reflect sales under normal circumstances. Finally, the third level of filtering excludes properties

[56] There are not many papers that have used ZTRAX yet, which is exciting. There's only few working papers out from 2017. Zillow has not officially released ZTRAX to the public.

[57] Dataset description from FAQ provided via email from Skylar Olson, a senior economist at Zillow

[58] I initially extracted Galveston County's property records. Galveston is a coastal county just south of Houston. However, the FIRM panels were not immediately available via NFHL. Instead I took neighboring counties Harris and Fort Bend county.

that have been sold only once or properties that had zero sales prices, most of which, in the second group, represented deeds that were not consumer-to-consumer home sales.[59]

The final repeat sales dataset for Harris and Fort Bend counties contains 18,528 pairs of consumer-to-consumer homes sales from 1991 to 2017. This represents approximately 37,056 transactions in the 27 year period. The distribution of the years for the transactions is show in Appendix 6.4. 48 cities are included in the sample, from Houston to Bellaire to Sugar Land. Though the property use code is not available for all transactions in the sample, the available information shows that the transactions represent properties ranging from single-family homes to condominiums to planned neighborhood houses (PUD).

### 3.1.1 Variables of Interest

Three types of variables, dependent, independent and the controls, make up the variables of interest. Each form of the variable was arrived at after careful thought and after exploring its descriptive statistics. In the repeat sales model, the dependent variable is the log ratio of home sales prices, the independent variables are the SFHA designations and period markings of whether a transaction spans the two policy changes in flood insurance, and the controls are the fixed neighborhood and time effects. This section describes the data cleaning process to prepare the variable of interest for analysis.

**Log Ratio of Sales Prices.** The log ratio of sales prices is the log of the second transaction price minus the log of the first transaction price. The transformation of the variable is necessary as house prices have a skewed distribution. Even so, there are a number of outliers in sales prices, with either extremely low or high prices. The higher priced transactions are usually within reason, signifying a valuable estate. The lower priced transactions are not; they range from \$0 to \$5,000. The final sample filters by two metrics: a sales price threshold and a sale ratio cutoff. Both can be adjusted. The sales price threshold sits at \$30,000 to \$100,000, and eliminates low priced transactions. The sale ratio cutoff sits at 1.5, eliminating any pair of transaction that is 1.5 of the other paired price.

**Treatment Period Markers.** The period markers rely on the variable *documentdate_n*, the date on the transaction record. In the paired transactions dataset, the dummy for paired sales that occur before and after the policy date is generated if the document date for the first and second sale straddle the policy date. Appendix 6.3 contains the schematic for bracketing. The period effects are coded by BW and HFIAA policy change dates: *BW12* and *HFIAA14* are when Congress passed the legislation and *BW13* and *HFIAA15* are when the policies are implemented. Lags are considered in installments of 6 months.

**Special Flood Hazard Areas.** The flood zone information comes from the National Flood Hazard Layer. The FIRM panels for Harris and Fort Bend counties effective in 2017 were processed in ArcGIS. These represent the most current flood risk designations, and may not reflect the flood risk assessment at the time of sale. The longitude and latitude coordinates of each house in the ZTRAX transactions dataset maps onto the FIRM panels. The flood risk information is then extracted from the geospatial data to a tabular form and merged with the ZTRAX transactions. SFHA designation were allocated to properties in zones A, AO, A1-A30, AE, A99, AH, AR, AR/A,

[59]Zero or low price records were the majority of the original ZTRAX dataset. This is partly resolved through the filtering process. However, there are still a number of low or zero price houses that are in the sample of interest.

AR/AE, AR/AH, AR/AO, AR/A1-A30, V1-V30 or V. They represent a 1-percent annual chance flood or the 100-year flood. The A designations correspond to inland flooding areas and the V designations correspond to coastal flooding areas, with additional risks of storm surge.

**Controls.** Neighborhood and time trend controls are represented by the variables *censustract* and *documentdateyr*. The census tracts denote individual neighborhoods, and document date year is coded for the document date of the second transaction once filtered for the sample of interest.[60]

## 3.2 Descriptives

Table 1 displays the summary statistics for the sample of interest. Appendix 6.4 contains more detailed descriptive information of the intermediate datasets. When filtered for house prices of greater than $30,000, the final paired dataset contains 10,496 individual transactions. Within these transactions, most of the houses are paired once with 2 transactions.[61] The variable yrsbtw shows how many years elapsed between the new and old sale. The average number of years is 3 years, and the maximum is 31 years. Among the explanatory dummies, 10% of the sample is in a SFHA flood zone. Around 6% each straddles BW12 and HFIAA14. There are 1% of paired sales that straddles both BW12 and HFIAA14.

Table 1: Summary statistics of sample of interest

| Variable | Mean | Std. Dev. | Min. | Max. | N |
|---|---|---|---|---|---|
| P0 | 94387.094 | 71662.978 | 30000 | 1800000 | 10470 |
| P1 | 95395.488 | 70809.55 | 30000 | 1800000 | 10470 |
| Log(P1/P0) | 0.013 | 0.187 | -0.405 | 0.405 | 10470 |
| SFHA | 0.105 | 0.307 | 0 | 1 | 10459 |
| Bracket BW12 | 0.061 | 0.239 | 0 | 1 | 10470 |
| Bracket HF14 | 0.069 | 0.254 | 0 | 1 | 10470 |
| Bracket Both | 0.011 | 0.105 | 0 | 1 | 10470 |
| Date0 | 2002.716 | 5.196 | 1976 | 2017 | 10470 |
| Date1 | 2006.133 | 5.855 | 1994 | 2017 | 10470 |
| Years Between (*yrsbtw*) | 3.417 | 3.56 | 0 | 31 | 10470 |

Figure 9 shows the paired transactions data in Harris and Fort Bend Counties. Through ArcGIS, I overlaid the FEMA flood maps, or the FIRM panels, with the properties in ZTRAX that have seen repeated sales. The properties are color-coded with their flood risk levels. Red points are the houses that have minimal flood risk, in zones B, C, and X, and yellow points are the houses situated in the SFHA. The grey background indicate areas that are not SFHA and the colored background indicate areas that are in the SFHA.

Figure 10 shows the time trend for aggregate house values in Houston, Dallas, and the US from 2010 to 2017. Home sales are generally upward sloping. However, local housing markets are much

[60] An analysis of missing observations for the variables of interest showed that only census tract information had missing variables (Appendix 6.4). The missing census tract observations were few and not nonrandom. No significant missing observations are reported in other explanatory variables.

[61] The maximum number of transactions of a property is 219 times, which is most likely to be a condominium with separate units.

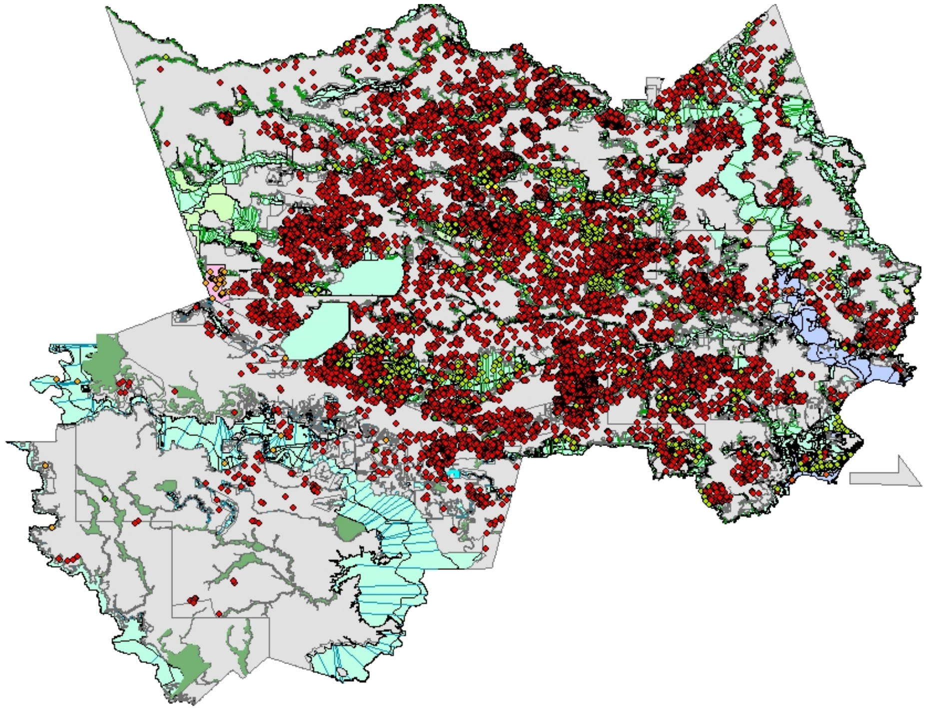

Figure 9: Houses of interest in ZTRAX in Harris and Fort Bend County, TX

more volatile than the national average. Houston home values show frequent fluctuations between -1% and 2%. Given the specified diff-in-diff model, Zillow Home Value Index is a good proxy for the housing market price trend for all houses in the area.

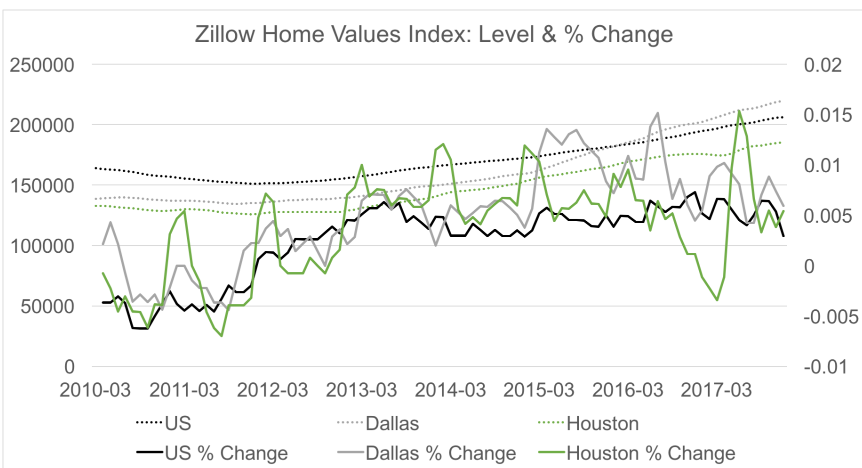


Figure 10: Zillow House Value Index, metropolitan areas

To visualize the relationship between the variables of interest, I plotted the paired sales records along the dates of transaction (Appendix 6.4). There does seem to be a relationship between certain cities and the average home sales prices. Given the characteristics of the paired sales, *ntrans* and *yrsbtw*, I explored how these two dimensions related to the change in prices. There is no obvious relationship here. Lastly, I explored the relationship between the dependent and independent variables and the relationship between the dependent and control variables. The results are shown in Appendix 6.4. The most interesting result was the relationship between the ratio of prices and the policy periods. The average ratio of prices for the Congressional legislation dates and fairly different from the average ratio of prices for the implementation dates. This provides me more reason to test the two versions of the model.

# 4 Results

## 4.1 Individual Experiments

These results are displayed holding the sample of interest constant (coded as *soi* dummy in the dataset). The filter for this sample eliminates outliers in property transactions data. These outliers are pairs of transactions that deviate too much from the previous price ($p_{i,2}/p_{i,1} > 1.5$ or $p_{i,2}/p_{i,1} < 2/3$) and pairs that have extremely low prices in either transaction ($p_{it} <$ \$30,000). The results are broken down by the policy markers used to define the treatment periods.

### 4.1.1 Policy Passage Dates

Table 2 shows the results of the simple diff-in-diff models for policy passage dates. These are individual experiments measuring the effect of BW12 and HFIAA14 in isolation.[62] While the passage of the legislation does not imply immediate rate increases, these dates do signify the firm Congressional decisions to remove pre-FIRM subsidies. If homeowners are rational actors who make decisions with a medium to long term horizon, then it is possible that the passage dates would prompt a forward looking capitalization of flood risk.

Models 1 and 2 use BW12's passage date, June 6, 2012, as the treatment period. Model 3 and 4 use HFIAA14's passage date, March 21, 2014, as the treatment period. Whereas models 1 and 3 are simple diff-in-diff regressions, models 2 and 4 incorporate time, years between transactions, and neighborhood controls into the diff-in-diff regression.

Table 2: Individual experiments, policy passage dates

| | (1)<br>ln_rsales<br>BW12 | (2)<br>ln_rsales<br>BW12 | (3)<br>ln_rsales<br>HFIAA14 | (4)<br>ln_rsales<br>HFIAA14 |
|---|---|---|---|---|
| SFHA | 0.0205** | 0.0186** | 0.0211*** | 0.0197** |
| | (3.24) | (2.86) | (3.42) | (3.10) |
| s_BW12 | 0.00811 | -0.0396*** | | |
| | (1.35) | (-5.53) | | |
| sfha_s_BW12 | -0.0253 | -0.0225 | | |
| | (-1.39) | (-1.26) | | |
| yrsbtw | | 0.0103*** | | 0.00863*** |
| | | (16.74) | | (14.99) |
| s_HF14 | | | 0.0301*** | -0.00494 |
| | | | (3.90) | (-0.57) |

[62] The dummies are constructed by whether or not a pair of transaction straddles the policy dates. I also tested models with a slight variation on how the policy marker periods are constructed, but the results do not differ significantly. The alternate specification takes out all paired transactions that occurred after the policy marker and define them as missing.

| | | | | |
|---|---|---|---|---|
| sfha_s_HF14 | | | -0.0525* | -0.0528* |
| | | | (-2.22) | (-2.29) |
| Constant | 0.0106*** | -0.0583 | 0.00953*** | -0.0281 |
| | (5.16) | (-0.32) | (4.77) | (-0.15) |
| Time & Nbhd Controls | No | Yes | No | Yes |
| N | 10445 | 10445 | 10445 | 10445 |

$t$ statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The coefficient *SFHA* shows the baseline difference in property value between houses in a flood zone and houses in the control group. When NFIP subsidies were in place, *SFHA* shows that properties in flood-prone zones have home values that are approximately 2% higher than properties in non-flood-prone areas. This may seem puzzling. However, the regression setup observes the naive differences. It may be possible that the properties in flood zones retain more non-flood related amenities than the properties in other areas. As a result, the positive amenities overwhelm the flood risk disamenities. One could imagine that properties near the waterfront are valued for their scenery.[63] The housing market time trends are captured by *s_BW12* and *s_HF14*. Generally, when neighborhood and time controls are included, *s_BW12* and *s_HF14* are no longer the only indicators of change over time. The signs of the coefficients in the models with additional controls flip from positive, increases in home value, to negative.

The coefficients of interest here are the interaction effects. As indicated by *sfha_s_BW12* in both specifications, the effect of BW12 on houses in SFHA zones is negative but not significant. The size of the effect doesn't change much between the simple and the fully specified models (1 and 2). On average, properties in flood zones after the passage of BW12 experiences a 2.3% decrease in home values across the Greater Houston area. The coefficient *sfha_s_HF14* shows significant and negative effect on flood prone houses after the passage of HFIAA14. On average, HFIAA14 resulted in a 5.3% decrease in house values for flood-prone houses across the Greater Houston area. Thus, individual experiments using policy passage dates seem to indicate that the passage of HFIAA14 led to changes in home prices. However, this effect might also include lagged effects from BW12. It is difficult to tease apart the spillover effects from the simple model.

### 4.1.2 Implementation Dates

To give FEMA time to adjust its program, the premium increases were not enforced until months later. Table 3 shows the regression outputs for BW12 and HFIAA14 implementation dates. The policy implementation dates are October 1, 2013 for BW12 and April 1, 2015 for HFIAA14. Since the research assesses the impacts of increased premiums, it makes sense to run the simple experiments through this set of implementation dates. Once again, models 1 and 3 are simple models,

[63]There is anecdotal evidence to indicate that flood-prone zones have better neighborhood amenities to compensate. In a recent New York Times article, a neighborhood in the greater Houston area, Canyon Gate within Cinco Ranch, had little awareness that they were designated reservoir for flooding in Houston. Home buyers were drawn to the gated communities in this area and are compensated with playgrounds and pools.
Wallace, Tim, et al. "How One Houston Suburb Ended Up in a Reservoir." The New York Times, The New York Times, 22 Mar. 2018, www.nytimes.com/interactive/2018/03/22/us/houston-harvey-flooding-reservoir.html.

and models 2 and 4 include time and neighborhood effects. The first two models examine BW12 implementation, and the latter two examine HFIAA14 implementation.

Table 3: Individual experiments, policy implementation dates

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | ln_rsales | ln_rsales | ln_rsales | ln_rsales |
| | BW12 | BW12 | HFIAA14 | HFIAA14 |
| SFHA | 0.0216*** | 0.0202** | 0.0189** | 0.0176** |
| | (3.49) | (3.15) | (3.11) | (2.79) |
| s_BW12 | 0.0203** | -0.0153 | | |
| | (2.89) | (-1.91) | | |
| sfha_s_BW12 | -0.0445* | -0.0444* | | |
| | (-2.03) | (-2.08) | | |
| yrsbtw | | 0.00895*** | | 0.00818*** |
| | | (15.33) | | (14.86) |
| s_HF14 | | | 0.0373*** | 0.00889 |
| | | | (3.88) | (0.87) |
| sfha_s_HF14 | | | -0.0195 | -0.0210 |
| | | | (-0.66) | (-0.72) |
| Constant | 0.00973*** | -0.0345 | 0.00983*** | -0.0205 |
| | (4.83) | (-0.19) | (4.99) | (-0.11) |
| Time & Nbhd Controls | No | Yes | No | Yes |
| N | 10445 | 10445 | 10445 | 10445 |

$t$ statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

With implementation dates as treatment markers, the effect on home values from increased premiums shifts to BW12. The baseline SFHA comparison and the housing market time trends do not deviate much from the results of the policy passage model. However, the interaction effects of the premium change on home values post-implementation show a different story.

As indicated by *sfha_s_BW12*, the effect of BW12 on houses in SFHA zones is negative and significant. On average, properties in flood zones after complete implementation of BW12 experiences a 4.4% decrease in home values across the Greater Houston area. The coefficient *sfha_s_HF14* is still negative but no longer significant. On average, HFIAA14 resulted in a 2% decrease in house values for flood-prone houses across the Greater Houston area.

In both the policy passage and the policy implementation specifications, the control of the number of years in between transactions, *yrsbtw*, show significant and positive impact on home values. As the years between sales increase, homes tend to accrue more value. Each additional year elapsed between sales results in a 0.8% increase in the value of the home.

## 4.2 Heterogenous effects

As Figure 7 alludes to, the relative cost of the premiums against the stream of rents, taxes, and discounting do contribute to differences in home value response. Homes with high replacement value exceeding the full coverage of $250,000 offered by NFIP should experience a smaller change in home value than homes that are below the full coverage threshold. In addition to variation in the relative cost of the premiums, homes also have heterogenous characteristics associated with differences in value. A waterfront mansion's value may not be as elastic to changes in the premiums as a one-story, prefabricated home. As a result, I test the heterogenous response to increases in premiums along a socioeconomic dimension. Table 4 shows a triple difference regression highlighting the effect of premium changes on low valued homes. The marker on low valued homes, *lowinchouse*, is based on a threshold cutoff of $100,000, the average sales price of the dataset. I use the BW12 implementation date, October 2013, as the treatment period marker to test for heterogenous effects across fully implemented premiums.

Table 4: Heterogeneous Effects, Policy Implementation Dates

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | ln_rsales | ln_rsales | ln_rsales | ln_rsales |
| | | | DDD | DDD, FE |
| SFHA | 0.0217*** | 0.0202** | 0.0213*** | 0.0202** |
| | (3.50) | (3.11) | (3.44) | (3.11) |
| s_BW12 | 0.0214** | -0.0186* | 0.0229** | -0.0171* |
| | (3.01) | (-2.49) | (3.20) | (-2.29) |
| sfha_s_BW12 | -0.0487* | -0.0466* | -0.00464 | 0.000362 |
| | (-2.18) | (-2.10) | (-0.15) | (0.01) |
| yrsbtw | | 0.00870*** | | 0.00871*** |
| | | (15.99) | | (16.01) |
| lowinchouse | | | 0.00804* | 0.00752 |
| | | | (2.11) | (1.88) |
| poor_sfha | | | -0.0844* | -0.0900* |
| | | | (-2.06) | (-2.22) |
| Constant | 0.00970*** | -0.00219 | 0.00457 | -0.00796 |
| | (4.82) | (-0.21) | (1.45) | (-0.73) |
| Fixed Effects | No | Yes | No | Yes |
| N | 10433 | 10433 | 10433 | 10433 |

$t$ statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The triple different interaction term *poor_sfha* gives the effect of increase in BW12 premiums for low valued houses in the flood zones. Without interacting with the baseline home value, models

1 and 2 give the aggregate effects of BW12 rate hikes on repeat sales properties in the greater Houston area. The coefficient for *sfha_s_BW12* in the fixed effects model (2) show a 4.66% decrease in home values on average for houses in the flood zone post-BW12. In the triple different regressions, the significance goes away. Instead, the low valued homes show a larger drop in prices. *poor_sfha* shows that low valued houses in flood zones experience a 9% decline in home values in response to increased premiums following BW12. This result suggests that low valued houses are much more sensitive to premium changes than higher valued houses.

## 4.3 Robustness Checks

To place the results in context, I conduct two forms of robustness checks. Given that the bulk of the effects shifted from HFIAA's passage in 2014 to BW12's implementation in 2013, between Tables 2 and 3, it is possible that increased premiums could be acting on home values through a number of channels. Because the timeline of events is clear, the first robustness check utilizes alternate definitions of the treatment period to evaluate the full extent of the NFIP rate policies' impacts on home values. The second robustness check adjusts the sample of interest. Rather than using the parameters of $30,000 as a floor for transaction prices and 1.5 as a bounded price change, the robustness check loosens up the sample to test these cutoffs.

### 4.3.1 Alternate Date Specifications

The construction of the treatment period follows the "bracketing" method outlined in Carbone et al. (2006). A bracket dummy is 1 if the paired observations, in this case home sales, occur first before the event and again after the event and 0 otherwise. The event here is the increase in NFIP premiums. Brackets can be adjusted accordingly by changing the timing of the event or the temporal distance from the event.

First, adjusting the timing of event along the NFIP policy period can help pinpoint the set of observations in the dataset that drive the decline in home values. Figure 11 shows the alternate dates specifications along a every-five day interval starting from January 1, 2012. Appendix 6.5 contains the robustness check conducted at a monthly interval from 2012 to 2017. Both figures show the coefficients that represent the interaction effect of houses in flood zones with the timing variable.

The trend, showing the estimated effect of "increased premiums" across time, support the earlier interpretation of the NFIP policy changes and the individual experiments. Policy passage of BW12, the first red vertical line, prompted housing market response. However, it was not until the second red vertical line, the start of BW12 implementation, that the values of the homes in flood zones really responded to the changes. The red dots show coefficients that are significant at the 95% confidence interval. The third and fourth red vertical lines signify the full implementation of BW12 in October 2013 and the passage of HFIAA14 in March 2014. It wasn't until a few days before the third line, the full implementation of BW12, that the effects of increased premiums became statistically significant. This coincides with the maximum magnitude of the effect, hovering around a 5% decrease in home values for houses in the flood zones. Appendix 6.5 includes a figure illustrating the corresponding p-values of the estimates. Most highly significant results occur from September 2013 to January 2014, with the most significant coefficient occurring in January 2014.

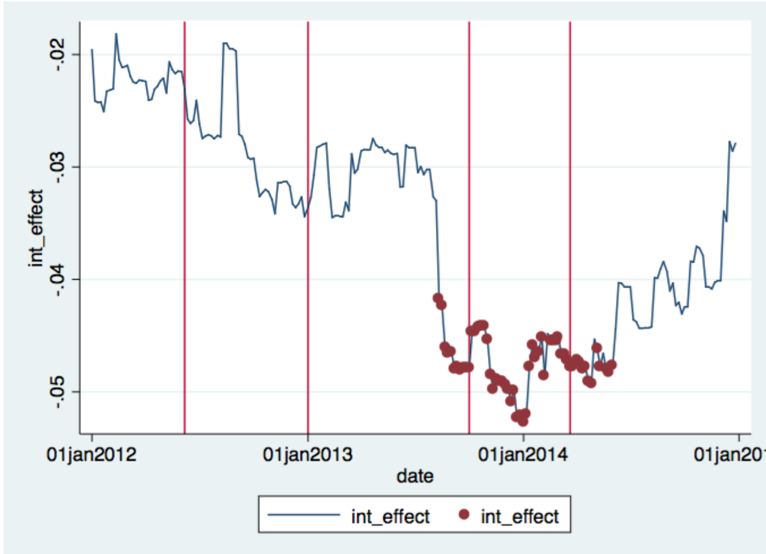


Figure 11: Robustness checks along an every-five day interval

This supports the view that the effects shown in individual experiments come primarily from the implementation of BW12. If we use the full BW12 implementation date as a marker, the housing market in greater Houston lags by a quarter, approximately 4 months.

If we assume January 2014 is when the effects of the raised flood insurance rate trickle through the housing market, the question that follows is how closely do the home sales have to occur around this date for home values to be impacted. To conduct this robustness test, I used January 1, 2014 as a fixed time marker. In each subsequent test, I increased the distance from Jan 1, 2014 by a span of two weeks.

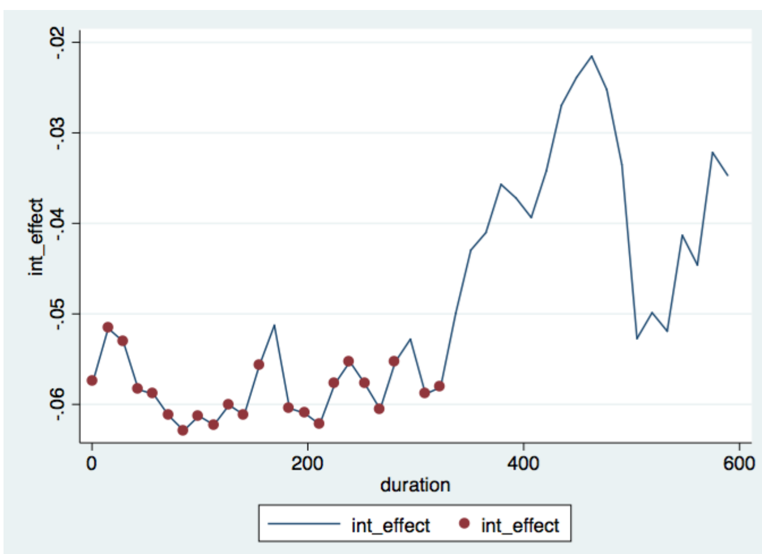


Figure 12: Robustness checks along varying bracketing distance

The blue line maps the coefficients of the interaction effect for a house in a flood zone that experienced the bracketed transaction against the bracketing distance in days. The red dots, again, represent the coefficients that are significant at the 95% confidence level. The size of the effect remains consistent as bracketing distance increases until the bracketing distance reaches 323 days, after which none of the coefficients are statistically significant. The significant interaction effects are also consistent with the timing robustness check outputs. Therefore, we may conclude that the paired transactions that experienced the drop in home values did not need to be tightly clustered around the event itself. Instead, the NFIP rate increases retain relevance in this wide bracketing period. A homebuyer who scours the market for a house, a year after January 1, 2014, would be evaluating the house in light of the capitalized flood risks.

Wider bracketing also gives rise to larger effects. Many of the estimates that bracket with 6 months or more show a decline in home values of 6% for houses in the flood zones after the BW12 rate hike was implemented. The difference in these estimate may include weaker effects generated by HFIAA14 in the following months or the accumulated effects of rate changes over time.

### 4.3.2 Variations along sample transactions of interest

The median value of a single family residence in Houston in 2017 is $225,903.[64] To test for robustness and to adjust for property prices that seem too low, I raised the threshold for properties to be included in the sample of interest from having a sales price greater than $30,000 to a sales price greater than $50,000 (models 3 and 4). I recognize that this cutoff is arbitrary, and the cut culls the number of observations in the regression to 80% its original size. Models 5 and 6 expand the sample of interest to include houses with sale prices greater than $10,000. The results, shown in Table 5, are fairly consistent across the different samples.

Table 5: Sample of Interest Robustness Test, Policy Implementation Dates

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | ln_rsales | ln_rsales | ln_rsales | ln_rsales | ln_rsales | ln_rsales |
| SFHA_TF | 0.0217*** | 0.0202** | 0.0270*** | 0.0239*** | 0.0205*** | 0.0202** |
| | (3.50) | (3.11) | (3.98) | (3.38) | (3.46) | (3.26) |
| s_12a | 0.0214** | -0.0186* | 0.0283*** | -0.0142 | 0.0177** | -0.0200** |
| | (3.01) | (-2.49) | (3.80) | (-1.81) | (2.61) | (-2.80) |
| int_s_12a | -0.0487* | -0.0466* | -0.0542* | -0.0524* | -0.0409 | -0.0421* |
| | (-2.18) | (-2.10) | (-2.30) | (-2.25) | (-1.94) | (-2.02) |
| yrsbtw | | 0.00870*** | | 0.00971*** | | 0.00805*** |
| | | (15.99) | | (15.78) | | (15.50) |
| Constant | 0.00970*** | -0.00219 | 0.00841*** | 0.00531 | 0.0120*** | -0.0000775 |
| | (4.82) | (-0.21) | (3.84) | (0.44) | (6.19) | (-0.01) |
| Fixed Effects | No | Yes | No | Yes | No | Yes |
| SOI Floor | $30,000 | $30,000 | $50,000 | $50,000 | $10,000 | $10,000 |
| N | 10433 | 10433 | 8530 | 8530 | 11415 | 11415 |

[64] Pulsinelli, Olivia. "Houston?s Housing Market Breaks More Records in 2016.? Bizjournals, 11 Jan. 2017, www.bizjournals.com/houston/news/2017/01/11/houston-s-housing-market-breaks-more-records-in.html.

$t$ statistics in parentheses

$^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$

Indeed, in the sample with the $50,000 floor, the impact of premiums on home prices is larger. While part of this result comes from removing noise in bad observations in the transactions dataset, part of the results may also be capturing the heterogenous effect in the baseline property values. In the sample with the $10,000 floor, the effect becomes slightly smaller.

## 4.4 Combined Experiments

To test the nuanced story shown in Figure 8, I ran a combined experiment that incorporates both policy signals, BW12 and HFIAA14. The goal was to tease out the micro-fluctuations in home values in the transition between BW12 and HFIAA14 rates regimes. However, results are inconclusive, partly due to the unavailability of quality paired transactions data between 2012 and 2014 and partly due to model specification. This section shares preliminary results and describes the challenges present with the combined model. Because there remain a number of problems with the analysis, I have placed the rest of the discussion in Appendix 6.5.

Table 6 displays the regression output the model described in Equation 11, where 3 time dummies are created to bracket either only BW12, HFIAA14 or to bracket both. Model 1 shows a simplified combined model where T1 brackets BW12 only, ending before HFIAA14, and T3 brackets both policies. In this model, T1 tests for the effects of BW12 rate changes and T3 tests for the combined effect of HFIAA14 following BW12.[65]

Model 2 shows the exact regression described in Equation 11, with three treatment periods, T1, T2, and T3, straddling BW12, HFIAA14, and both BW12 and HFIAA14, respectively. The addition of T2, sales that bracket HFIAA14 directly before and after, seeks to capture the response of home values to HFIAA14 conditional on having acted on BW12 rates. The house in this scenario would have been bought at full discount after BW12 but sold at either a slightly higher value or the same value after HFIAA14.[66] Models 3 and 4 are variations on model 2: model 3 with neighborhood and time trend controls (*censustrac* and *documentdateyr*) and model 4 with a narrower sample of interest to properties with full coverage.

Table 6: Combined model, policy passage dates

| | (1)<br>ln_rsales (no T2) | (2)<br>ln_rsales | (3)<br>ln_rsales, FE | (4)<br>ln_rsales, FC |
|---|---|---|---|---|
| SFHA | 0.0206$^{**}$ | 0.0202$^{**}$ | 0.0206$^{**}$ | 0.0206$^{**}$ |
| | (3.25) | (3.17) | (3.11) | (3.22) |
| t1 | -0.0180$^{*}$ | -0.0181$^{*}$ | -0.00854 | -0.0177$^{*}$ |

[65] The scenario here is that the T1 homeowner sells at a discount in the intervening period between BW12 and HFIAA14 with the higher flood insurance premiums, whereas the T3 homeowner sleeps through the policy turmoil to sell only with the HFIAA14 scheme in place.

[66] Asymmetrical information and short time horizons in the homebuyer mentality would contribute to a slightly higher sales price. Perfect information with long time horizons would correspond to no change.

| | | | | |
|---|---|---|---|---|
| | (-2.23) | (-2.24) | (-1.03) | (-2.17) |
| t3 | 0.0344*** | 0.0343*** | 0.0479*** | 0.0349*** |
| | (4.16) | (4.15) | (5.72) | (4.19) |
| sfha_t1 | 0.0132 | 0.0136 | 0.0168 | 0.0127 |
| | (0.54) | (0.56) | (0.70) | (0.52) |
| sfha_t3 | -0.0614* | -0.0611* | -0.0617* | -0.0622* |
| | (-2.44) | (-2.43) | (-2.49) | (-2.47) |
| t2 | | -0.00795 | -0.00418 | -0.00805 |
| | | (-0.43) | (-0.17) | (-0.44) |
| sfha_t2 | | 0.0256 | 0.0220 | 0.0252 |
| | | (0.46) | (0.40) | (0.46) |
| Constant | 0.0105*** | 0.0106*** | 0.138 | 0.0107*** |
| | (5.14) | (5.16) | (0.75) | (5.18) |
| Observations | 10485 | 10485 | 10485 | 10391 |
| $R^2$ | 0.003 | 0.003 | 0.046 | 0.003 |

*t* statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The regression outputs here correspond to only the policy passage dates. Whereas the individual experiments showed that the effects are concentrated after the implementation of the BW12 rate hike, around the time of HFIAA14's passge, the combined model shows that in aggregate, houses that have experience both BW12 and HFIAA14 retain the price drop. In fact, in the scenario where the homeowner sleeps through the policy changes (*sfha_t3*), the decline in home values for houses in the flood zone is 6.1%. This is consistent across all four specifications.

Compared to the average 4-5% decrease in the ratio of home prices in response to premium hikes in the individual experiments, *sfha_t3*, signifying properties that were bought pre-BW12 and sold post-HFIAA14 passage, shows a magnified cross-policy effect. The effect is slightly larger when neighborhood and time trend controls are added (3), and again, when the model only tests for full coverage policies (4).

Both *sfha_t1* and *sfha_t2* are positive and not significant, which may indicate that the housing market did not pick up the effects of BW12 or the effect of HFIAA14 contingent on BW12. For *sfha_t2*, it may also mean that home values did not experience a slight upward revision in home values between BW12 and HFIAA14.

Thus, the combined model is effective in pinpointing the compounded effect (*sfha_t3*) of a house experiencing both BW12 and HFIAA14. The compounded effect may contain cross-policy effects that are not picked up in the individual experiments. For one, there could be uncertainty associated with the two NFIP legislation that lowered the home values for properties that waited longer to sell. On the other hand, the combined model does not elucidate the effect of transitioning from BW12 to HFIAA14 well. Whereas *sfha_t2* is positive, it is not significant and inconclusive. Furthermore, observations bracketing T2 would have had to be bought and resold in a short period of time, within a year or two, and it is possible that these houses are lemons and do not represent the effect that we are interested in. Finally, the current combined model only test for policy passage dates. If possible, the ideal model would follow the evolution of the NFIP policymaking to incorporate both passage and implementation dates. I currently do not have a specification that can tease out the right effects without redundancy.

# 5 Conclusion

Taken together, the results show on average a 4-6% decline in home values following the removal of flood insurance subsidies for houses in flood zones. Both NFIP policies, BW12 and HFIAA14, removed subsidies by increasing pre-FIRM rates to reflect FEMA's full risk rates, but the two policies differed in the way the rate hikes were implemented over time. Each had a 6-12 month lag between policy passage and full implementation. Most of the effects of increased premiums are seen in declines in house prices around January 2014, 4 months after the full implementation of BW12 in October 2013. As a result, homes appear to have experienced a larger loss in value following BW12 rather than HFIAA14. The result is consistent across varying samples of interest.

Home value responses to premium changes may be nonlinear for two reasons. The first is because the NFIP has a coverage limit at $250,000 for residential policies, only the relatively cost of premiums matter. Houses that exceed the full coverage limit may not seen a similar drop in home values. Second, high and low valued properties have different characteristics. As Table 4 shows, low valued properties in flood zones have highly elastic responses to premium changes. The effect increases from 4.66% to 9% decline in home values. One could imagine that a lower valued house may derive proportionally more value from functionality of the structure itself.

Individual experiments of BW12 and HFIAA14 do not tell the full story. Hinted at by the robustness tests across bracket distance and verified in the combined model, BW12 gives lasting effects that compound when the house experiences both policy changes. The cross-policy interaction increases the effect of premiums on home values from 4.66% to 6.17% for houses in SFHA flood zones. Because BW12's implementation overlaps with the passage of HFIAA14, it is possible that uncertainty in the intervening period of the two policies is the source of the added effect.

What does all of this tell us about the housing market? Figure 7 calculated the expected drop in home value in response to the change in rates between 2012 and 2015 for properties of different replacement values and of flood risk profile in A zones. The prediction for a building with a replacement value of $250,000 experiencing a 20% increase in premiums over the policy periods was that the home value would decline by 2.4%.[67] However, the estimated decline in home values in flood zones over the same period is 4.66%. This discrepancy raises the question of the true discount rates used by homeowners to capitalize the cost of flood insurance premiums. Whereas the theoretical predictions relied on the mortgage rate ($r = 3\%$), the empirical results would require an internal discounting rate of $r = 0.5\%$. If this is true, then the housing market may be overreacting and over penalizing home values in response to the updated flood risk information.

The results come with limitations. While most of the selection and measurement errors are responded to, the solutions are not perfect. Especially in the combined model, this research would benefit from better transactions data and a refined specification. Nevertheless, the empirical evidence speaks for itself.

It is fascinating how such an arcane system of flood insurance provision has become so politicized. This paper accomplishes a few things. First, I use Zillow's ZTRAX dataset to get at property level effects in way that has not been done before. Villar (2015) relies on median home values only. Second, I include HFIAA14 in the analysis in a nontrivial way. Though the effects of premiums on home values are concentrated in the period following full implementation of BW12, HFIAA14

[67] The 20% premium increases is calculated from the NFIP Flood Insurance Manuals for agents; it is an empirical data point.

nonetheless carries the lasting impact of the rate hikes forward. The question that remains is by how much; this leaves the transition from the BW12 to HFIAA14 regimes an open question for further research. Third, through robustness checks of the bracketing method, I am able to pinpoint the lag with which the premium effects show up in the housing market. Finally, the results support the notion that capitalizing flood risks, in the form of premiums, into homeownership is necessary. The declines in home values show that premiums prompted participants in the housing market, both the homeowners and home buyers, to reassess transaction decisions. The last section briefly describes the policy implications of having a housing market with properly capitalized flood risk.

## 5.1 Policy Implications

The ability to quantify the housing market response to the NFIP policy change captures the ability for premium increases, or more accurate flood risk information, to affect behavioral change or changes in homeowner expectations. Specifically, the signaling is done in a legally and financially binding way. In contrast to public awareness campaigns or local government intervention, the flood insurance legislations compel homeowners to prepare for future flooding hazards in a market-based mechanism. Thus, the benefits of a well-functioning flood insurance mechanism can be realized. Neighborhoods would be financially better able to navigate flood risk, have more flood-resilient infrastructure, and avoid overbuilding into flood-prone areas.

On the flip side, embedded in the post-BW12 policy debate and remaining unresolved is the issue of affordability. Homeowners have seen their NFIP rates jump multifold overnight. An efficient flood insurance mechanism is not necessarily an equitable one. Consider the case of Houston, where house prices are cheaper for homes in flood-prone, less desirable areas. In fact, poorer families might live in areas with higher premiums and have to to pay a disproportionate amount to maintain their homeownership. Furthermore, alternative housing arrangements might not be readily available or more expensive.

Fair rates can also encourage private sector participation and offering of insurance.[68] Once the subsidies are removed, private insurance companies might find an incentive to enter the flood insurance market if they can provide insurance more efficiently. Florida is the only state that has a private flood insurance market. A related concern involves the low penetration of NFIP policies in certain communities, even ones that are classified as SFHA. Because the mandatory purchase requirement applies only to houses under a federally-backed mortgage, flood insurance policies often lapse after the loan expires.[69] The worry with increased rates is that homeowners would substitute away from flood insurance, whether private or public, entirely once the mandatory purchase requirement no longer applies.

The political economy of local housing markets plays a huge role in the effectiveness of flood insurance. Because the NFIP is cumbersome, dependent on house-specific elevation data, and complex, the incentives between the range of agents, from the homeowners, to insurance agents,

[68] Smith, Ryan. "Want More Private Flood Insurers? Increase Federal Rates." Insurance Business, 27 Oct. 2017, www.insurancebusinessmag.com/us/news/catastrophe/want-more-private-flood-insurers-increase-federal-rates-83018.aspx.

[69] Federally-backed mortgage include loans that are issued by a regulated lender or loans that originated from non-regulated institutions but have been sold on the secondary market to Fannie Mae or Freddie Mac.
Tobin, Richard J., and Corinne Calfee. *The National Flood Insurance Program's Mandatory Purchase Requirement: Policies, Processes, and Stakeholders.* American Institutes for Research., 2005.

property developers, local government, and FEMA, are not always aligned.[70] As a result, the property developers and some homeowners exploit a number of loopholes existing in the program to build in unsafe areas and avoid the rate increases. Second, the flood risk information embedded in the FIRM panels take time to gather, assess, and adopt. Friendswood, a municipality straddling Harris and Galveston counties, have not updated their flood maps since 1997.[71] These groups and lags in information give rise to imperfect compliance with the actuarially fair designs of the post-HFIAA14 NFIP program.

Underlying the static conception of flood risk and the NFIP are dynamic impacts from climate change on local flood zones. While the BW12 and HFIAA14 legislations removed the subsidized rates for current flood risk, the full risk rates do not reflect anticipated future changes in flood risk (sea level rise and storm changes).[72] The law requires FEMA to update and reassess flood risks every 5 years. This is not the issue. However, the FIRM panels currently do not model out how flood risk in a neighborhood might change in the medium to long term. The determination of flooding probability is inherently backwards looking since the calculation of flood risk relies on past storm and flooding events. Thus, for an urban planner whose job is to anticipate which areas of the city should be approved for future residential development or how much suburban sprawl to allow, the FEMA flood maps do not currently communicate the full risk of future flooding. Amending this backward looking feature of flood maps would encounter significant unpopularity with changing risk boundaries. A failure to do so, however, would hide the signal of future flood risk change for making housing investments.

[70] Schwartz, John, et al. "Builders Said Their Homes Were Out of a Flood Zone. Then Harvey Came." The New York Times, The New York Times, 2 Dec. 2017, www.nytimes.com/2017/12/02/us/houston-flood-zone-hurricane-harvey.html.

[71] FEMA Community Status Book and through the Friendswood City Government's GIS department.

[72] Scata, Joel. "FEMA's Outdated and Backward-Looking Flood Maps." NRDC, 12 Oct. 2017, www.nrdc.org/experts/joel-scata/femas-outdated-and-backward-looking-flood-maps.
Beider, Perry. National Flood Insurance Program: Factors Affecting Actuarial Soundness. DIANE Publishing, 2010.

# 6 Appendices

## 6.1 BW12 & HFIAA14 Timeline of Premium Changes

**BW-12 QUICK REFERENCE GUIDE**

FEMA

NATIONAL FLOOD INSURANCE PROGRAM

Subsidized Pre-FIRM Buildings in Special Flood Hazard Areas (SFHAs)

| | Pre-FIRM Primary or Non-primary Residence or Business | Pre-FIRM Residence or Business With a Lapsed Policy | Pre-FIRM Primary Residence | Pre-FIRM Non-primary Residence | Pre-FIRM Severe Repetitive Loss or Cumulative Payments Exceeding Fair Market Value | Pre-FIRM Business** |
|---|---|---|---|---|---|---|
| **Policy Effective Date** | Policy first in effect *on or after* July 6, 2012* | Policy reinstated *on or after* October 4, 2012 | Policy in effect *before* July 6, 2012 | Policy in effect *before* July 6, 2012 | Policy in effect *before* July 6, 2012 | Policy in effect *before* July 6, 2012 |
| **Premium Change (when and how)** | **October 1, 2013:**<br>• Immediate shift to full-risk rates<br>• Tentative rates available for 1 year<br>• Elevation Certificate required | **October 1, 2013:**<br>• Immediate shift to full-risk rate<br>• Tentative rates available for 1 year<br>• Elevation Certificate required | **October 1, 2013:**<br>Average increases of 16-17 percent increases within the 20 percent cap authorized by law | **January 1, 2013:**<br>• 25 percent premium increase at renewal<br>• Elevation Certificate needed to determine full-risk rate | **October 1, 2013:**<br>• 25 percent premium increase at renewal<br>• Elevation Certificate needed to determine full-risk rate | **October 1, 2013:**<br>• 25 percent premium increase at renewal<br>• Elevation Certificate needed to determine full-risk rate |
| | **Future:**<br>Increases based on actuarial analysis and the Reserve Fund | **Future**:<br>Increases based on actuarial analysis and the Reserve Fund | **Future**:<br>Increases based on actuarial analysis and the Reserve Fund | **Future**:<br>25 percent annual increases until full-risk rates are reached | **Future**:<br>25 percent annual increases until full-risk rates are reached | **Future**:<br>25 percent annual increase until full-risk rates are reached |
| **All Pre-FIRM Buildings** | | | | | | |
| **Map Changes** | FEMA is still analyzing the impacts section 100207 of BW-12 will have on rates other than pre-FIRM subsidized premiums upon the effective date of a new, revised,or updated FIRM.<br><br>For now, grandfathering and the Preferred Risk Policy Eligibility Extension remain cost-saving options for policyholders when maps are updated. | | | | | |

* Assignment of an NFIP policy is allowed. However, the assignment of an NFIP policy from a seller to a buyer occurring on or after July 6, 2012, could require re-rating and an Elevation Certificate for the buyer if it is currently rated with a subsidized rate (e.g., not a standard Zone X or PRP rate).

** BW-12 calls for increases to business properties. Businesses are included in a larger group of non-residential properties. Consequently, all subsidized pre-FIRM policies for non-residential properties will see the same increase upon purchase or renewal on or after October 1, 2013.

Figure 13: BW12 Implementation Schedule

FEMA Fact Sheet

Federal Insurance and Mitigation Administration

# How April 2015 Program Changes Will Affect Flood Insurance Premiums

The National Flood Insurance Program (NFIP) is in the process of implementing Congressionally mandated reforms required by the Homeowner Flood Insurance Affordability Act of 2014 (HFIAA) that repeal and modify the Biggert-Waters Flood Insurance Reform Act of 2012 (Biggert-Waters). The new law slows some flood insurance rate increases and offers relief to some policyholders who experienced steep flood insurance premium increases in 2013 and early 2014. Flood insurance rates and other charges will be revised for new or existing policies beginning on April 1, 2015. In addition to insurance rates, other changes resulting from Biggert-Waters and HFIAA will be implemented that will affect the total amount a policyholder pays for a flood insurance policy. Highlights of some of those changes follow. For full explanations and guidance, see WYO Bulletin (W-14053) and the Flood Insurance Manual.

The changes taking place in April include an increase in the Reserve Fund Assessment, the implementation of an annual surcharge on all new and renewed policies, an additional deductible option, an increase in the Federal Policy Fee, and rate increases for most policies. Key changes include:

- Implementing annual rate changes that set rates using rate-increase limitations set by HFIAA for individual premiums and rate classes:
  - Limiting increases for individual premiums to 18 percent of premium.
  - Limiting increases for average rate classes to 15 percent.
  - Mandatory increases for certain subsidized policyholders under Biggert-Waters and HFIAA.
- Increasing the Reserve Fund assessments required by Biggert-Waters.
- Implementing annual surcharges required by HFIAA.
- Guidance on substantially damaged and substantially improved structures, and additional rating guidance on buildings constructed before their communities' first Flood Insurance Rate Maps (FIRMs) became effective (known as pre-FIRM structures).
- Implementing a new procedure for properties newly mapped into the Special Flood Hazard Area (SFHA) and existing **Preferred Risk Policy Eligibility Extension** (PRP EE), a cost-saving flood insurance coverage option for property owners whose buildings were newly mapped into an SFHA. The premiums will be the same as the PRP, which offers low-cost flood insurance to owners and tenants of eligible residential and non-residential buildings located in moderate- to low-risk areas for the first year (calculated before fees and assessments) to comply with provisions of HFIAA.
- Reformulating expense loading on premiums, reducing the expense load on the highest-risk policies as an interim step while investigating expenses on policies as required by Biggert-Waters.

The changes will take effect on April 1, 2015.

OCTOBER 2014 1

Figure 14: HFIAA14 Fact Sheet

## 6.2 Insurance Agent Manual Rates

**I. AMOUNT OF INSURANCE AVAILABLE[1, 2]**

| BUILDING COVERAGE | EMERGENCY PROGRAM | REGULAR PROGRAM Basic Insurance Limits | REGULAR PROGRAM Additional Insurance Limits | REGULAR PROGRAM Total Insurance Limits |
|---|---|---|---|---|
| Single-Family Dwelling | $ 35,000[3] | $ 60,000 | $190,000 | $250,000 |
| 2–4 Family Building | $ 35,000[3] | $ 60,000 | $190,000 | $250,000 |
| Other Residential Building | $100,000[5] | $175,000 | $325,000 | $500,000 |
| Non-Residential Building (including Business Buildings and Other Non-Residential Buildings)[4] | $100,000 | $175,000 | $325,000 | $500,000 |
| **CONTENTS COVERAGE** | | | | |
| Residential Property[6] | $ 10,000 | $ 25,000 | $ 75,000 | $100,000 |
| Non-Residential Business, Other Non-Residential Property[4] | $100,000 | $150,000 | $350,000 | $500,000 |

1. This Table provides the maximum coverage amounts available under the Emergency Program coverage and the Regular Program, and the columns cannot be aggregated to exceed the limits in the Regular Program, which are established by statute. The aggregate limits for building coverage are the maximum coverage amounts allowed by statute for each building included in the relevant Occupancy Category.
2. These limits apply to all single condominium units and all other buildings not in a condominium form of ownership, including cooperatives and timeshares. Refer to the Condominiums section of this manual for basic insurance limits and maximum amount of insurance available under the RCBAP.
3. In Alaska, Guam, Hawaii, and U.S. Virgin Islands, the amount available is $50,000.
4. For further guidance on Non-Residential Business and Other Non-Residential occupancies, refer to the General Rules section of this manual.
5. In Alaska, Guam, Hawaii, and U.S. Virgin Islands, the amount available is $150,000.
6. The Residential Occupancy Category includes the Single Family, 2–4 Family, Other Residential, and Residential Condominium Occupancies.

Figure 15: Basic and additional coverage, broken down by property and program type

$$RATE = \left[\sum_{i=Min}^{Max} (PELV_i \times DELV_i)\right] \times \frac{LADJ \times DED \times UINS}{EXLOSS}$$

Where: *Min* = minimum elevation relative to lowest floor at which flood damage occurs.

*Max* = elevation relative to lowest floor at which flood damage approaches a maximum.

Figure 16: Actuary formula for determining NFIP rates

Exhibit A
Page 1

NATIONAL FLOOD INSURANCE PROGRAM

Effects of Rate Revision on Average Annual Written Premium (plus FPF) per Policyholder*
Based on Projected Distribution of Business and Projected Amounts of Insurance

| | Distribution of Business | Average Annual Premium with October 2011 Rates | Increase over Annual Premium with Current Rates |
|---|---|---|---|
| REGULAR PROGRAM - ACTUARIAL RATES | | | |
| AE | 29.2% | 527.93 | 4.7% |
| A | 1.7% | 864.66 | 5.5% |
| AO, AH, AOB & AHB | 8.2% | 389.34 | 0.5% |
| ZONES AE,A,AO,AH,AOB,AHB | 39.0% | 513.18 | 4.1% |
| POST-81 V,VE | 0.8% | 3,088.06 | 3.5% |
| B,C,X (Standard) | 7.8% | 637.87 | 4.5% |
| PRP | 30.9% | 362.08 | 0.0% |
| TOTAL ZONES B,C,X | 38.7% | 417.48 | 1.3% |
| SUBTOTAL ACTUARIAL | 78.5% | 491.74 | 2.9% |
| REGULAR PROGRAM - SUBSIDIZED RATES | | | |
| Pre-FIRM AE | 16.3% | 1,219.87 | 5.1% |
| Pre-FIRM V,VE | 0.7% | 1,897.37 | 7.4% |
| Pre-FIRM Other | 3.8% | 1,115.27 | 4.8% |
| PRE-FIRM SUBSIDIZED | 20.8% | 1,229.18 | 5.2% |
| 75-81 POST V,VE | 0.1% | 1,571.23 | 9.7% |
| A99 & AR | 0.5% | 960.71 | 4.9% |
| EMERGENCY | 0.0% | 433.62 | 0.0% |
| SUBTOTAL SUBSIDIZED | 21.5% | 1,224.04 | 5.2% |
| TOTAL | 100.0% | 649.11 | 3.8% |

*Computations are based on counting and pricing units insured under Condo Master Policies separately.

** Includes all other Pre FIRM zones, including AO, AH, AOB, AHB, D, AR, and A99.

Figure 17: Rates from the 2011 Rate Review Report

## 6.3 Treatment Period Definition

The combined model uses T1, T2, T3 as the period markers. This diagram shows the buy, sell decisions that would correspond to these three dummy classifications.

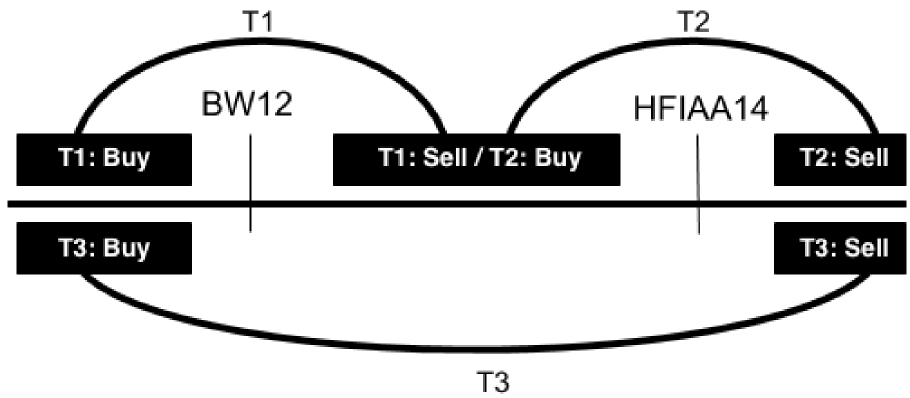


Figure 18: Treatment periods with both policies

## 6.4 Data Attributes

All observations in ZTRAX comes from public records, sourced from a major large third-party provider and through an internal initiative at Zillow called County Direct. County Direct supplements the third-party coverage by collecting data directly from county Assessor and Recorder's offices.

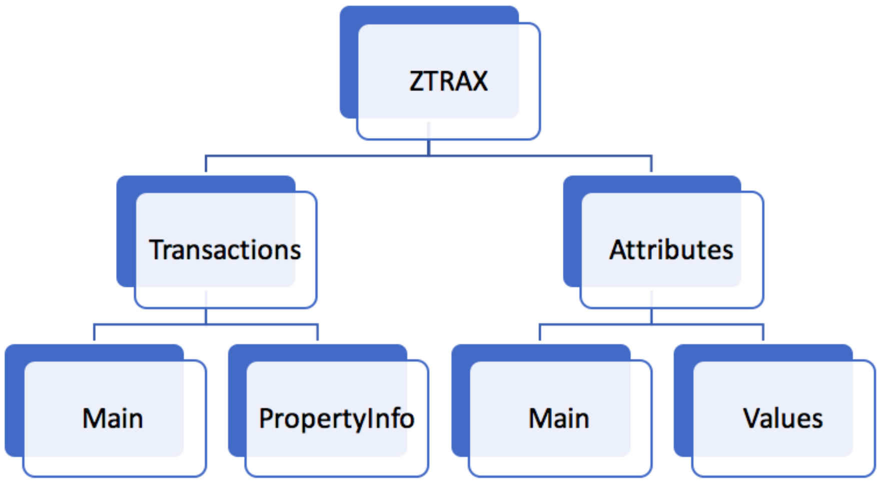


Figure 19: Structure of ZTRAX

This is the summary statistics of all the data in the paired transactions database rather than just the sample of interest.

Table 7: Summary statistics of paired transactions dataset

| **Variable** | **Mean** | **Std. Dev.** | **Min.** | **Max.** | **N** |
|---|---|---|---|---|---|
| P0 | 77542.053 | 189148.737 | 100 | 19443940 | 18528 |
| P1 | 97393.839 | 1806337.226 | 100 | 245000000 | 18528 |
| ln_rsales | 0.162 | 1.042 | -7.273 | 8.002 | 18528 |
| SFHA | 0.113 | 0.317 | 0 | 1 | 18449 |
| Bracket BW12 | 0.064 | 0.245 | 0 | 1 | 18528 |
| Bracket HF14 | 0.086 | 0.281 | 0 | 1 | 18528 |
| Bracket Both | 0.012 | 0.109 | 0 | 1 | 18528 |
| Date1 | 1999.517 | 120.594 | 0 | 2017 | 18528 |
| yrsbtw | 3.931 | 4.096 | 0 | 89 | 18528 |

Lastly, county level aggregates of NFIP policy statistics are available.[73] Figure 20 shows the county level average premiums for Harris and Fort Bend counties from 2012 to 2018. This is a figure of average premiums per house not the change in premiums for a specific set of houses. The premiums are derived from total number of policies in-force and the total premiums collected.

This figure provides at best a reference for a macro view of the NFIP market in the greater Houston area. The average would change as a result of a number of factors, from the value of the

[73] via FEMA's website and the archived pages of the Wayback Machine

houses insured, number of policies in force, to the risk of the houses who hold NFIP policies. The drop in premiums at end of dataset may be from a change in the insured sample.

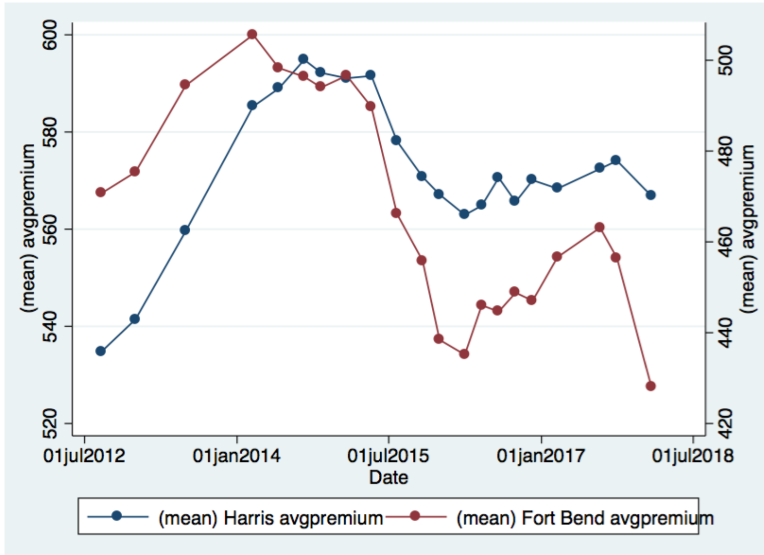


Figure 20: Average Premium Changes

## 6.5 Supplemental regression results

### Robustness check

The following figures are continuation of the robustness tests on timing. Figure /refmnth shows regressions with markers along a monthly interval from 2012 to 2017. Sample consists of houses from $30,000 and upwards. The red dots are the results that are significant at the 95% level.

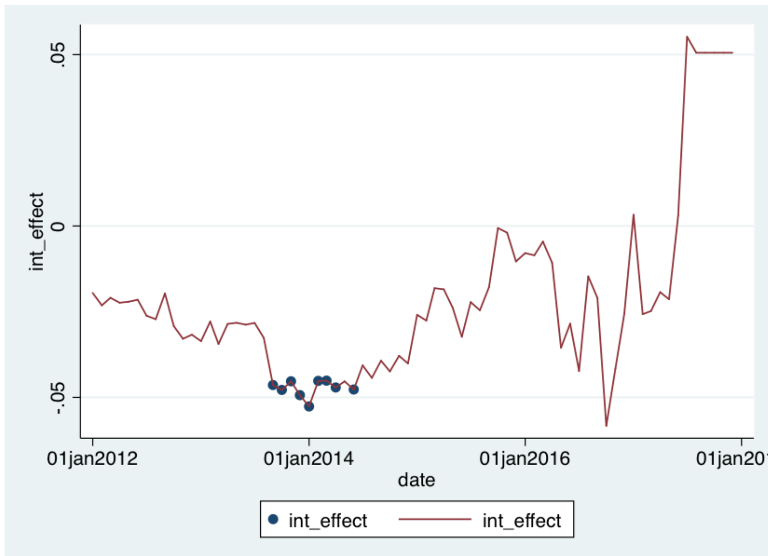


Figure 21: Date marker robustness checks on a monthly level

Figure 22 shows regressions with markers along a yearly interval from 2010 to 2017. When we look at the yearly effects, 2014 is the only year that shows the significant effects.

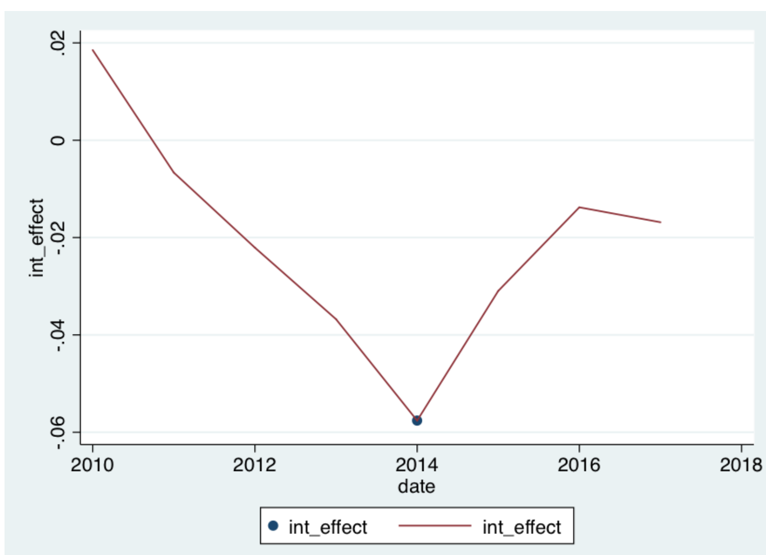


Figure 22: Date marker robustness checks on a yearly aggregated level

Figure 23 shows the p-values corresponding to the coefficients generated by the every-5-day robustness check.

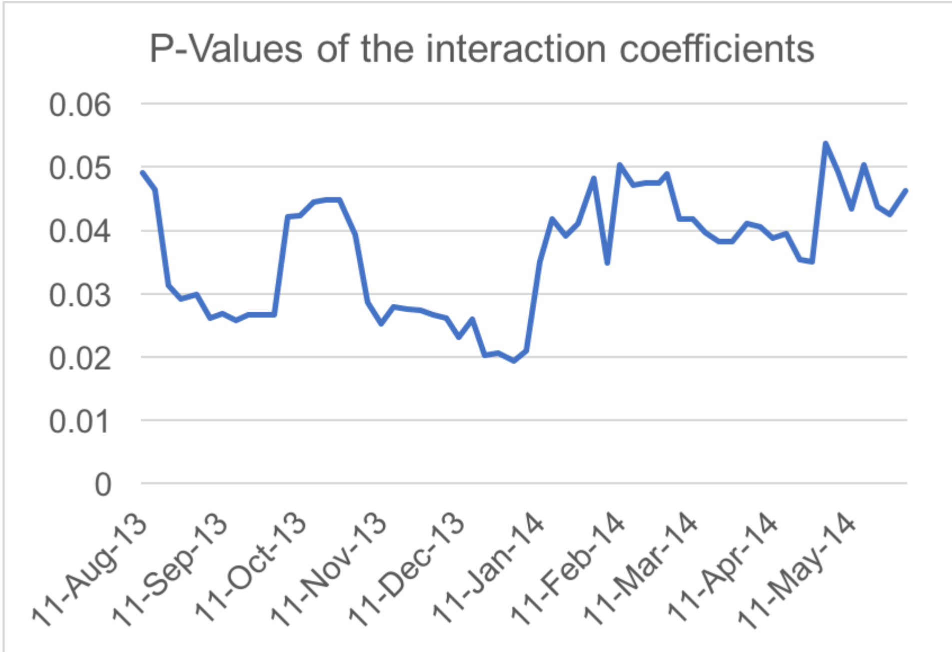


Figure 23: P-values corresponding to the coefficient

**Combined model**

Table 8 shows the regression outputs for BW12 and HFIAA14 implementation dates. The policy implementation dates are October 1, 2013 for BW12 and April 1, 2015 for HFIAA14. I focus on the combined model (Equation 11) rather than the individual experiments because the combined model allows for a more nuanced understanding of cross-policy effects. Once again, model 1 shows only T1 and T3, corresponding to BW12 or both BW12 and HFIAA14. Model 2 shows the repeat sales, diff-in-diff model as stated with all three treatment periods. Model 3 adds on time and neighborhood controls. Model 4 regresses only on houses with full NFIP coverage.

Table 8: Combined model, policy implementation dates

| | (1)<br>ln_rsales (no T2) | (2)<br>ln_rsales | (3)<br>ln_rsales, FE | (4)<br>ln_rsales, FC |
|---|---|---|---|---|
| SFHA | 0.0213*** | 0.0215*** | 0.0220*** | 0.0218*** |
| | (3.45) | (3.47) | (3.39) | (3.51) |
| t1 | 0.00635 | 0.00656 | 0.0210* | 0.00666 |
| | (0.68) | (0.71) | (2.21) | (0.71) |
| t3 | 0.0373*** | 0.0375*** | 0.0541*** | 0.0386*** |
| | (3.65) | (3.67) | (5.22) | (3.73) |
| sfha_t1 | -0.0641* | -0.0643* | -0.0628* | -0.0648* |
| | (-2.21) | (-2.21) | (-2.18) | (-2.23) |
| sfha_t3 | -0.0206 | -0.0208 | -0.0261 | -0.0223 |
| | (-0.65) | (-0.65) | (-0.83) | (-0.70) |

| | | | | |
|---|---|---|---|---|
| t2 | | 0.0381 | 0.0448 | 0.0409 |
| | | (1.40) | (1.36) | (1.48) |
| sfha_t2 | | -0.0314 | -0.0294 | -0.0347 |
| | | (-0.39) | (-0.36) | (-0.43) |
| Constant | 0.00978*** | 0.00958*** | 0.138 | 0.00969*** |
| | (4.87) | (4.75) | (0.75) | (4.78) |
| Observations | 10485 | 10485 | 10485 | 10391 |
| $R^2$ | 0.003 | 0.003 | 0.046 | 0.003 |

$t$ statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Compared to the complex model under policy passage dates, the coefficients of interest, *sfha_t1, sfha_t2,* and *sfha_t3*, are all negative, which may indicate that there is indeed a lag. The negative effect on home values now show up in the T1 coefficient, *sfha_t1*, representing properties that straddle BW12 only. The size of the coefficient is similar to what was observed in the policy passage outputs. On average, the ratio of home prices in flood-prone areas in Greater Houston are 6.4% lower after BW12. *sfha_t2* and *sfha_t3* both experienced negative but not significant results; these are hard to interpret. Similar to the policy passage results, the quality of the data may not be sufficient nor the model well defined enough to tease out the transition between BW12 and HFIAA14.

# 7 References


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