The Effects of Flood Insurance on Housing Markets

Agustín Indaco* Francesc Ortega† Süleyman Taşpınar‡

January 30, 2018

Abstract

We analyze the role of flood insurance on the housing markets of coastal cities. To do so we have assembled a parcel-level dataset including the universe of residential sales for three coastal urban areas in the United States – Miami-Dade county (2008-2015), New York city (2003-2016), and Virginia Beach – matched with their FEMA flood maps, which characterize the flood risk level for each property. First, we compare trends in housing values and sales activity among properties on the floodplain, as defined by the National Flood Insurance Program (NFIP), relative to properties located elsewhere within the same city. Despite the heightened flood risk in the last two decades, we did not find evidence of divergent trends, suggesting that flood insurance may have cushioned the effects of the increase in flood risk. Secondly, we analyze the effects of the recent reforms to the NFIP. In 2012 and 2014, Congress passed legislation that led to important increases in flood insurance premia, and updates of flood maps. We fail to find an effect of increases in premia on the values of floodplain properties in Virginia Beach and Miami-Dade, but we do find evidence of an effect in New York. We also find some evidence of price changes for properties that experienced a change in risk classification in the new FEMA flood maps. We conclude that the full effects of flood insurance reform are yet to materialize.

JEL Classifications: JEL codes H56, K42, R33

Keywords: Climate change, Real estate, Cities, Flood Insurance

*The Graduate Center CUNY, New York, U.S.A., email: aindaco@gmail.com
†Department of Economics, Queens College CUNY, New York, U.S.A., email: fortega@qc.cuny.edu
‡Department of Economics, Queens College CUNY, New York, U.S.A., email: staspinar@qc.cuny.edu

1 Introduction

Rising sea levels have increased the risk of coastal flooding over the last few decades, becoming the most economically damaging impact of climate change for many coastal locations (Buchanan et al., 2017). The increasing flood risk has been shown to arise from increased likelihood of tidal flooding in low-lying areas (Sweet et al., 2014; Sweet and Park, 2014; Cooper et al., 2013), increased frequency and severity of coastal flooding (Vitousek et al., 2017), and intensification of extreme flooding events (Hunter, 2010; Park et al., 2011; Tebaldi et al., 2012).

At the same time there has been a large increase in population in shoreline counties in the United States (Hauer et al., 2016). One factor that may have contributed to this trend is the availability of subsidized flood insurance through the National Flood Insurance Program, or NFIP, (Conte and Kelly, 2017). The program, managed by the Federal Emergency Management Agency (FEMA), was created through the 1968 National Flood Insurance Act and has risen to over 5 million policy holders in 2016. Over the last two decades, the NFIP has become burdened with enormous amounts of debt following hurricanes Katrina (2005) and Sandy (2012), which prompted a profound reform in years 2012 and 2014, and more recently hurricane Harvey (2017). A major goal of the reform was to increase insurance rates in order to reflect the increase in flood risk between now and the inception of the program. As a result, flood insurance premia increased substantially for many floodplain properties.[1].

The main goal of this paper is to examine whether flood insurance affects the housing markets of coastal cities. To do so we have assembled a parcel-level dataset including the universe of residential sales for three coastal urban areas in the United States – Miami-Dade county (2008-2015), New York city (2003-2016), and Virginia Beach (2000-2016) – matched with their FEMA flood maps, which characterize the flood risk level for each

[1]Flood insurance premia vary as a function of flood risk and elevation. To understand the consequences of flood insurance reform on housing values in a simple manner it is helpful to consider an example based on (Kousky, 2017). On the basis of the 2012 reform, the new rates corresponding to a single-family home within the 100-year flood plain and 4 feet below the base flood elevation increase from $\$2,644$ to $\$10,263$. However, given that the pre-reform rates did not vary by elevation, some properties sitting above the base flood elevation may experience a decrease in premia. Properties outside the 100-year floodplain pay much lower rates. As a result the median premium across all single-family policies is $512

property. Parts of these cities are prone to flooding events, and flood insurance is a first-order policy issue in all of them.[2]

The first question we ask is whether there has been any divergence in trends regarding housing values and sales activity among properties under high risk of flooding, as defined by the NFIP, relative to properties located elsewhere within the same city. Evidence of divergence in trends would suggest that housing markets are already incorporating the increases in coastal flooding risk. We find that these variables behaved very similarly in the floodplain of these coastal areas, relative to the rest of the respective cities, mostly tracing the economic cycle. The only exception is the emergence of a persistent drop in housing values in New York's floodplain from year 2013 onward, coinciding with the aftermath of hurricane Sandy. The lack of evidence of a generalized differential trajectory for housing values on the floodplain of the coastal areas we analyze may be explained by the role of flood insurance. After all, we would not expect an increase in flood risk to affect housing values in a setting where properties are fully insured and insurance premia remain constant over time.

Secondly, we focus on the recent reforms to the NFIP in order to identify the effects of flood insurance on the housing market. In 2012 and 2014, Congress passed legislation in order to take into account the updated (higher) estimated flood risk, and to ensure the financial viability of the flood insurance program. We focus on two important features of the reform: the increase in flood insurance premiums scheduled to take place from July 2012 onward, and the release of updated flood maps and the resulting changes in the set of properties subject to mandatory flood insurance requirements. We hypothesize that the increases in premia mandated by the reforms should have negatively affected the values of properties located in the floodplain, many of which are subject to mandatory flood insurance requirements. Specifically, we ask whether the increase in premiums affecting properties sold after July 2012 had an effect on sale prices. We conduct a difference-in-difference analysis on the change in sale prices around the date of the reform affecting properties located on the floodplain, net of the changes experienced by properties located elsewhere in the city. Our estimates do not reveal a differential effect on the values of

[2] Lacking a national sales registry, obtaining from local sources and homogenizing individual sales data is a time-consuming endeavor.

floodplain properties for the cities of Virginia Beach and Miami-Dade. However, we do find evidence of a negative effect (of approximately 10%) on the sale prices of floodplain houses in New York city, confirming the earlier finding. To o discern whether the latter finding is truly due to flood insurance reform or to the aftermath of hurricane Sandy (October 2012), we exploit the changes in the flood map of New York. Specifically, we focus on the changes in the values of properties whose idiosyncratic flood risk has been updated in the new flood map. We do not find evidence of a negative effect on the prices of properties that have suffered an upward revision in flood risk, but we do find a large *positive* effect on the prices of properties whose risk was assessed *downward*. We estimate the price appreciation for these properties to be approximately 10% in New York and roughly 30% for Virginia Beach.

The rest of this paper is organized as follows. Section 2 presents a brief review of the related literature. Section 3 provides background information on the history of flood insurance and recent policy changes. Section 4 describes the main data sources and the merging process. Section 5 presents descriptive statistics on the main variables. Section 6 studies overall trends of housing prices in flood risk areas relative to the overall city. Sections 7 and 8 present the main results. Section 9 ends the paper with concluding remarks. All Tables and Figures related to our main results are gathered at the end of the paper. Some details are relegated an appendix.

2 Literature

There is a large literature estimating the price discount on sales of houses located within the 100-year floodplain (Harrison et al., 2001; Bin and Polasky, 2004; Bin et al., 2008; Atreya et al., 2013; Bin and Landry, 2013). Most studies use highly localized data and find evidence of a discount, but the magnitude ranges widely (from about 4% to 12%). In a recent study, Zhang (2016) estimates a spatial quantile regression model using data for the Fargo-Moorhead MSA. She finds evidence of a $3-6\%$ floodplain penalty, larger among lower-priced homes. She argues that this heterogeneous effect may reflect the existence of upper bounds on coverage limits. Her study also shows that the penalty rose sharply following a large flooding event in 2009, but went back to its normal value two years later.

Compared to these studies, our dataset is much larger and we focus on the role of flood insurance, rather than the evolution of housing markets in the aftermath of large storms or flooding episodes.

Our study is also related to Ortega and Taşpınar (2016). These authors analyze the effects of hurricane Sandy on the New York housing market, using a parcel-level dataset with data on housing sales combined with FEMA point-damage data. They can identify which building structures were damaged by the hurricane, and to what degree. Their estimates provide robust evidence of a negative impact on the price trajectories of houses that were affected by Sandy, ranging from 6% to 20%, with larger price reductions for properties that were more severely damaged. The authors argue that these effects appear to be much more persistent than typically found in previous studies of the effects of hurricanes on housing markets, which can be rationalized through a model of belief updating responding to a rare, extreme event.

Several recent papers have focused explicitly on measures of flood risk. Gallagher (2014) studies how economic agents update flood risk beliefs after floods occur, as measured by insurance take-up rates. Using a national dataset with information on all flood insurance policies and whether a community is hit by a flood, he finds strong evidence of an immediate increase in the fraction of homeowners covered by flood insurance in the affected communities, though the effect vanishes after a few years. Conte and Kelly (2017) document that the distribution of aggregate hurricane damage in the U.S. is fat tailed. They argue that this may be due to the fact that the distribution of coastal property itself is also fat tailed. Namely, storms tend to intersect geographic areas with little or no property, but also areas with large amounts of property more often than expected given a normal distribution. The authors then go on to present a model of homeowner behavior for buying insurance, which includes a disaster relief agency which reimburses a fraction of household losses, and show that moral hazard leads to an increase in the number of households living on the coast, and on the size (value) of these properties, resulting in more damage during catastrophic storms. Bakkensen and Barrage (2017) survey perceptions of flooding risk in Rhode Island and find evidence of sorting according to these beliefs. Specifically, they find that waterfront homeowners perceive a lower risk of flooding. Heterogeneity in flood risk perceptions among households may also help explain the sluggishness in the response of home prices in flood-prone areas to the arrival of new information suggesting high flood risk.

Our analysis is particularly related to two recent studies. We share the goals of the study by Bernstein et al. (2017), but differ in how we measure flooding risk. While we rely on the FEMA flood maps, these authors use the National Oceanic and Atmospheric Administration's sea level rise calculator. These authors combine these measures of risk with housing prices data from the Zillow Transaction and Assessment Dataset, and compare exposed and unexposed homes with similar characteristics sold in the same month, within the same zip code, in the same 200 foot band of distance to coast, and in the same 2 meter elevation bucket. They find that exposed properties trade at a 7% to 8% discount relative to comparable unexposed properties. Additionally, they find that the size of the discounts increases with risk exposure, and that exposed properties are more likely to be sold.

Our use of changes to the flood maps as a source of identification is reminiscent of Votsis and Perrels (2016). These authors study the effects of flood risk on housing values in Finland, exploiting the introduction of flood maps following the European Union Water Directive. These flood risk maps were made publicly available in 2006-07 for a number of flood prone areas in Finland. The authors employ a difference-in-difference approach to capture the price differential of flood risk disclosure. They define the treatment group as those dwellings that are located in the flood prone area, and the control group as nearby dwellings outside of the flood-prone area. They find a significant price drop after the flood risk maps were released, with values ranging between 6% to 30%.

3 Flood insurance

3.1 Background: a brief history of flood insurance

Congress created the NFIP in 1968, which is administered by FEMA, with the goal of providing affordable flood insurance to homeowners. An integral part of the program is the Flood Insurance Rate Map (FIRM), which establishes risk zones. These zones determine flood risk for each property, building code requirements, and flood insurance requirements. Importantly, properties located on the high-risk zone, also known as the 100-year floodplain, are required by law to purchase flood insurance if they have federally backed mortgages (or if they have received FEMA assistance in the past).[3]

Largely because of hurricane Katrina, the NFIP accumulated a large amount of debt – over 25 billion dollars. In order to make the program financially stable Congress passed the *Biggert-Waters Flood Insurance Reform Act* in 2012, which planned to eliminate subsidies to flood insurance rates and phase out a number of exemptions. However, as a result of vigorous public opposition in affected areas, Congress passed the 2014 *Homeowner Flood Insurance Affordability Act*. This act repealed some mandates of the 2012 Act and slowed down some rate increases (as of April 1, 2015). Next, we summarize the most relevant implications of these reforms for the purposes of our analysis.[4]

3.2 Premium increases

The 2012 Biggert-Waters Act stated that policies for properties purchased, or newly insured, after July 2012 would have to pay full-risk rates. The Act also mandated annual premium increases of 25 percent until rates reflect full risk for structures with severe repeated flood losses (as well as for non-primary residences and businesses). The 2014 Act slowed down the premium increases to 18 percent per year, but did not repeal them. The Act instantly eliminated subsidies on approximately 36% of the 1.2 million policies in effect (Government Accountability Office, 2013), and initiated steps toward the gradual elimination of the subsidies for the remaining policies.

3.3 Grandfathering

The 2012 Biggert-Waters Act allowed primary residences on the floodplain to keep their subsidized rates until (i) the property was sold, (ii) the policy lapsed, or (iii) the property suffered severe flood losses (where the owner refuses an offer to mitigate). The Act also required a phasing out of grandfathered rates over 5 years.

However, the 2014 Act restored the grandfathering rule. Grandfathering remains an option for policyholders when new maps show their buildings in a higher risk area (or an

[3] According to a study by RAND (Dixon et al., 2013), when New York City was hit by hurricane Sandy, 3 out of 4 properties in the high-risk zone in New York City were required to have flood insurance, but only slightly more than half of all properties had it. Among homeowners not required to have flood insurance, take up rates are low.

[4] The Appendix contains further details.

increase in base flood elevation), both of which may imply higher premia. These policy-holders have the option of using the flood zone of the flood map that was in effect when the building was originally constructed (for those built in compliance) or when coverage was first obtained (for those with continuous coverage). It is estimated that as a result of grandfathering, rates will not change immediately for about 70% of the properties. Importantly, the subsidized rates will end when the house is sold. Thus the effect of the flood reform on prices is likely to be staggered over time.

3.4 New flood zone maps

In addition to the above-mentioned changes in flood insurance rates, revised FEMA flood maps were commissioned by the 2012 Act. The release of these maps differs across areas of the United States. For instance, the new flood zones map for New York City were released in June of 2013, although due to city appeals, those maps have not become effective (as of early 2018). The new flood zones map for Virginia Beach went into effect on January 2015, whereas the flood map for Miami-Dade has not yet been revised.

4 Data

Our dataset merges two different types of data for each of the three cities that we include in our analysis. The first type of data is the universe of sales in the cities of New York, Virginia Beach and Miami-Dade. These datasets have a similar structure across cities, but the coverage in terms of years and the actual property characteristics vary somewhat. The second type of data that we use are the flood insurance rate maps produced by FEMA for each of these three cities. These data contain shape files that allow us to overlay the tax parcel from the sales dataset onto the flood risk zones.

The resulting dataset contains all sales that took place for these three cities, along with the flood risk class for each of the properties involved. We next provide further details on the sources and structure of each of the datasets.

4.1 Housing sales data

The New York sales data are provided by the New York City Department of Finance, and contain the universe of transactions between years 2003 and 2016. We are able to identify properties uniquely on the basis of the borough, block, lot and apartment number associated to each sale.[5] Besides the sale price, the dataset also contains some additional information: building class, tax class, and the exact date the sale took place. The data contain residential properties, as well as other building types, such as commercial or office properties. The sales dataset for New York does not contain geo-coordinates.[6] However, we are able to merge the sales data with the PLUTO dataset (New York City Department of Planning), which contains tax lot numbers along with geo-coordinates and shape files for the footprints of each property. The merged dataset contains approximately 623,000 observations.[7]

We obtained the sales data for Virginia Beach from the Virginia Beach Government, Real Estate Assessor's Office. The dataset contains the sale price and date for the last three transactions for every property in Virginia Beach. There are a approximately 160,000 properties included in this dataset that have been sold at least once. The data contain all transactions between January 2000 and September 2016.[8] This dataset does not provide information on the FEMA flood risk class of each property. However, we are able to merge the sales data with another dataset provided by the Virginia Beach Government that contains the precise FEMA code for each property both for the previous map of 2009, as well as the most recent map that came into effect in 2015. The merged dataset contains data on 72,289 properties and 120,551 transactions realized after January 2000.

Our data for Miami-Dade county is based on the Florida Department of Revenue tax data files. Specifically, we obtained and merged the Sales-Data-Files (SDF), the Name-Address-Legal (NAL) and the Name-Address-Personal (NAP) files. The merged dataset

[5] For the majority of one-family houses, the so-called BBL (for borough, block and lot) identifies each house (and we set the apartment number to one).

[6] The data does contain the exact address. However, this field is not coded in a systematic manner.

[7] About 194,000 observations cannot be matched. The vast majority of these (87%) correspond to condominium apartments. For this type of properties, PLUTO uses tax lot numbers that do not correspond to the tax lots numbers of the sales dataset. Correspondingly, we drop all these observations.

[8] The first recorded sales are from 1776, although no other transaction appears to have taken place between 1776 until 1925. At any rate, our interest is on sales from year 2000 onward.

contains detailed information on parcels including land use code, sales price, sales year, sales month and assessment value, as well as on the geographic characteristics of the parcels. Our sample corresponds to sales recorded from 2008 to 2015, with a total of 356,672 observations. The flood zone information for the parcels is based on the FEMA flood insurance risk maps (effective since 2009).

4.2 Flood Insurance Rate Maps

We obtain the shape files for the FEMA flood insurance maps for our three cities of interest. These maps partition the cities into three areas: the 100-year floodplain (also known as Special Flood Hazard Areas), the 500-year floodplain, and the rest of the city. Among these, the highest risk of flooding pertains to the 100-year floodplain.[9] In the last few years, FEMA has been producing revised flood maps. The release of the revised maps has been staggered, and for some cities the new maps are still under construction. As of early 2018, there exist revised maps for New York (though not yet effective) and for Virginia Beach. We provide more details on these maps in a later section.

5 Descriptive Statistics

In order to get rid of entries affected by typos in the sale price, and to eliminate sales of tiny parcels or other transactions that do not refer to proper housing units, we restrict to sales with sale price above \$10,000, and lso trim observations at the 99th percentile of the sale price. Table 1 provides information on the distribution of sales by housing type in each of our three cities. Our dataset for New York contains over 665,351 sales for the period 2003-2016. Almost half (48%) correspond to 1-family or 2-family homes, with most others corresponding to apartments. Only 2.4% of these sales (16,362) correspond to properties on the floodplain. Importantly, the distribution of housing types on the floodplain is characterized by a larger share of 1-family and 2-family homes (62%) than

[9] The flood maps actually include a finer partition of the set of properties, which can then be aggregated. As reported by FEMA (`https://www.fema.gov/flood-zones`), the 100-year floodplain is the union of the following categories: A, AO, AH, A1-A30, AE, A99, AR, AR/AE, AR/AO, AR/A1-A30, AR/A, V, VE, V1-V30. The 500-year floodplain (not including the 100-year floodplain) is the union of category B properties and the X-shaded category. Finally, the minimal flood risk zone is the rest of the city, defined as the union of category C properties and the X-unshaded category.

the city as a whole. For Virginia Beach, the data covers the period 2000-2016. The data contains 120,542 sales and 3.9% correspond to properties located on the flood plain. As was the case in New York, there is a higher share of 1-family and 2-family homes on the floodplain (80%) than in the rest of the city (74%). The data for Miami-Dade cover the period 2008-2015 and contains 220,303 sales. In Miami-Dade, the floodplain accounts for a much larger share of sales (51%) than for the other cities, and the share of sales corresponding to 1-family and 2-family homes is similar on the floodplain (67%) and in the rest of the city (68%).

We now turn to the timing of sales, which is summarized in Table 2. This table reports only sales pertaining to single-family homes in order to focus on a more homogeneous subsample that can be better compared within and across cities. The first three columns refer to sales in New York City. Annual sales of single-family homes on New York's floodplain averaged 468 per year. This amounts to 4 percent of city sales. As seen in column 3, the ratio of sales on the floodplain to the rest of the city fell to 3 percent in years 2010-2012 but then gradually climbed up to 5 percent in years 2014-2016. Columns 4-6 refer to Virginia Beach. On average there were 199 sales of single-family homes on the floodplain on average, or 4% of the citywide sales. Again, this ratio has fluctuated very little during the period 2000-2016. The last three columns of the table refer to Miami-Dade. On average there were 7,890 sales of single-family homes located on the floodplain annually, amounting to 42% of citywide sales.[10] In sum, these data suggest that sales activity on the floodplain has kept the same pace as in the rest of the respective cities during our period of analysis.

Let us now turn to the evolution of median sale prices. Table 3 reports median sale prices for single-family homes. The average price of such a home on New York's floodplain is around $345,000, significantly lower than the $416,500 in the rest of the city. Column 3 reports the floodplain price premium, defined as the ratio between the median price on the floodplain and the median price of a similar house elsewhere in the city. Over the period 2003-2016, this ratio has dropped substantially, from 0.85-0.89 in the earlier years to less than 0.80 in years 2013-2015. In comparison, the average sale price for a single

[10] We note that the frequency of sales for year 2015 in Miami-Dade county is roughly half the size of the number of sales in year 2014. This is because the data is missing the sales corresponding to the last two quarters of year 2015. Note, however, that the share of sales corresponding to floodplain properties is 43%, in line with the share for the previous years.

family home in Virginia Beach is substantially higher on the floodplain than elsewhere in the city (\$296,000 versus \$229,000) by about 29%. Column 6 shows that this ratio has also fluctuated substantially between years 2000 and 2016, but without a clear trend. The last three columns in the table report the data for Miami-Dade county. In this case median sale prices are very similar inside and outside the floodplain (\$186,000 versus \$182,000). The floodplain premium has remained fairly constant at around 3% in the period 2008-2015. In sum, we only observe a reduction in the price premium associated to houses located on the floodplain in the case of New York, taking place from year 2013 onward.

6 Climate change and the housing market: trends analysis

In the cities included in our analysis, the main effects of climate change are associated to rising sea levels and the associated increase in flood risk. If the latent increase in flood risk is rapidly incorporated into the beliefs of market agents, one would expect a gradual divergence in average housing values between the floodplain and elsewhere in the city, which should probably take place in all coastal areas with flooding risk. We refer to this prediction as the *climate change hypothesis*.

In order to examine this hypothesis more formally, we compare the trends in sale prices and sales activity for properties located on the floodplain of each of the three cities relative to properties located elsewhere within the same city. Importantly, in doing so we will also account for individual-property or neighborhood-level heterogeneity.

6.1 Sales activity

We begin by analyzing sales activity. One option would be to compare annual counts of sales in the floodplain to sales in the rest of the city. However, the same goal can be attained while accounting for property-level heterogeneity. Specifically, we build a balanced property-level panel where each property i is observed in each year. Then we estimate a linear probability model where the dependent variable is an indicator $Sold_{it}$ for whether property i was sold in year t:

$$Sold_{it} = \alpha_i + \lambda_t + \beta_t FP_i + \varepsilon_{it}, \tag{1}$$

where we are including property fixed effects (α_i) in addition to year fixed effects (λ_t) that capture the evolution over time of the sale probability outside the floodplain. Time-varying β_t captures the premium in the sale probability associated to being located in the 100-year floodplain (FP). The probability that a property is sold in a given year can be interpreted as a measure of selling activity based on the share of the stock of housing that is sold in any given year.

We begin with the results for New York City. Figure 1(a) plots the city-wide trend $\{\widehat{\lambda}_t\}$ in sales probability (top panel). The figure shows that this trend was clearly influenced by the economic cycle. There was a large reduction in sales activity between 2004 and 2011. From 2012 onward, sales have rekindled but are still far below the 2004 level. Figure 1(b) reports the estimated *floodplain sale premium* (bottom panel). The figure reveals a large reduction in this premium during years 2004-2012. In year 2012, the sale probability for properties on the floodplain was two percentage points lower than for similar properties located elsewhere in the city. One interpretation for this finding is that these properties are being perceived as increasingly less attractive than properties elsewhere in the city, consistent with the *climate change hypothesis*. However, the figure also shows that the penalty has vanished in the period 2013-2016, which runs counter to that interpretation.[11]

Let us turn to the results for the other cities. The results for Virginia Beach are shown in Figure 2(a) and Figure 2(b). The former figure shows a citywide large and fairly monotonic drop in sales between 2004 and 2008, which then plateaus between 2009 and 2011. From 2011 onward sales have been slowly increasing, but are still far below the 2004 level.[12] Once again, this evolution clearly reflects the economic cycle. Turning now to the floodplain sale premium depicted in Figure 2(b), we do not find evidence of a floodplain penalty. If anything, the data suggest a slight increase in the sale probability for properties on the floodplain. The picture for Miami-Dade county also confirms this pattern (Figure 3(a) and Figure 3(b)).[13]

In conclusion, our analysis shows that sales in each city have been largely driven by

[11] The corresponding estimates are reported in columns 1 and 2 in Table 4.

[12] Column 4 in Table 4 reports these estimates.

[13] The estimates are collected in column 6 of Table 4. Note also the sharp drop in Figure 3(a) corresponding to year 2015. This reflects the fact that our data for year 2015 is missing the sales for the last two quarters. However, this seems to affect similarly properties on and off the floodplain. Thus it probably does not bias the estimated floodplain premium coefficients plotted in Figure 3(b).

the housing cycle and we do not find systematic evidence of a differential evolution of sales activity in the floodplain of the cities we have analyzed.

6.2 Sale prices

Next, we turn to the analysis of sale prices. Let p_{izt} denote the sale price of property i in neighborhood z in year t. We assume the log of the sale price is given by

$$\ln p_{izt} = \alpha_z + \lambda_t + \beta_t FP_i + \varepsilon_{izt}, \tag{2}$$

where FP_i is an indicator for being located on the 100-year flood plain (as defined at the beginning of the sample period). Because most properties on our sample are sold only once or not at all, we cannot include property fixed-effects. Instead, we account for heterogeneity in property characteristics by restricting the sample to 1-family homes and including fixed-effects at the level of narrowly defined neighborhoods (α_z). Importantly, houses in the same neighborhood (defined as a city or Census block) tend to share many characteristics, such as construction year and size, because they were developed around the same time. The point estimates for $\{\lambda_t\}$ trace out the average housing prices (for 1-family homes) in the city, while $\{\beta_t\}$ captures the *floodplain price premium.*

We report the time-varying coefficients graphically, beginning with the results for New York City. Figure 4(a) plots the estimated city-wide trend $\{\widehat{\lambda}_t\}$, which clearly traces out the housing cycle, with prices peaking in 2007, falling until 2012 and recovering since then. The figure shows that the 2016 prices are back to the level of 2007. We now turn to the flood-plain price premium, captured by the path of estimates $\{\widehat{\beta}_t\}$, plotted in Figure 4(b). We find no evidence of a premium, or penalty, in the period 2004-2012. However, from 2013 onward, we observe the sudden appearance of a large price penalty. Initially this penalty amounted to roughly 25 log points, but later stabilized at about 14 log points.[14] It has been argued that this price penalty has been the result of hurricane Sandy (Ortega and Taşpınar (2016)), which hit New York on October 29, 2012, although it may also reflect the release of information regarding the revised flood map for New York city. We will return to this point later in the paper.

[14]The third column in Table 4 presents the detailed estimates for $\{\widehat{\beta}_t\}$.

We now turn to the city of Virginia Beach. As shown in Figure 5(a), the housing cycle was also clearly noticeable in this city, with prices peaking in 2006, falling until 2011 and recovering since then. More relevant for our purposes, Figure 5(b) suggests the existence of a fairly stable floodplain price *premium* of about 10%. Figure 6(a) illustrates the results for Miami-Dade. As seen in the figure, sale prices outside the floodplain remained depressed between 2009 and 2011, and then increased rapidly from 2012 onward. But, once again, we see no evidence of a differential trend in sale prices on the floodplain relative to the rest of the city in Figure 6(b).

Summing up, our analysis in this section suggests that sales activity and housing prices have been strongly influenced by the economic cycle. This has been true both for properties located on the floodplain as elsewhere in the city. But, in general, we find very little evidence of differential trends for the floodplain areas. The only exception is New York City. The data show the clear emergence of a floodplain price penalty from 2013 onward, following hurricane Sandy, which hit the city at the end of October 2012. Ortega and Taşpınar (2016) argue that the persistence of this penalty is due to belief updating on flood risk after an extreme, rare event. However, an alternative explanation is that the floodplain price penalty reflects the release of the new preliminary flood map during the second half of 2012, which substantially expanded the 100-year floodplain in New York city. The next section will delve deeper into this issue.

7 Flood insurance reform: premium increases

The results in the previous section suggest that agents in the housing market have not reacted to the increase in flooding risk over the last few decades. However, it is important to keep in mind that the connection between flood risk and housing values is mediated by flood insurance. The lack of response of housing values could easily be explained in a setting where properties are fully insured to flood risk and the premia associated to these policies remains constant over time, even if the underlying risk has gone up. Obviously, such an insurance system suffers from a growing financial imbalance if flood risk is rising over time, as seems to have been the case with the National Flood Insurance Program since the arrival of hurricane Katrina in 2005.

In 2012 legislation was passed to increase premia and update flood maps to reflect the current (higher) risk of flooding. Naturally, the resulting increases in premia and the expansion of the areas with mandatory insurance requirements should be expected to negatively affect the values of properties located on the floodplain. This section examines this hypothesis, and the following section will examine the effects of the changes in flood maps.

7.1 Difference-in-difference estimation

As argued earlier, the 2012 flood reform ushered in increases in flood insurance premia that affected sales that took place after July 2012. The 2014 Act attenuated the increases (to 18% per year) but did not eliminate them. As a result, it is natural to consider a difference-in-difference estimator around that date, comparing properties in the floodplain to properties located elsewhere in the city.

In order to more cleanly identify the effects of the policy change, we follow Hallstrom and Smith (2005) (who were interested in the effects of flood risk) and focus our analysis on the repeat sales subsample that bracket July 2012.[15] We hypothesize that the price increases between two such sales for properties on the floodplain will be smaller than the price increase experienced by properties located elsewhere in the city. It is helpful to think of our 'treatment group' as containing houses located on the floodplain that were sold before and after July 2012. The 'control group' includes repeat sales that happened before July 2012 and repeat sales that may straddle across 2012 but refer to properties located outside the floodplain.[16]

More specifically, we define a new indicator $PostBW_t$ (for Biggert-Waters Act) for sales that took place after July 2012, and FP_i denotes the floodplain dummy as before. We then pose that the log of the sale price for property i in year t is given by

$$\ln p_{it} = \alpha_i + \lambda_t + \beta PostBW_t \times FP_i + \varepsilon_{it}, \tag{3}$$

where coefficient β identifies the effects of the 2012 Biggert-Waters Act (effective from July

[15]For houses that were sold more than once after July 2012, we keep only the first sale and drop the later ones.

[16]We can experiment with different variations of the control group, e.g. restricting only to repeat sales that bracket July 2012. In that case the control group is made up of the repeat sales outside the FP only.

2012) on houses in the floodplain. We expect this coefficient to be negative because of the increase in flood insurance for houses located on the floodplain, and estimate the model separately for each of our three coastal areas.

As before, we restrict to the sample of single-family houses.[17] In the case of New York, our data contains 344,652 sales corresponding the period 2003-2016. About 55% of these sales corresponds to properties that were sold only once within the sample period and, therefore, are dropped from the analysis. Among the remaining observations the number of sales for a given property ranges from 2 to 9.[18] The data for Virginia Beach contain 89,275 sales for single-family units between January 2000 and September 2016. Roughly 31% of these correspond to properties that have been sold only once in this period and are thus dropped. In our sample period, roughly 40% of properties were sold exactly twice and roughly 29% were sold at least three times.[19] For Miami, our data contains 131,099 sales for single-family homes from 2008 to 2015. Approximately 76% of the sales refer to properties that were sold only once in this period. Among properties sold more than once, about 20% of the sales correspond to properties that were sold twice and about 2.7% were sold three times.[20]

Let us now turn to our estimation results. The key coefficient is the one associated to the interaction between the post-reform and the floodplain indicators, denoted by β. This coefficient is identified by the change in price for houses that were sold both before and after the reform and are located on the floodplain, net of the price changes between other pairs of sales. Table 5 collects the estimates. We begin with the results for New York City (columns 1-3). The estimates in the first column suggest that post-reform (July 2012), the increase in housing prices was 13 log points *lower* for properties located on the flood plain, compared to houses in the rest of the city. This suggests a large effect

[17] In the case of New York our sample consists of tax-class one properties, which includes residential properties of up to three units, but we restrict to those that do not contain an apartment number so that we are essentially using single-family homes as well. These properties are uniquely identified by their borough, block and lot numbers.

[18] In the repeat sales sample, 62% of the sales correspond to houses that were sold exactly twice within the sample period. Respectively, 3-sale and 4-sale properties account for 23 and 10 percent of the observations so that combined, properties sold 4 times or less in the 13-year period account for 95% of all repeat sales.

[19] Recall that the data provided to us by the Virginia Beach Government, Real Estate Assessor's Office, includes only the last three sales for each household.

[20] The remaining 3% makes up the units sold more than 3 times up to 6.

of the reform on housing values. However, it is important to keep in mind that New York was hit by hurricane Sandy on October 29, 2012. Obviously, the affected properties were heavily concentrated on the coastline and many of them were on the 100-year flood plain. Thus that the drop in prices in the New York floodplain may have been the result of the hurricane, rather than flood reform. One way to try to isolate the net effect of flood insurance reform is to exclude from the sample all properties that were damaged by the hurricane.[21] As shown in column 2, the point estimate for β falls but is still highly significant. Nonetheless, the analysis in Ortega and Taşpınar (2016) suggests that even houses that were not directly damaged by the hurricane but were located on flood-prone areas suffered price declines because of an upward revision in the risk of flooding. Column 3 removes the effect of hurricane Sandy by limiting the analysis to the pre-Sandy period. In column 3 the estimated coefficient for the interaction between the post-reform period and being located on the floodplain is no longer significantly different from zero, although the post-reform period has now been reduced to merely three months. In sum, the experience of New York is not very helpful to try to identify the effects of flood insurance reform due to the short period between the implementation of the reform and hurricane Sandy.

We now move to the other two cities in our dataset. Importantly, both Virginia Beach and Miami-Dade county were affected by the flood insurance reform, but not by hurricane Sandy, which provides a potentially cleaner setup for the identification of the effects of the flood insurance reform. Columns 4 and 5 in Table 5 report the estimates. For Virginia Beach (column 4), the point estimate of the coefficient of interest is positive but not statistically different from zero. In the case of Miami-Dade (column 5) it is negative but, again, we are unable to reject the zero null hypothesis. Taken together, these estimates suggest that the premium changes associated to the 2012 Act have not had, for the time being, any effect on sale prices for properties located on the floodplain on account of the data for the three cities in our sample.

7.2 Market Segments

We also consider the possibility that flood insurance reform may have affected housing prices differently in different segments of the market, as suggested by Zhang (2016). For

[21] This is accomplished using FEMA's damage determination point data for hurricane Sandy.

each year we calculated the cutoff price that divide sale prices (of that year) into terciles and assigned each observation to the corresponding group. We then estimated difference-in-difference specifications (Equation 3) separately for each market segment, both for the sale probability and the log of sale prices.[22]

The results are presented in Table 6. The table presents results for New York, Virginia Beach and Miami-Dade in the top, middle and bottom panels, respectively. We report the coefficient of the interaction term between the post-reform period (July 2012) and the floodplain indicator. We begin with the results regarding the sale probability (columns 1-4). The first column presents estimates based on the whole sample. The point estimates are positive and significant for New York and Virginia Beach only. Columns 2-4 present the estimates based on each of the market segments. The results suggest that there is indeed heterogeneity in the evolution of the sale probability on the floodplain, relative to elsewhere in the city, across the price distribution. The general pattern is that sale probabilities increased in the floodplain but only for the highest-price properties, as can be seen in the estimates corresponding to Virginia Beach and Miami-Dade. The exception to this pattern is once again New York, where we find a positive effect on sales activity in the floodplain only for the lowest-price segment of the housing market.

Let us now turn to the results for sale prices (columns 5-8). The results for Virginia Beach and Miami do not reveal clear differences between the evolution of sale prices after 2012 in the floodplain and elsewhere in the city. There seems to be a slight tendency toward smaller price increases in the floodplain for the top segment of the market, but the estimates are small in magnitude and not significantly different from zero. Once again, the results for New York paint a different picture. When considering all segments of the market together, we find a relative decline in sale prices on New York's floodplain of about 13 log points relative to the rest of the city, in line with our previous estimates based on the repeat sales subsample (column 1 of Table 5). When allowing for different effects along the price distribution, we find that the largest declines in sale prices for properties on the floodplain took place in the lowest segments of the housing market.

In sum, the results in this section suggest that in Virginia Beach and Miami-Dade,

[22] As discussed earlier, the linear probability model on sales is based on a balanced panel for all properties in each of the cities.

flood insurance reform may have increased sales activity but only among the highest-price properties, but has left prices unchanged relative to the rest of the city. The estimates for New York suggest a somewhat different picture, with increases in sales activity accompanied by substantial reductions in prices for floodplain properties in the lowest-price segment of the market.

8 Flood insurance: new flood maps

The 2012 Biggert-Waters Act called for updating the flood maps across the country. This is a staggered process. Whereas New York's maps were updated in 2012 (though not yet effective as of early 2018), the new maps for Virginia Beach were only completed and put in effect in 2015. Last, the revision of the flood map for Miami-Dade is still under construction with unknown release date.

Interestingly for our purposes, the new flood maps typically change the risk classification for some properties. For instance, when the floodplain is expanded, some units that were located outside the floodplain under the old map, now find themselves located inside the new floodplain because of the increased risk of flooding. This has potentially large consequences in terms of flood insurance. First, these properties are now subject to the mandatory flood insurance requirements. In addition, the premiums faced by these properties are typically substantially higher, in line with the new risk classification.[23] It is important to keep in mind that the 2012 and 2014 reforms allow for 'grandfathering'. Namely, properties that were already insured can keep their old (lower) premia. However, when the property is sold (or the insurance policy lapses), the applicable premia will be those that correspond to the new risk classification.

Our goal in this section is to exploit the variation in the risk category of the properties that were re-classified in the new flood maps. In some instances, the new map has already become effective (e.g. Virginia Beach). In others, detailed preliminary versions of the new

[23]Flood insurance premia vary as a function of flood risk and elevation. To understand the consequences of flood insurance reform on housing values in a simple manner it is helpful to consider an example based on (Kousky, 2017). On the basis of the 2012 reform, the new rates corresponding to a single-family home within the 100-year flood plain and 4 feet below the base flood elevation increase from $2,644 to $10,263. However, given that the pre-reform rates did not vary by elevation, some properties sitting above the base flood elevation may experience a decrease in premia.

flood map have been publicly released but the map is not yet effective (e.g. New York). Either way, we hypothesize that the prices of the houses subject to risk re-classification may have been affected by the release of relevant information.

8.1 FEMA flood maps

The current effective flood map in New York city (as of early 2018) dates back to 1983 and has suffered only minor updates since then, with the latest version dating back to 2007. However, preliminary versions of the new flood map were released to the public throughout 2013.[24] The 2013 map expands substantially the 100-year flood plain, doubling the number of properties that may be subject to mandatory flood insurance. The 1983/2007 map contains approximately 21,000 residential parcels (with mostly 1-to-4 family houses) in the high-risk zone. The 2013 preliminary map contains over 47,000 residential parcels in the high-risk zone, which amounts to more than 6 percent of all city parcels. In addition the new map also increases the required elevations for the buildings already located in high-risk zones, warning that properties that fail to do so will face steep increases in flood insurance premiums. The 2013 preliminary flood map has not yet become effective because New York City filed an appeal, arguing that the proposed map overestimates flood risk in some parts of the city.

Table 7 describes the changes in risk classification, summarized in a transition matrix. Columns 1-4 refer to New York City. As a result of the changes in the flood map, our data contains 18,580 sales of properties that transitioned from being outside the floodplain under the old map to being on the floodplain under the new map. Because 1,303 sales refer to properties that were in the old floodplain and are considered as being outside of the floodplain under the new preliminary map, the net increase in sales is 17,277. As a share of all sales in the city, the floodplain increases from 2.4% to 5.0% under the new 2013 map. Columns 3 and 4 report the figures for the subsample of single-family homes. Under the new flood map, 7% of all citywide sales corresponding to single-family homes involve properties located on the floodplain, doubling the initial 3.5% share.

[24] On January 28, 2013, the New York Times published an article discussing the main changes in the new flood map. In June 2013, FEMA released information at the plot level. In 2013 RAND published an extensive report ((Dixon et al., 2013)) on flood insurance coverage in New York city and the consequences of flood insurance reform.

There is also a new flood map for Virginia Beach. The previous map dates back to 2009 and was replaced in January 2015 by a new one.[25] Interestingly, while the new map for New York greatly expanded the 100-year flood plain, in the case of Virginia Beach, the new map contains fewer buildings than the 2009 map.[26] Columns 5-8 in Table 7 summarize the changes in risk classification. In terms of sales, our data contain 520 instances referring to properties that were not part of the 100-year floodplain under the 2009 map but have been included in the newly defined floodplain. At the same time, 683 sales correspond to properties that were previously in the floodplain but are now excluded from it. The corresponding numbers for single family homes are 485 and 534.

8.2 Regression Analysis

In order to analyze the effects of a change in the flood risk zone designation, we restrict to sales corresponding to properties located in the floodplain under the old map or the new one (or both). Accordingly, we build indicators for sales corresponding to properties located within the floodplain under both maps ($InIn = 1$), for sales of properties that were initially outside the floodplain but are within it under the new map ($OutIn = 1$), and for sales of properties that were initially within the floodplain but are excluded from it under the new map ($InOut = 1$). The resulting sample sizes (in terms of sales) are 34,455 for New York and 5,162 for Virginia Beach.

As before, we consider regression models for both sales activity and sale prices. As before, the latter analysis is based on a balanced panel and the dependent variable is an indicator for whether a given *property* i was sold in year t:

$$Sold_{it} = \alpha_i + \lambda_t + \beta_{OI} Post_t \times OutIn_i + \beta_{IO} Post_t \times InOut_i + \varepsilon_{it}. \tag{4}$$

We note that property fixed-effects and year dummies are included in the regression, and the omitted category are properties that were located on the floodplain in both maps ($InIn = 1$). The *Post* indicator in the regression on New York data takes a value of 1 for years 2013 and later and for Virginia Beach this indicator takes a value of 1 for year 2016.

[25] Link: `https://www.servicelinknationalflood.com/Content/pdfs/2015_Revision_List.pdf`

[26] Individual properties or whole developments can request changes in risk classification to FEMA by providing their own technical assessments and by adopting protective measures.

In terms of sale prices, we consider the following specification:

$$\ln p_{izt} = \alpha_z + \lambda_t + \beta_{OI} Post_t \times OutIn_i + \beta_{IO} Post_t \times InOut_i + \varepsilon_{izt}, \tag{5}$$

where the dependent variable is the log of the sale price of property i in city block z and quarter-year t. As argued earlier, we employ narrow definitions of neighborhood (city blocks), which soak up a large degree of heterogeneity in property characteristics.

Our hypothesis is that $\beta_{OI} < 0 < \beta_{IO}$, indicating that properties that are being assigned a higher flood risk and subject to the mandatory insurance requirement should experience a drop in price, while properties whose risk is revised downward should experience a price increase. The predictions in terms of the sale probability are less clear. An increase in the risk assessment could lead to either an increase or a decrease in the probability of being sold, depending on the speed of adjustment of the property's price.

The results are collected in Table 8. Columns 1-3 refer to the New York city sample. The estimates in column 1 suggest that properties that experienced an increase in their risk assessment according to the new (preliminary) flood map did not experience a change in the sale probability relative to houses that were in the floodplain under both maps. However, properties that were now re-classified as being outside the floodplain under the new map appear to have suffered a reduction in the sale probability of about 1 percentage point. We turn now to the effects on prices. The estimates in column 2 refer to sales for all types of properties. The point estimates suggest that properties that transition in either direction experienced an increase in sale price relative to sales of properties that were located on the floodplain under both the old and new maps. Column 3 restricts the estimation to single family homes. Again both point estimates are positive, though we can only reject the zero null for the case of sales that were initially outside the floodplain but are now considered within it, which goes against our hypothesis.

Let us now turn to the data for Virginia Beach. Column 4 reports the estimates regarding the sale probability. The point estimates for both β_{OI} and β_{IO} are negative, and they are statistically significant at 10 and 5 percent levels, respectively. That is, the sale probability for houses experiencing a change in their risk assessment (in either direction) seems to have fallen, relative to houses that were in the floodplain under both the old and new maps. In terms of sale prices (columns 5 and 6), our estimates do not support the hypothesis of a price reduction associated to an increase in flood risk. However, we do find evidence of a large price *increase* for properties that were removed from the floodplain under the new maps. According to our estimates, these properties appreciated by 27 to 34 log points, with the latter estimate corresponding to the subsample of single-family homes.

Summing up, our analysis of the risk re-classification for properties in New York and Virginia delivers two conclusions. Somewhat surprisingly, we do not find evidence of a reduction in sale price for properties that experienced an upward revision of their flood risk. However, we do find consistent evidence of a large price appreciation for properties experiencing a downward revision in their flood risk. Thus, a property's risk classification in the FEMA maps does seem to have an sizable effect on its sale price.

9 Conclusion

Our main goal in this paper has been to investigate the effects of flood insurance on the housing markets of three urban coastal areas: New York city, Virginia Beach and Miami-Dade county.

Our first finding is that property sales and sale prices have evolved similarly in the floodplains of Virginia Beach and Miami-Dade and elsewhere in these cities, largely tracing the economic cycle. Given the increasing evidence of higher flooding risk, the lack of a floodplain price *penalty* is somewhat surprising but may simply reflect the availability of flood insurance at (constant) and subsidized rates up until 2012.

The only exception to the previous pattern has been the emergence of a substantial floodplain price *penalty* in New York from year 2013 onward. To try to disentangle if this was the result of the 2012 flood insurance reform or the aftermath of hurricane Sandy, which hit New York at the end of October 2012, we exploit the changes in insurance premia and FEMA flood maps mandated by the 2012 (and 2014) reforms to the National Flood Insurance Program.

We focus on two specific features of the reform. First, we ask whether the scheduled increase in premiums affecting properties sold after July 2012 had an effect on sale prices. We do so by conducting a difference-in-difference analysis for each of the cities, based on the change in sale prices around the date of the reform affecting properties located on the floodplain, net of the changes experienced by properties located elsewhere in the city. The estimates simply echo the finding of our trends analysis. Only New York's housing market may have been affected by this aspect of the reform, but it is difficult to tell whether this effect was simply due to hurricane Sandy, given the large overlap of the two events, both in time and geographically.

The reform also mandated that FEMA update the flood maps of all cities, which took place in New York during 2013 and in Virginia Beach in 2015. The new maps provide an additional source of identification. Specifically, we focus on the properties that have experienced an upward or downward revision in flood risk in the new flood maps. Our analysis does not find evidence of a negative effect on the prices of properties that have suffered an upward revision in flood risk, but we do find a large positive effect on the prices of properties whose risk was assessed downward. We estimate the price appreciation for these properties to be approximately 10% in New York and roughly 30% for Virginia Beach.

Our findings lead us to the following conclusions. First, the availability of subsidized flood insurance may have muted the responses of coastal housing markets to the increasing risk of flooding over the last few decades. Second, flood insurance reform has the potential to affect substantially housing values for floodplain properties, particularly through the risk classification of each individual property in the FEMA flood maps. In our view, the main effects of the 2012 and 2014 reforms on the housing values of coastal cities have only began to materialize. The bulk of the effects will likely take place over the next decade.

References

Atreya, Ajita, Susana Ferreira, and Warren Kriesel, "Forgetting the Flood? An Analysis of the Flood Risk Discount over Time," *Land Economics*, 2013, *89* (4).

Bakkensen, Laura A. and Lint Barrage, "Flood Risk Belief Heterogeneity and Coastal Home Price Dynamics: Going Under Water?," Working Paper 23854, National Bureau of Economic Research September 2017.

Bernstein, Asaf, Matthew Gustafson, and Ryan Lewis, "Disaster on the Horizon: The Price Effect of Sea Level Rise," Working Papers, Social Science Research Network December 2017.

Bin, Okmyung and Craig Landry, "Changes in implicit flood risk premiums: Empirical evidence from the housing market," *Journal of Environmental Economics and Management*, 2013, *65* (3), 361–376.

_ and Stephen Polasky, "Effects of Flood Hazards on Property Values: Evidence Before and After Hurricane Floyd," *Land Economics*, 2004, *80* (4).

_ , Jamie Brown Kruse, and Craig Landry, "Flood Hazards, Insurance Rates, and Amenities: Evidence From the Coastal Housing Market," *Journal of Risk & Insurance*, 2008, *75* (1), 63–82.

Buchanan, Maya K, Michael Oppenheimer, and Robert E Kopp, "Amplification of flood frequencies with local sea level rise and emerging flood regimes," *Environmental Research Letters*, 2017, *12* (6), 064009.

Conte, Marc N. and David L. Kelly, "An imperfect storm: Fat-tailed tropical cyclone damages, insurance, and climate policy," *Journal of Environmental Economics and Management*, 2017.

Cooper, Hannah M., Charles H. Fletcher, Qi Chen, and Matthew M. Barbee, "Sea-level rise vulnerability mapping for adaptation decisions using LiDAR DEMs," *Progress in Physical Geography*, 2013, *37* (6), 745–766.

Dixon, Lloyd, Noreen Clancy, Bruce Bender, Aaron Kofner, David Manheim, and Laura Zakaras, "Flood Insurance in New York City Following Hurricane Sandy," Technical Report, RAND Corporation, Santa Monica, CA 2013.

Gallagher, Justin, "Learning about an Infrequent Event: Evidence from Flood Insurance Take-Up in the United States," *American Economic Journal: Applied Economics*, July 2014, *6* (3), 206–33.

Government Accountability Office, "Flood Insurance: More Information Needed on Subsidized Properties," Report to Congressional Committees 13-607, United States Government Accountability Office July 2013.

Hallstrom, Daniel G. and V. Kerry Smith, "Market responses to hurricanes," *Journal of Environmental Economics and Management*, 2005, *50* (3), 541 – 561.

Harrison, David M., Greg T. Smersh, and Jr Arthur L. Schwartz, "Environmental Determinants of Housing Prices: The Impact of Flood Zone Status," *Journal of Real Estate Research*, 2001, *21* (1/2), 3–20.

Hauer, Mathew E., Jason M. Evans, and Deepak R. Mishra, "Millions projected to be at risk from sea-level rise in the continental UnitedStates," *Nature Climate Change*, March 2016, *6*, 691.

Hunter, John, "Estimating sea-level extremes under conditions of uncertain sea-level rise," *Climatic Change*, April 2010, *99* (3), 331–350.

Kousky, Carolyn, "Financing Flood Losses: A Discussion of the National Flood Insurance Program," Working Papers 17-03, Resources for the Future February 2017.

Ortega, Francesc and Süleyman Taşpınar, "Rising Sea Levels and Sinking Property Values: The Effects of Hurricane Sandy on New York's Housing Market," IZA Discussion Papers 10374, Institute for the Study of Labor (IZA) November 2016.

Park, Joseph, Jayantha Obeysekera, Michelle Irizarry, Jenifer Barnes, Paul Trimble, and Winifred Park-Said, "Storm surge projections and implications for water management in South Florida," *Climatic Change*, July 2011, *107* (1), 109–128.

Sweet, William, Joseph Park, John Marra, Chris Zervas, and Stephen Gill, "The Geography of Development: Evaluating Migration Restrictions and Coastal Flooding," NOAA Technical Report NOS CO-OPS 073, National Oceanic and Atmospheric Administration 2014.

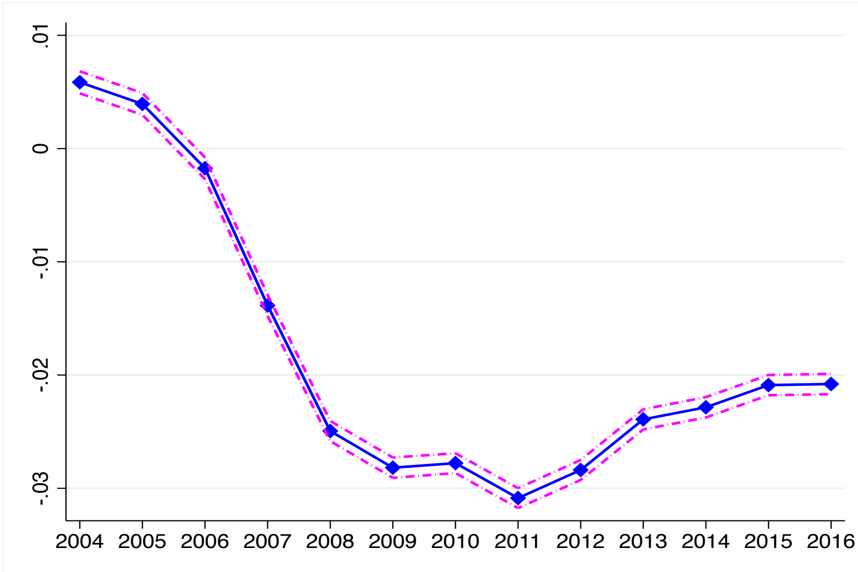
Sweet, William V. and Joseph Park, "From the extreme to the mean: Acceleration and tipping points of coastal inundation from sea level rise," *Earth's Future*, 2014, *2* (12), 579–600. 2014EF000272.

Tebaldi, Claudia, Benjamin H Strauss, and Chris E Zervas, "Modelling sea level rise impacts on storm surges along US coasts," *Environmental Research Letters*, 2012, *7* (1), 014032.

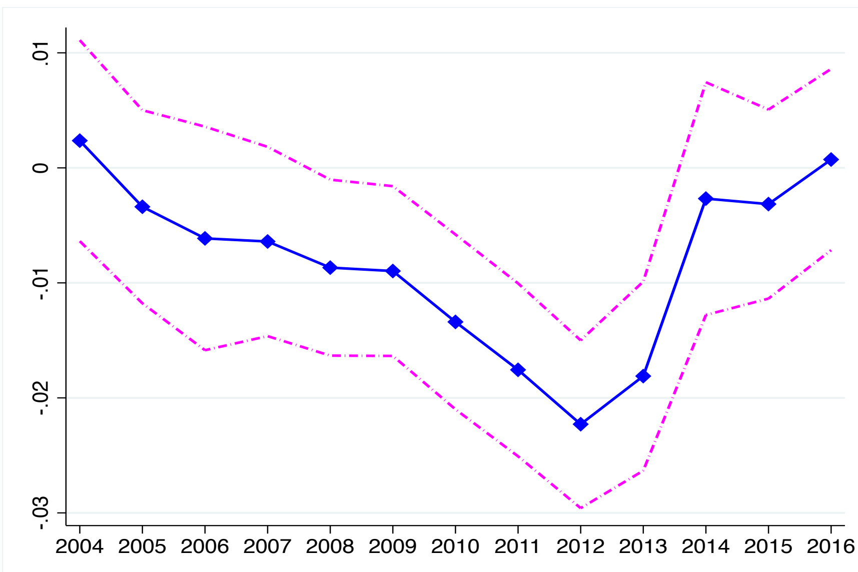
Vitousek, Sean, Patrick L. Barnard, Charles H. Fletcher, Neil Frazer, Li Erikson, and Curt D. Storlazzi, "Doubling of coastal flooding frequency within decades due to sea-level rise," *Scientific Reports*, May 2017, *7* (1), 1399.

Votsis, Athanasios and Adriaan Perrels, "Housing Prices and the Public Disclosure of Flood Risk: A Difference-in-Differences Analysis in Finland," *The Journal of Real Estate Finance and Economics*, Nov 2016, *53* (4), 450–471.

Zhang, Lei, "Flood hazards impact on neighborhood house prices: A spatial quantile regression analysis," *Regional Science and Urban Economics*, 2016, *60* (Supplement C), 12 – 19.



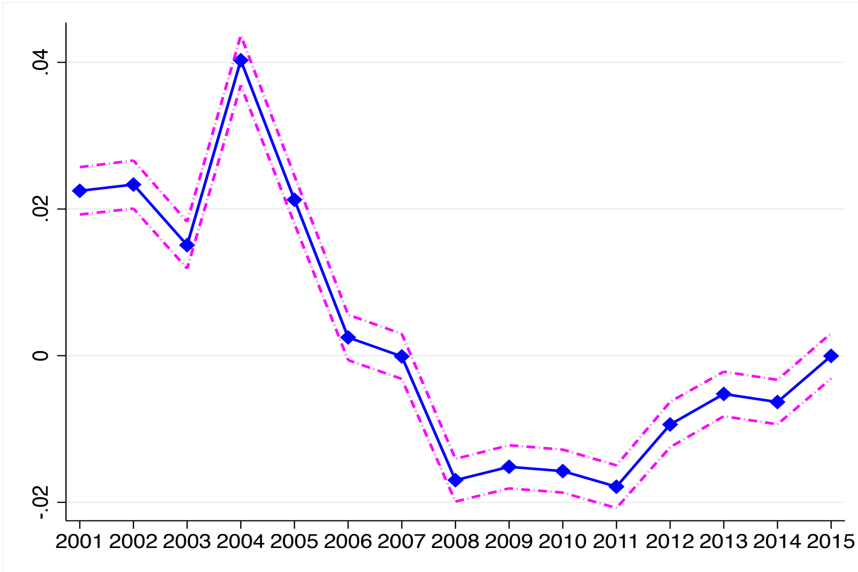
(a) Citywide



(b) Floodplain premium

Figure 1: NYC, Sale probability.

Notes: Point estimates from the event study at annual frequency on the sample of 1-family homes. We are plotting the coefficients of the year dummies (top) and interactions with FP100 (bottom). Regressions include city block fixed-effects.

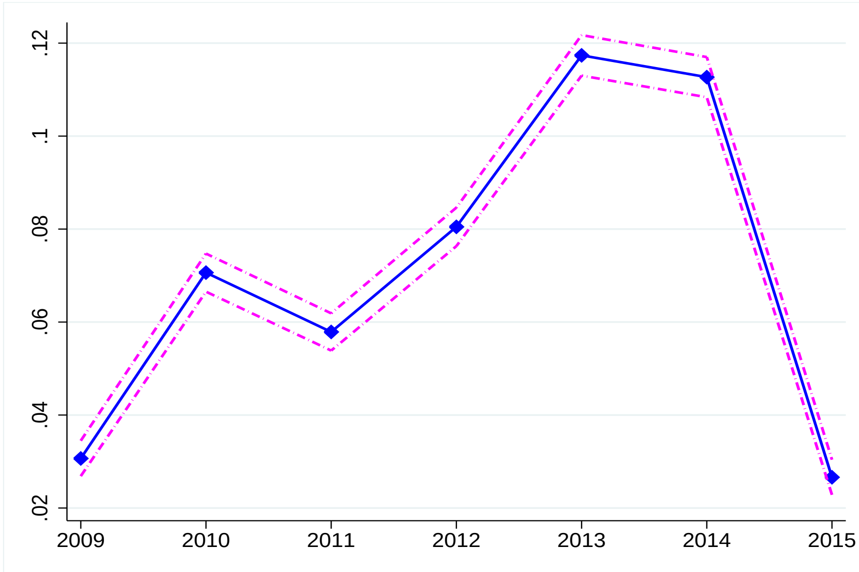


(a) Citywide

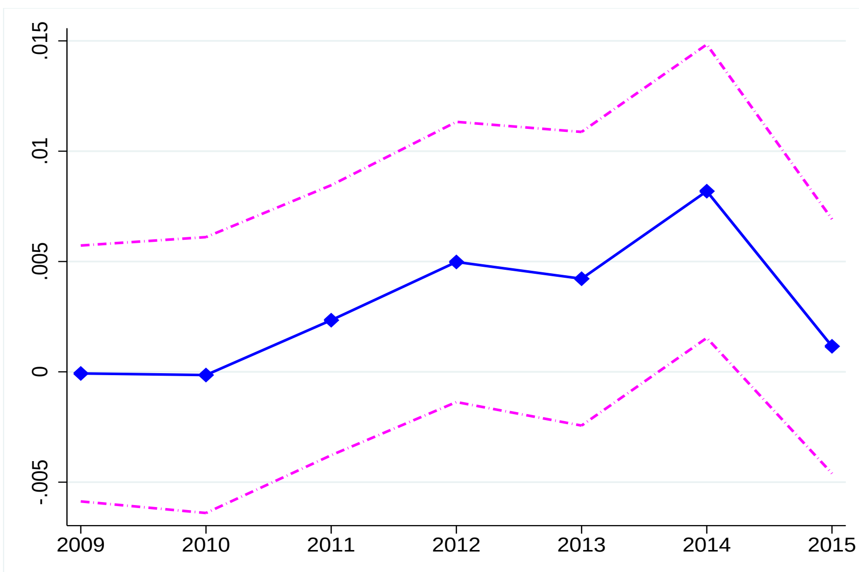
(b) Floodplain premium

Figure 2: Virginia Beach, Sale probability.

Notes: Point estimates from the event study at annual frequency on the sample of 1-family homes. We are plotting the coefficients of the year dummies (top) and interactions with FP100 (bottom). Regressions include parcel fixed-effects.



(a) Citywide

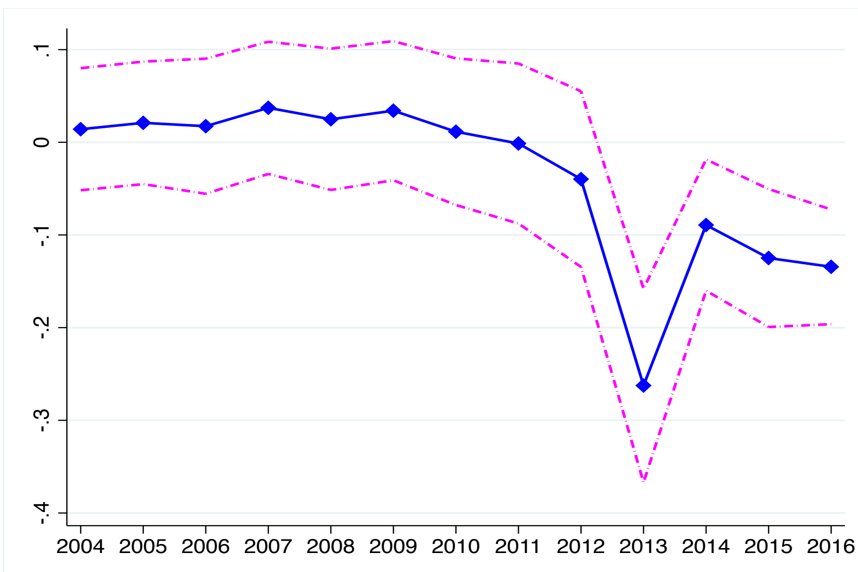


(b) Floodplain premium

Figure 3: Miami-Dade, Sale probability.

Notes: Point estimates from the event study at annual frequency on the sample of 1-family homes. We are plotting the coefficients of the year dummies (top) and interactions with FP100 (bottom) Regressions include parcel FE.

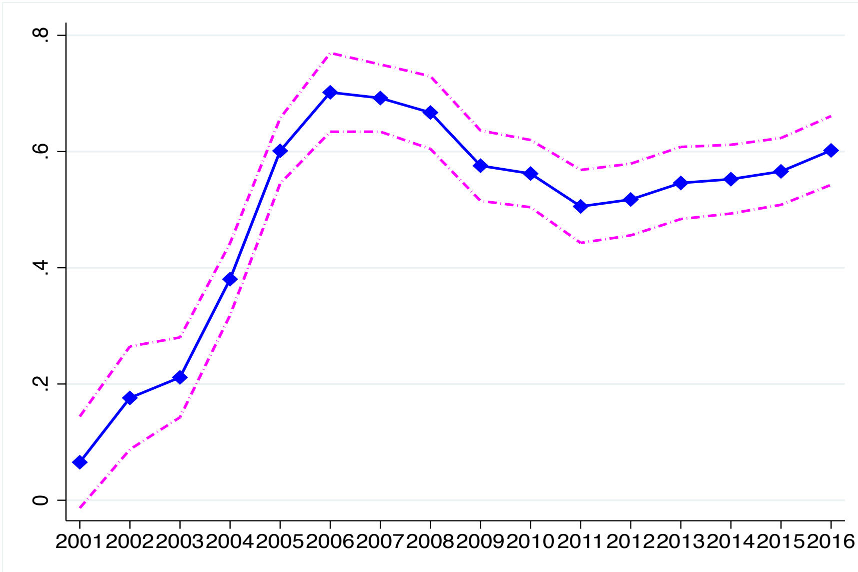
(a) Citywide



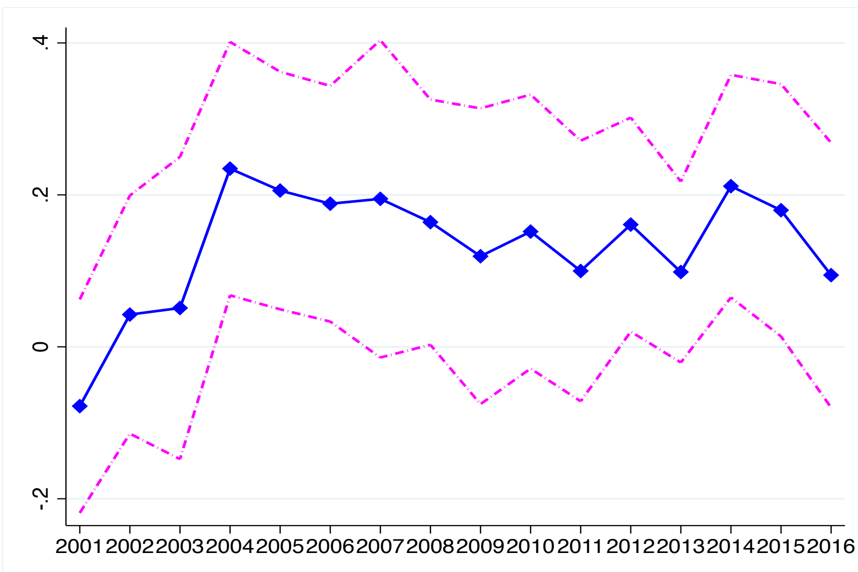
(b) Floodplain premium

Figure 4: NYC, sale prices.

Notes: Point estimates from the event study at annual frequency on the sample of 1-family homes. In top Figure we are plotting the coefficients of the year dummies. In bottom Figure We are plotting the interactions of the year dummies with indicator FP100.



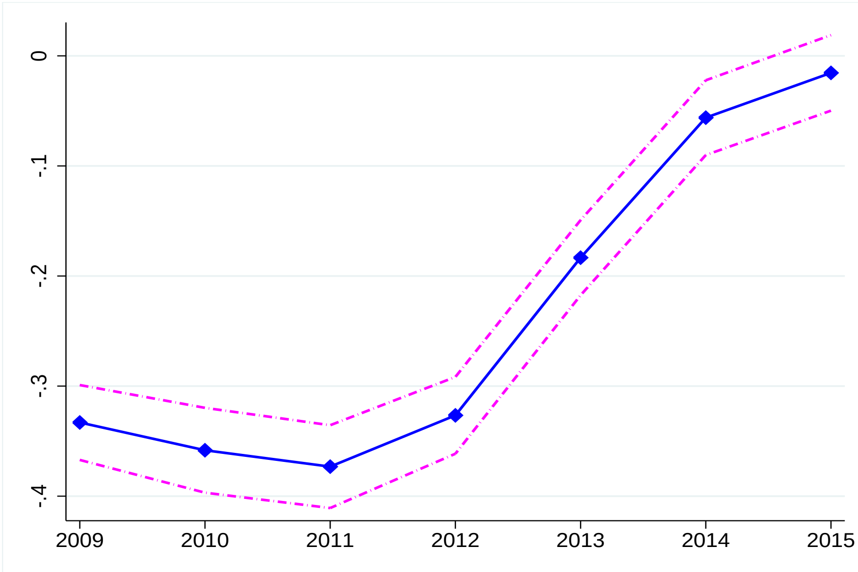
(a) Citywide



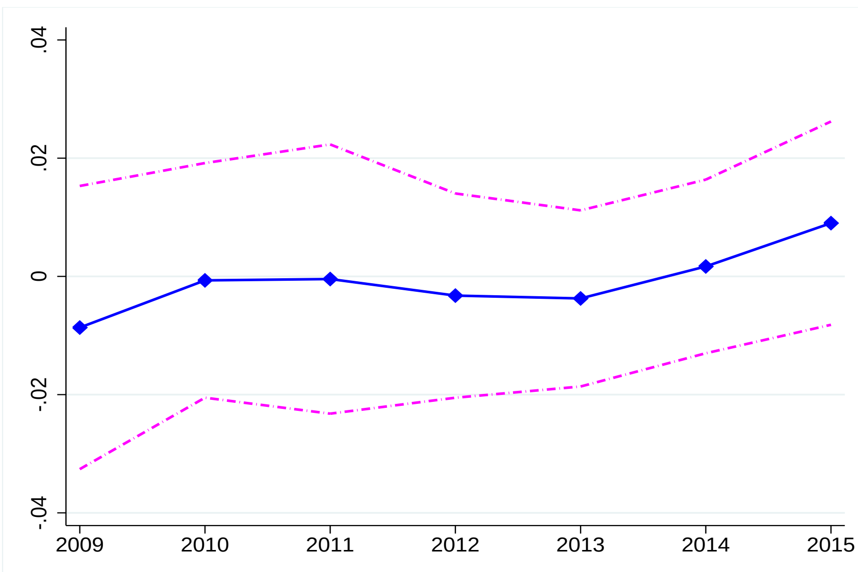
(b) Floodplain premium

Figure 5: Virginia Beach, sale prices.

Notes: Point estimates from the event study at annual frequency on the sample of 1-family homes. In top Figure we are plotting the coefficients of the year dummies. Bottom Figure plots the interactions of the year dummies with indicator FP100. Regressions include Census block FE.



(a) Citywide



(b) Floodplain premium

Figure 6: Miami-Dade, sale prices.

Notes: Point estimates from the event study at annual frequency on the sample of 1-family homes repeat sales. We are plotting the coefficients of the year dummies. Regressions include parcel FE.

Table 1: Frequency of sales by type of property (land use)

	freq All	freq FP	freq Outside FP	rel. freq. All	rel. freq. FP	rel. freq. Outside FP
New York 2003-2016						
1fam-2fam	321,347	10,091	303,062	0.48	0.62	0.48
Multifamily (more than 2)	292,439	4,234	280,898	0.44	0.26	0.44
Other	51,565	2,037	47,998	0.08	0.12	0.08
Total	665,351	16,362	631,958	1.00	1.00	1.00
Virginia Beach 2000-2016						
1fam-2fam	89,275	3,713	85,562	0.74	0.80	0.74
Multifamily (more than 2)	173	12	161	<0.01	<0.01	<0.01
Other	31,094	917	30,177	0.26	0.20	0.26
Total	120,542	4,642	115,900	1.00	1.00	1.00
Miami-Dade 2008-2015						
1fam-2fam	149,118	63,120	86,101	0.68	0.67	0.68
Multifamily (more than 2)	14,172	6,063	8,126	0.06	0.06	0.06
Other	57,013	25,507	31,593	0.26	0.27	0.25
Total	220,303	94,690	125,820	1.00	1.00	1.00

Notes: FP stands for 100-year floodplain. Floodplains are defined on the basis of the FEMA flood insurance rate maps. The floodmap used for New York is the 2007 version (still in effect in January 2018). The Virginia Beach and Miami-Dade floodmaps are the 2009 versions.

Table 2: Frequency of sales by year. Single-family homes only

year	NYC FP	NYC Outside FP	NYC FP share	VB FP	VB Outside FP	VB FP share	MD FP	MD Outside FP	MD FP share
2000				173	4,831	0.03			
2001				213	6,210	0.03			
2002				205	6,376	0.03			
2003	676	17,449	0.04	201	5,754	0.03			
2004	740	19,512	0.04	299	7,219	0.04			
2005	669	18,268	0.04	256	6,304	0.04			
2006	566	15,834	0.03	175	5,108	0.03			
2007	489	12,840	0.04	204	4,888	0.04			
2008	359	9,519	0.04	140	3,821	0.04	4,406	6,182	0.42
2009	342	8,822	0.04	174	4,132	0.04	5,917	8,330	0.42
2010	303	8,938	0.03	162	4,145	0.04	8,491	11,786	0.42
2011	247	7,509	0.03	188	4,059	0.04	7,544	10,333	0.42
2012	211	8,536	0.02	209	4,287	0.05	8,980	12,090	0.43
2013	340	9,909	0.03	218	4,716	0.04	11,000	14,792	0.43
2014	540	9,960	0.05	186	4,478	0.04	10,958	14,552	0.43
2015	500	11,075	0.04	224	4,843	0.04	5,824	8,036	0.42
2016	571	11,279	0.05	161	3,592	0.04			
Avg.	468	12,104	0.04	199	4,986	0.04	7,890	10,763	0.42

Notes: FP stands for 100-year floodplain and it is defined on the basis of the FEMA flood insurance rate maps. For New York it is based on the 2009 flood map. For Virginia Beach and Miami-Dade it is based on the 2009 flood map. Sales in the last year for Virginia Beach and Miami-Dade do not include data for the last quarter.

Table 3: Median sale price by year. Single-family homes only

year	NYC FP100	NYC Outside FP	NYC FP/Out	VB FP100	VB FP/Out	VB FP premium	MD FP100	MD FP/Out	MD FP premium
2000				172,500	137,900	1.25			
2001				148,000	145,000	1.02			
2002				202,140	159,500	1.27			
2003	262,575	310,000	0.85	225,000	175,500	1.28			
2004	315,000	355,000	0.89	309,900	210,000	1.48			
2005	365,000	419,205	0.87	381,750	265,000	1.44			
2006	381,300	459,421	0.83	399,000	284,900	1.40			
2007	376,300	475,000	0.79	355,950	285,000	1.25			
2008	370,000	438,800	0.84	300,000	267,885	1.12	256,500	255,000	1.01
2009	340,000	400,000	0.85	257,000	250,000	1.03	165,000	165,000	1.00
2010	359,000	403,173	0.89	299,375	250,000	1.20	141,100	140,000	1.01
2011	330,000	400,000	0.83	290,041	240,000	1.21	149,250	145,200	1.03
2012	342,000	410,000	0.83	310,000	245,000	1.27	160,000	154,000	1.04
2013	304,752	425,000	0.72	295,000	245,000	1.20	185,000	180,000	1.03
2014	360,000	441,090	0.82	377,000	247,638	1.51	203,905	199,000	1.02
2015	360,000	460,000	0.78	341,000	250,000	1.36	224,250	220,000	1.02
2016	374,805	491,000	0.76	307,500	259,000	1.18			
Avg.	344,665	416,500	0.83	296,346	229,347	1.29	185,626	182,275	1.02

Notes: FP stands for 100-year floodplain. For New York it is based on the 2009 flood map. For Virginia Beach it is based on the 2009 flood map.

Table 4: Estimation floodplain premia

Dep. Var.	New York Sold	New York Sold	New York ln price	Virginia Sold	Virginia ln price	Miami Sold	Miami ln price
FP × D2000	.	.	.	-0.012*	-0.499***	.	.
	.	.	.	[0.007]	[0.081]	.	.
FP × D2001	.	.	.	-0.021***	-0.290***	.	.
	.	.	.	[0.007]	[0.059]	.	.
FP × D2002	.	.	.	-0.028***	-0.226***	.	.
	.	.	.	[0.007]	[0.058]	.	.
FP × D2003	.	.	.	-0.020**	-0.037	.	.
	.	.	.	[0.007]	[0.063]	.	.
FP × D2004	0.0024	0.0021	0.01	-0.011	-0.007	.	.
	[0.0045]	[0.0045]	[0.03]	[0.007]	[0.050]	.	.
FP × D2005	-0.0034	-0.0037	0.02	-0.012	-0.032	.	.
	[0.0043]	[0.0043]	[0.03]	[0.007]	[0.052]	.	.
FP × D2006	-0.0061	-0.0068	0.01	-0.019***	-0.043	.	.
	[0.0050]	[0.0049]	[0.04]	[0.007]	[0.052]	.	.
FP × D2007	-0.0064	-0.0068	0.03	-0.009	0.028	.	.
	[0.0042]	[0.0042]	[0.04]	[0.007]	[0.053]	.	.
FP × D2008	-0.0087**	-0.0091**	0.02	-0.013**	-0.000		
	[0.0039]	[0.0039]	[0.04]	[0.006]	[0.062]		
FP × D2009	-0.0090**	-0.0093**	0.03	-0.009	-0.043	-0.000	0.052
	[0.0038]	[0.0038]	[0.04]	[0.007]	[0.052]	[0.003]	[0.037]
FP × D2010	-0.0134***	-0.0139***	0.01	-0.006	-0.015	-0.000	0.005
	[0.0039]	[0.0039]	[0.04]	[0.007]	[0.056]	[0.003]	[0.033]
FP × D2011	-0.0176***	-0.0180***	0	0.002	-0.015	0.002	0.022
	[0.0038]	[0.0039]	[0.04]	[0.007]	[0.064]	[0.003]	[0.033]
FP × D2012	-0.0223***	-0.0227***	-0.04	0.006	0.080	0.005	0.026
	[0.0037]	[0.0038]	[0.05]	[0.007]	[0.056]	[0.003]	[0.031]
FP × D2013	-0.0181***	-0.0187***	-0.25***	0.009	-0.095	0.004	0.013
	[0.0042]	[0.0043]	[0.05]	[0.007]	[0.060]	[0.003]	[0.030]
FP × D2014	-0.0027	-0.0033	-0.09***	-0.005	-0.012	0.008**	0.009
	[0.0052]	[0.0052]	[0.04]	[0.007]	[0.060]	[0.003]	[0.030]
FP × D2015	-0.0032	-0.0038	-0.13***	-0.001	0.003	0.001	0.024
	[0.0042]	[0.0042]	[0.04]	[0.007]	[0.054]	[0.003]	[0.032]
FP × D2016	0.0007	0.0001	-0.14***	.	.	.	.
	[0.0040]	[0.0041]	[0.03]	.	.	.	.
Observations	9157348	9157348	179515	1063928	89275	8155272	131219
Number of BB	23339	665930	18351	54268	54268	101909	101909
R-squared	0.004	0.005	0.088	0.004	0.115	0.012	0.159
Fixed-effects	block	parcel	block	parcel	parcel	parcel	parcel
Clustering s.e.	block	block	block	parcel	parcel	parcel	parcel

Notes: Sales of one-family homes only. The sample periods are 2003-2016 for New York, 2000-2016 for Virginia Beach and 2008-2015 for Miami-Dade county. In the cases of New York and Miami-Dade, the coefficients referring to the first year in the sample are dropped to avoid perfect collinearity. For Virginia Beach, the coefficient referring to the last year has been dropped.

Table 5: Difference-in-Difference estimator around July 2012. Repeat sales sample

	1	2	3	4	5
Dep. Var.	NYC	NYC	NYC	VB	MD
FP × PostBW	-0.13***	-0.08***	0.08	0.04	-0.008
	[0.02]	[0.02]	[0.12]	[0.023]	[0.020]
Observations	153880	145438	117643	61281	49290
R-squared	0.148	0.149	0.176	0.329	0.222
Number of BBL	65705	62099	61541	26428	23808
Year-month dummies	yes	yes	yes	yes	yes
Sample	2003-2016	undamaged	2003-2012m10	2000-2016m9	2008-2015

Note: PostBW is an indicator taking a value of one for sales that took place after July 2012. In column 2 we only include observations for properties that were not damaged by hurricane Sandy. The sample includes only repeat sales where we exclude second, or higher order, sales after July 2012.

Table 6: Difference-in-Difference estimator around July 2012. Market Segments

	1	2	3	4	5	6	7	8
Dep. Var.	sold	sold	sold	sold	lnp	lnp	lnp	lnp
New York								
$PostBW \times FP$	0.01***	0.01***	-0.01***	0	-0.13***	-0.09***	-0.04***	0.01
	[0.00]	[0.00]	[0.00]	[0.00]	[0.02]	[0.02]	[0.01]	[0.03]
Observations	9323020	2840820	2831921	2826116	649575	212642	210856	220845
R-squared	665930	348462	417923	327716	0.068	0.092	0.525	0.164
Clusters	0.004	0.007	0.005	0.003	25376	18466	20931	21874
Virginia Beach								
$PostBW \times FP$	0.00**	0	0	0.01***	0.02	0.06**	0	-0.02
	[0.001]	[0.003]	[0.004]	[0.002]	[0.031]	[0.025]	[0.009]	[0.029]
Observations	1,415,284	386,257	498,406	530,621	120,418	40,193	40,179	40,046
R-squared	0.004	0.006	0.003	0.004	0.121	0.37	0.079	0.135
Clusters	72,289	20,420	26,314	27,756	288	254	272	269
Miami-Dade								
$PostBW \times FP$	0.003	0.004	-0.002	0.007**	-0.001	0.002	0.004	-0.007
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.00]	[0.00]
Observations	815304	281592	322640	293552	131218	43034	46232	41926
R-squared	0.011	0.012	0.011	0.009	0.028	0.128	0.415	0.035
Clusters	101913	35199	40330	36694	17854	8211	8653	7435
Type houses	All	All	All	All	All	All	All	All
Quantiles	All	below p33	p33-p66	above p66	All	below p33	p33-p66	above p66
FE	property	property	property	property	block	block	block	block

Notes: FP stands for 100-year floodplain. For New York it is based on the 2009 flood map. For Virginia Beach it is based on the 2009 flood map. For each year and city, we classify sales according to percentile ranges 1-33, 34-66, 67-100. The sample of all sales is then split across these three classes.

Table 7: Transition matrix flood zones: Sales counts

	NYC All	NYC All shares	NYC 1-fam	NYC 1-fam shares	VB All	VB All shares	VB 1-fam	VB 1-fam shares
Out-Out	621,292	0.947	166,263	0.928	115,389	0.957	85,077	0.953
FP-FP	14,711	0.022	6,312	0.035	3,959	0.033	3,179	0.036
Out-FP	18,580	0.028	6,208	0.035	520	0.004	485	0.005
FP-Out	1,303	0.002	288	0.002	683	0.006	534	0.006
Total	655,886		179,071		120,551		89,275	

Note: A property is considered to be in the (100-year) floodplain if it has risk classification A, AE, AH or VE in the FEMA flood map. All these categories are subject to mandatory flood insurance requirements. The specific definitions for the flood zone designations are given in the Appendix. The flood maps for New York are dated 1983/2007 and 2013. As of the end of 2017, the 1983/2007 map is still effective. The flood maps for Virginia Beach are dated 2009 and 2015. Columns 2 and 4 report the shares relative to the total number of properties in the corresponding city.

Table 8: Effects of risk re-classification

	1	2	3	4	5	6
City	NYC	NYC	NYC	VB	VB	VB
Dep. Var.	Sold	ln p	ln p	Sold	ln p	ln p
$Post \times OutIn$	0	0.07***	0.10***	-0.01*	0.12	0.11
	[0.00]	[0.02]	[0.02]	[0.06]	[0.085]	[0.089]
$Post \times InOut$	-0.01**	0.12**	0.10	-0.01**	0.27**	0.34***
	[0.00]	[0.05]	[0.07]	[0.04]	[0.104]	[0.090]
R-squared	0.003	0.049	0.06	0.004	0.144	0.176
Observations	726478	34455	12765	62033	5162	4198
Number of groups	71579	2338	1501	3380	177	163
Building class	All	All	Fam1	All	All	Fam1

Note: The 'Post' indicator in the regression on New York data takes a value of 1 for years 2013 and later. For Virginia Beach this indicator takes a value of 1 for year 2016. Property fixed-effects included in regressions with dependent variable Sold, block fixed-effects in all sale price regressions. The sample includes only sales referring to properties that are located on the floodplain under the old or new flood maps (or both). The omitted category in the regression models consists of sales of properties located on the floodplain under both the old and new maps. In column 1, only houses (1 to 3 family houses) are included. All columns include year dummies. Standard errors clustered at the city-block level in all columns. $***p < 0.01, **p < 0.05, *p < 0.1$.

Appendix

A The Flood Insurance Reform Acts in detail

A.1 The 2012 Biggert-Waters Act (BWA)

With BWA the high-risk zones are expanded to reflect current risk levels. Regarding insurance rates, there are increases for some properties (described below). Even though rates will not change immediately for about 70% of the properties (because of grandfathering rules), once those houses are sold (or experience massive flood damage) the new rates will kick in.

Specific implications:

- Policies will be written or renewed at full-risk rates for properties purchased or newly insured after July 5, 2012.

And from October 1, 2013:

- Subsidized policies for (1) non-primary residences, (2) businesses and (3) structures with severe repeated flood losses will have annual premium increases of 25 percent until rates reflect full risk.
- Primary residences in Special Flood Hazard Area's (SFHA) can keep their subsidized rates until (1) property is sold, (2) policy lapses, (3) property suffers severe flood losses (where the owner refuses an offer to mitigate), or (4) a new policy is purchased.
- Phasing out of grandfathered rates over 5 years.[27]
- Establishment of a Reserve Fund to help cover costs when claims exceed the annual premiums collected by NFIP.

A.2 The 2014 Homeowner Flood Insurance Affordability Act (HFIAA)

This act repealed some mandates of the 2012 Act and slowed down some rate increases. Amended most provisions mandating that certain policies transition immediately to full-risk rates.

Specific implications from April 1, 2015:

- Limit increases for individual premiums to 18 percent per year.
- Limit increases for average rate classes to 15 percent per year.
- Increases the Reserve Fund assessments required by BWA.

[27] Prior to BWA, when revised maps showed higher risk zones, policyholders were permitted to grandfather and use the zone and elevation of an older map.

- Implements annual surcharges on all new and renewed policies. This is meant to compensate for the loss in revenue from slowing down BWA rate increases. These surcharges will be collected until all subsidies are eliminated. The surcharges are flat fees applied to all policies regardless of the flood zone where the building is located. The annual surcharge for primary residences is $25 and for non-primary residences or non-residential properties it is $250.

- Introduces a cost-saving flood insurance coverage for properties newly mapped into the Special Flood Hazard Area (SFHA). They will receive PRP (Preferred Risk Policy) rates for 1 year after the maps become effective. The rates at renewal will increase no more than 18 percent per year.

- Resuscitates grandfathering. Grandfathering remains an option for policyholders when new maps show their buildings in a higher risk area (e.g. zone A to zone V, or increase in the Base Flood Elevation). Available to property owners who (1) have flood insurance policies in effect when the new flood maps become effective, or (2) have built in compliance with the FIRM in effect at the time of construction. These policyholders have the option of using the flood zone on a previous FIRM that was in effect when the building was originally constructed (for those built in compliance) or when coverage was first obtained (for those with continuous coverage).

A.3 Flood zone designations

Zone A is the flood insurance rate zone determined by approximate methods, as no Base Flood Elevations (BFEs) are available for these areas. Mandatory flood insurance purchase requirements apply.

Zone AE is the flood insurance rate zone that corresponds with flood depths greater than 3 feet. Mandatory flood insurance purchase requirements apply.

Zone AH is the flood insurance rate zone that corresponds to areas of shallow flooding with average depths between 1 and 3 feet. Mandatory flood insurance purchase requirements apply.

Zone VE is the flood insurance rate zone that corresponds to coastal areas that have additional hazards associated with storm waves. Mandatory flood insurance requirements apply.

Zone X and Zone X-500 are flood insurance rate zones that are outside the flood plain or with average flood depths of less than 1 foot. Flood insurance purchase is not mandatory.