Heterogeneity in the Recovery of Local Real Estate Markets After Extreme Events: The Case of Hurricane Sandy

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Abstract:
This paper examines the effect of Hurricane Sandy on local real estate markets in New York City. A natural disaster, like Sandy, generates two important shocks that can affect real estate markets: it creates physical blight and it provides new information about the risk of future damage. Unlike previous research, we consider how the information provided by the storm differs inside and outside of official flood zones and the role of localized economic conditions in mitigating storm-induced blight. Results indicate that the price of 1-3 family homes that were hit by high storm surges drop by about 16 percent and remain 12 percent lower than pre-storm levels six years after the storm. We show that these long-term effects are concentrated in areas *outside* of existing flood zones and in low-income neighborhoods. Properties in higher income neighborhoods experience large initial price shocks but then mostly recover, while those in lower income areas appear to experience a delayed response and exhibit no sign of recovery. Finally, the storm led to a change in the composition of homebuyers in storm surge areas that were low-income and outside the flood zone. After the storm, homebuyers in those areas were more likely to be black and Hispanic, suggesting that the flooding and damage may have shifted the nature of neighborhood change that was underway prior to the storm. Preliminary analyses of rebuilding activity suggest that any price decline is due more to new information about risk than persistent blight.

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Hurricane; Price capitalization; urban blight

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1. Introduction

This paper examines the effect of Hurricane Sandy on local real estate markets in New York City. A natural disaster, like Sandy, generates two important shocks that can affect real estate markets: (i) it creates new (and often severe) physical blight and (ii) it provides new information about the risk of future damage. These shocks can manifest very differently across sub-markets, and policymakers need to understand this variation so that they can manage post-disaster recovery and plan for future events in a targeted way. Thus, we focus on heterogeneity in price recovery across neighborhoods, and conduct analyses of population shifts that help to unpack the sub-market responses. Our analysis cannot pinpoint the precise mechanisms, but we surmise that pre-existing knowledge and beliefs about neighborhood risk and long-run expectations about a neighborhood's economic potential or quality contribute to the differences we observe. Differential access to resources for repairs may also play a role.

We rely on a combination of several longitudinal, micro-datasets on property sales transactions, property characteristics, and mortgage application activity in New York City. We overlay these data with spatial information on flood zones, to capture the perceived risk prior to Hurricane Sandy, as well as spatially detailed data on storm surge heights. Our results indicate that the prices of properties that saw high storm surges fell in the immediate aftermath of the storm. In the year after the storm, 1-3 family properties on high-surge blocks saw price declines of about 16 percent compared to properties on blocks without any storm surge. On average, values of these properties remained about 12 percent lower than pre-storm levels six years after the storm. We find that properties located on blocks in low-surge areas also saw a sustained, though more gradual, reduction in value, with property values falling to about 14 percent below pre-storm levels by 2018.

One of our core contributions is to illustrate significant differences in recovery inside and outside of official flood zones, or FEMA zones. Specifically, the prices of properties on high surge blocks located inside FEMA zones saw an initial decline in prices but recovered quickly after the storm, perhaps because greater insurance coverage allowed for quick repairs, or perhaps because these areas were already considered risky before the storm so the storm did not provide any additional information. Further, we see no evidence that the price discount from location in the flood zone increased after the storm. By contrast, prices of properties outside FEMA zones remained depressed six years after the storm, on both high- and low-surge blocks.

A second key contribution is our finding of differential recovery in high- and low-income neighborhoods. We find that properties in higher income neighborhoods that were hit by high storm surges experienced larger initial price shocks than those in low-income areas. Prices in higher income areas recovered over time, however, while those in lower income areas exhibited no sign of recovery and experienced further decline. Finally, the storm led to a change in the racial composition of homebuyers in low-surge areas. After the storm, homebuyers in those areas were more likely to be black and Hispanic.

We cannot fully determine whether these results are due to heightened perceptions of risk in low-income areas outside the flood zone or lingering physical damage as property owners either do not have the resources or simply choose not to repair their properties due to a lack of confidence in the neighborhood's future. We plan to probe this further in future work, but the fact that, outside the flood zone, we see such similar price effects in both high- and low-surge areas suggests that new knowledge of risk may be the more important channel. We see some evidence that more repairs were made inside the flood zone and in higher income areas, but the increase in alteration permits we see in those areas occurs *after* prices have largely recovered.

2. Determining storm risk: Information, physical blight and localized neighborhood conditions

2.1 Background

A natural disaster can affect property prices in several ways. First, prices can be influenced by changes in information about future flooding risk. The storm provides information to buyers of properties in areas that were impacted about the likelihood of future flood exposure and damage. The value of this information, and how much it is reflected in price changes after the storm, depends on how much information on that risk was available prior to the storm (i.e. was the parcel already in a zone known to be prone to flooding?).

Second, the physical damage inflicted by the storm can reduce property values. The damage can be both direct (i.e. to the parcel itself) or indirect (i.e. to nearby parcels). Damage to the parcel itself, from, for example, excessive water or wind, can depress the value of the property due to the costs necessary to make physical repairs. The damage the storm inflicts can also affect the value of neighboring properties. Nearby damage can drive down prices due to the physical blight or the illicit activity that might accompany it (Campbell, Giglio, Pathak, 2011; Gerardi et al, 2015; Harding, Rosenblatt and Yao, 2009; Schuetz, Been and Ellen, 2008; Hartley, 2014).

Furthermore, immediate price effects and any subsequent recovery can be mediated by localized neighborhood conditions. Decisions to buy or invest in Sandy-affected areas can be influenced by calculations about future flood risk along with long-run expectations about the neighborhood's economic potential or quality. And the economic circumstances of the local residents can determine the likelihood and degree of rebuilding after storm-induced damage.

Past research has not successfully disentangled these mechanisms. Existing research emphasizes the impact of new information that a storm provides about risk, but it fails to consider that the information provided by the storm differs inside and outside of official flood zones. Further, past research has not considered the role that localized neighborhood conditions play in calculating future risk, and therefore investment, in the affected neighborhoods.

2.2 Empirical literature

Many researchers document negative effects of hurricanes on residential property prices and interpret them as the capitalization of flooding risk (Hallstrom and Smith, 2005; McKenzie and Levendis, 2010; Kousky, 2010; Bin and Landry, 2013; Giglio, et al., 2018).[1]

These studies argue that, after the storm, flood risk becomes more salient to both potential buyers and sellers. For example, Atreya and Ferreira (2015) find prices drop more for residential properties in inundated areas than comparable properties in flood-prone areas without inundation. However, they argue that this housing price discount in the inundated areas reflects increased insurance premiums and greater salience of residual risks for non-insurable losses rather than damages from the flood, because insurance would cover reconstruction and cleaning fees. Bernstein, Gustafson and Lewis (2017) examine the perception of risk and residential mobility rather than property values. They show that households whose residential properties are damaged by hurricanes are more likely to be concerned about flooding risk, and concerned households are more likely to leave coastal areas in the five years after the storm.

A number of papers focus on the case of Hurricane Sandy. They all find price declines after the storm and, consistent with earlier studies, interpret them as evidence of increased salience of flood risk. Ortega and Taspinar (2017), for example, find that the prices of homes in New York City's evacuation zones (areas that encompass but are considerably larger than the FEMA flood zones) that were not damaged by Hurricane Sandy experienced

[1] Among this literature, McKenzie and Levendis (2010) points out higher compliance costs associated with rebuilding under more stringent National Flood Insurance Program (NFIP) guidelines could cause the price reduction as well.

a gradual decline over the five years after the storm, reaching 8% in 2017. Residential properties that were damaged by Hurricane Sandy meanwhile suffered an immediate 17-22% drop; but, by 2017, they had recovered to about the same level as evacuation-zone residential properties that did not suffer damage. The authors argue that the persistent price discount is due to the increase in the perceived risk in areas at risk of flooding. However, they do not separately examine effects on properties inside and outside the FEMA flood zone, nor do they consider heterogeneity across neighborhoods.

Gibson, Mullins and Hill (2017) use NYC residential property transactions from 2003 to 2016, and estimate that Hurricane Sandy reduced sales prices by 3-5%, which they argue was due to changes in perceived risk. In addition, sales prices for residential properties that were not categorized as flood-prone by the 1983 FEMA map but were categorized as flood-prone by the revised 2013 FEMA map, decreased by 7-8%. They hypothesize that the information signal of the FEMA map revision induces risk-premium changes, causing residential property sales price to decrease. However, while FEMA recommended preliminary maps following Hurricane Sandy, those proposed maps were never formally adopted, and the boundaries were still being negotiated in 2018 (Toure, 2018).[2] Therefore, it is highly unlikely that homeowners or homebuyers were fully aware of the map revision. As we show in the robustness check, it seems more likely that these properties saw reduced values because they actually experienced flooding and therefore had a new understanding of their risk.

[2] Indeed in 2016, FEMA announced that it would not use the 2013 flooding map and would continue using the 2007 map.

Our paper also contributes to a related literature on heterogeneity in flooding impacts, though we have found no study that separately looks at the effects of flooding inside and outside of pre-existing flood zones. Barr, Cohen, and Kim (2017) find that New York City houses, apartments, and commercial properties in census tracts with better subway access and higher incomes were more affected by Hurricane Sandy. They claim it is likely that residents in those neighborhoods are more responsive to the shock, but they only examine price effects through 2014 so they are capturing short-term effects. Bakkensen and Barrage (2017) also find that the capitalization of flooding risk is greater among non-owner-occupied properties that are located in wealthier and more educated zip codes. On the other hand, there is evidence to show that low-income and minority neighborhoods are more vulnerable to the harmful impacts of disasters (for example, Shirley, Boruff, and Cutter, 2012; Van Zandt et. al. 2012).

3. Data and analytical strategy

In October of 2012, Hurricane Sandy hit the east coast of the United States. It was the strongest storm on record to hit the coast, and New York City was hit particularly hard. The storm surge covered nearly nine percent of all residential units in the city, and roughly four percent of all households registered with the Federal Emergency Management Agency (FEMA) for post-disaster assistance (Furman Center, 2013). Hurricane Sandy is estimated to be the fourth-costliest hurricane on record in the U.S., after Hurricane Katrina in 2005, Hurricane Harvey in 2017, and Hurricane Maria in 2017.[3]

The sheer scale of New York City provides a sizable and diverse sample of properties and neighborhoods to study. Further, New York City neighborhoods experienced wide variation in levels of flooding and damage. For example, FEMA estimates that within Lower Manhattan, the Bowling Green neighborhood saw 58.1% of its land surface flooded while the Church Street neighborhood experienced a flooding rate of only 19.6%.

3.1 Data

We compile a rich micro-dataset that captures property sales transactions, parcel characteristics and flooding risk and storm surge for neighborhoods across New York City. The heart of our data is the universe of property sales transactions provided by New York City's Department of Finance. These data include the date and amount for each transaction and extend from 2006 to 2018. We focus on 1-3 family properties because their lower height (as compared to condos, coops, and multifamily rental buildings) makes them more vulnerable to damage.[4] They are also more likely to be owner-occupied and subject to flood insurance requirements if mortgaged and located in the FEMA flood zones. While we focus on 1-3 family properties, we also test for heterogeneous effects across property types (displayed in Appendix A).

[3]See the NOAA website for details: https://www.coast.noaa.gov/states/fast-facts/hurricane-costs.html
[4] In future analyses, we plan to replicate the regressions using assessed values AVs) instead of prices. Although AVs are stickier than prices, they are available for the universe of parcels in New York City, so we overcome the selection concerns that apply to the transaction data. Note that we exclude a few census tracts in the Rockaways where a large number of city-subsidized homes were sold around the time that Sandy hit (but unrelated to the storm).

Second, we supplement the sales data with parcel characteristics, like built year, height, size, and number of residential and commercial units, from the Department of Finance's Real Property Assessment Dataset (RPAD). These data track information on the universe of parcels in the city from 2006 through 2018.

Third, we obtain maps with the boundaries of the 100-year flood zones in effect at the time of Hurricane Sandy, as well as information on the damage incurred by the storm. Both are obtained from FEMA and displayed in Figure 1. The flood zones are used to proxy for the pre-storm flooding risk, since those in the 100-year zone are required to purchase flood insurance when assuming a home mortgage. The storm surge levels, on the other hand, capture the storm's actual physical impact. We obtain the surge map from the FEMA Modeling Task Force (MOTF), which uses high-water marks and surge sensor data to interpolate water surface elevation after the storm.[5] MOTF reports surge levels at a very micro level (one- or three-square meter), and we use them to calculate surge levels at both the block and census tract-level. The surge heights across blocks vary widely. Note that we use surge heights rather than FEMA's assessment of property damage because the surge heights are more clearly exogenous, though there is considerable overlap between the two measures.[6]

[5]Surge levels for the boroughs of Manhattan, Brooklyn, Queens and Staten Island are based on 1-meter digital elevation model (DEM) resolution and for the Bronx, 3-meter resolution. Information on the FEMA MOTF is available here: http://www.arcgis.com/home/item.html?id=307dd522499d4a44a33d7296a5da5ea0.

[6] The damage reports generated by FEMA are partially determined by surge information, as well as other inputs, like interpretations of visible aerial imagery, that can introduce bias and noise into the indicators. 8.62% of damaged properties in the FEMA damage map are outside the surge areas. Nonetheless, we replicate our analyses using the damage data for a robustness check and obtain qualitatively similar results.

Finally, we merge in information on residents and homebuyers. We obtain information on mortgage applicants (retaining only those who originated loans) from the Home Mortgage Disclosure Act (HMDA) data. They include information on the census tract of the property, the loan amount, the loan provider, and the mortgage applicant's race, income, and sex. We rely on these data to observe changes in the composition of homebuyers. We also use information on census tract median household income from the 2007-2011 American Community Survey to capture baseline differences in neighborhood income.

3.2 Dimensions of heterogeneity and buyers' response

As discussed above, we consider several dimensions of heterogeneity in price effects. First, we test for differences with respect to information about risk. We can distinguish price effects across properties located inside and outside the FEMA flood zones. If a property is located in the flood zone, the owner is required to purchase flood insurance if they obtain a mortgage for their home, and they also have salient information about the risk of future flooding. This is not the case for properties outside the flood zone. We expect that properties located in the flood zones will experience less severe price drops and a higher likelihood of recovery due both to the information about risk leading up to the storm and the insurance-aided physical rebuilding, assuming insurance provides reasonable coverage.[7] Prices for properties in the flood zone should reflect the potential for flooding-related damage even before Sandy occurred, and therefore the storm does not introduce any new information about risk. By contrast, the storm provided new information to potential buyers of properties outside of the flood zone that experienced storm surge.

[7] While we know that the designation of the FEMA flood zone did not change after Sandy, we are still investigating whether the cost of insurance in the zone changed.

Further, even if properties inside flood zones experience direct physical damage, the availability of insurance should cover much of the repair costs and speed up the recovery.

Second, we test for differential price effects and recovery across neighborhoods with different income levels. Income should capture both the degree to which the residents in the neighborhood possess the resources to rebuild post-Sandy and other unobserved pre-existing characteristics of the neighborhood like property blight and perceptions of local market strength. We also plan to supplement these analyses with information on the variation in property price appreciation across neighborhoods leading up to the storm.

Finally, we explore whether the storm changes the nature of investment, i.e. who is buying or building, in the areas with the biggest price declines. Using HMDA data, we test for differential changes in the income and racial composition buyer composition in area with more damage from the storm. We also test for changes in the institutional status of the buyer (i.e. investor or private individual). We expect to see changes due to some combination of different risk tolerances and the opening up of markets to buyers who might have been previously priced out.

3.3 Estimation

We estimate two sets of models, the first using the natural logarithm of sales price as the dependent variable and the second using information on mortgage applicants (such an income and race) as the dependent variable.

3.4.1 Prices

For the price models, the unit of analysis is the parcel-sale. We have an unbalanced panel of sales, such that each parcel does not transact in every year, and parcels sell at different frequencies. The price regression model takes the following general form:

$$ln(price)_{int} = \lambda_1 HighSurge_i + \beta_1 LowSurge_i + \lambda_2 HighSurge_i * PostSandy_t +$$
$$\beta_2 LowSurge_i * PostSandy_t + \delta B_{i,n} + N_n + \varphi Q_t + \theta D_{b,t} + e_{it} \qquad (1)$$

where *PostSandy* takes on a value of 1 starting in 2012 Quarter 4; *HighSurge* is 1 if the property is on a block that experienced an average surge of over two feet; *LowSurge* is 1 if the property is located on a block that saw, on average, some level of surge, but less than two feet.[8] We include $B_{i,n}$, a set of building characteristics (number of units, size, height, age, building class). N_n is a vector of census tract fixed effects; Q_t a vector of Year-Quarter dummies, and $D_{b,t}$, a vector of borough-year dummies to control for broader neighborhood changes over time. The sample is restricted to sales in sub-borough areas with either at least one block with surge or at least one property in the flood zone, so the comparison group is nearby properties located on blocks without any storm surge. We also run versions of this regression interacting *HighSurge* and *LowSurge* with year-specific dummies instead of a single *PostSandy* dummy to estimate prices effects over time and to test for pre-existing trends.

[8] We also run models where we use a continuous variable calculated as the share of damaged properties on the same block as property i (excluding parcel i). The results are consistent with those presented: a higher share of damage yields bigger price declines.

In some models, we also add a variable (FloodZone) to identify properties that are located in the FEMA flood zone. This allows us to test whether the storm led to a reduction in the value of properties located in the flood zone, independent of damage. Here the comparison group is properties outside the FEMA flood zone but still in the same census tract.

$$ln(price)_{int} = \lambda_1 HighSurge_i + \beta_1 LowSurge_i + \gamma_1 FloodZone_i + \lambda_2 HighSurge_i * PostSandy_t + \beta_2 LowSurge_i * PostSandy_t + \gamma_2 FloodZone_i * PostSandy_t + \delta B_{i,n} + N_n + \varphi Q_t + \theta D_{b,t} + e_{it} \quad (1)$$

While we cannot employ property-level fixed effects, we are able to include census tract fixed effects, and thus we are able to identify effects from differences in price changes for properties in the same census tracts facing varying degrees of property damage.

For all models, we also stratify, and then analyze, the sample across properties inside and outside of the FEMA zone and across tracts with median incomes above and below the median for all neighborhoods in our sample.

3.4.2 Mortgage applicants

We use the HMDA data to test for compositional changes in property buyers. Here, the unit of analysis is the mortgage applicant and we examine two outcomes, income and race. The general regression model takes the following form:

$$Outcome_{it} = \beta_1\ TractHighSurge_i * PostSandy_t + \beta_2\ TractLowSurge_i * PostSandy_t + \delta S_i + \theta D_{b,t} + e_{it} \qquad (2)$$

where *Sandy* takes on a value of 1 starting in 2013; *TractHighSurge* is 1 if the average surge level in tract *i* is higher than 2, and *TractLowSurge* is 1 if the average surge level in tract *i* is lower than 2 feet and higher than 0 feet. We include S_i, census tract fixed effects, and $D_{b,t}$, a vector of borough-year dummies, to control for broader neighborhood changes over time. The sample is restricted to sub-borough areas with at least one damaged property or one property within the flood zone.[9] We separately estimate for census tracts inside and outside of the FEMA zone and for tracts with median incomes above and below $68,777, the median for all census tracts in our sample. Again, we also run versions of this regression interacting *TractSurge* dummies with year-specific dummies instead of a single *PostSandy* dummy to estimate prices effects over time and to test for pre-existing trends.

Finally, to try to pinpoint mechanisms (and distinguish the new information and lingering blight channels), we use data from the Department of Buildings on alteration permits to examine whether some neighborhoods saw more investment in repairs after the storm.

4. Preliminary findings

4.1 Composition of the sample

[9] Sub-borough areas are groups of census tracts summing to at least 100,000 residents, determined by the New York City Department of Housing Preservation and Development.

In order to implement our estimation strategy, we need enough variation in terms of location in the flood zone and degree of flooding from the storm. Table 1 shows cross-tabulations across our main indicators of risk exposure (location in the flood zone) and surge heights for 1-3 family properties. The correspondence between *FloodZone* and both *HighSurge* and *LowSurge*, is naturally positive, but there are actually more properties located on high-surge blocks outside the flood zone than inside, suggesting there is enough variation to separately estimate the effects of surge heights inside and outside of the flood zone.

4.2 Testing for price effects

We first examine the extent of price declines for 1-3 family properties affected by the storm. These results are displayed in Table 2 and show that these small residential properties inundated in the storm sold at a 14% discount after the storm in high-surge areas, and 11% discount in low-surge areas, compared to areas without any flooding. (By contrast, as shown in Appendix A, other types of properties in surge areas -- coop and condo buildings, commercial and rental properties -- saw no significant change in value.) As shown in column 2, this price effect is similar with and without controls for being in the flood zone, and we see no change in the flood zone discount after the storm, suggesting that the storm did little to change the risk premium buyers demanded for properties in the flood zone. It appears that the price response is largely driven by the degree of storm impact, and the new information about risk that it introduces. Note that the coefficients on other variables display coefficients consistent with expectations. For example, larger and newer properties all sell for more.[10]

Figure 2 shows results from regressions with individual year dummy variables and confirms that there were no pre-existing trends in prices of properties that were located on blocks that saw flooding during the storm, relative to those on blocks without any surge. The figures also show that impacts are persistent. In the year after the storm, 1-3 family properties located on blocks that experienced high storm surges saw a 16 percent decline relative to similar properties on blocks that saw no flooding. On average, values of these properties remained about 12 percent lower than pre-storm levels six years after the storm. Impacts on prices of properties located on blocks that saw low surge levels were initially much smaller but then fell to about the same level as prices on high-surge blocks six years after the storm.

4.3 Testing for heterogeneity

These average effects may conceal considerable heterogeneity in the price response, across flood zone status and neighborhood income level.

4.3.1 Flood Zone

We first consider whether prices respond differently inside and outside of the FEMA flood zones. We assume that the zone designations, and the flood insurance required if financing a home inside the zone, signals both knowledge about flood risk leading up to Sandy and

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[10] The age dummy indicates whether the building age is missing. Many properties do not have an accurate build year because they are extremely old.

also an ability to recoup losses that are not present for properties outside the flood zone. Figure 3 distinguishes between the effects of storm flooding inside and outside of the flood zone and shows that properties on high-surge blocks inside the flood zone experienced an immediate price decline after the storm but then recovered right away. Low-surge blocks in the flood zone meanwhile saw no price declines at all in the aftermath of the storm. By contrast, price effects are large and persistent outside of the flood zone, both for properties on high-surge blocks and those on low-surge blocks. (again, we see no significant pre-trends). These results are also evident in the coefficients displayed in the last two columns of Table 2.

4.3.2 Neighborhood characteristics

As for heterogeneity across neighborhoods with different economic circumstances, we expect that property owners in higher income neighborhoods are more able to repair their properties after the storm and mitigate the damage (and the subsequent price discounts) without insurance. It is also possible that higher income neighborhoods possess other features or fundamentals that signal better returns on investment in the future (even in the presence of increased flood risk). While the current analysis cannot tease apart these mechanisms, future analyses will address them. The coefficients on *HighSurge*PostSandy* and *LowSurge*PostSandy* in Table 3, which shows results for the sample of 1-3 family properties stratified by the income of the neighborhood, are significantly different across high-income and low-income areas. Consistent with predictions, price drops are larger for low-income areas, suggesting that higher income households were able to mitigate the negative impacts through reinvestment, or perhaps that buyers simply had more confidence in the ability of these neighborhoods to rebound. These differences hold when we restrict the sample to properties outside of the FEMA flood zone.

We see a consistent, but more nuanced, story when we look at the time path of prices (see Figure 4): properties on high-surge blocks in higher income neighborhoods (the cutoff is set as the median for the sample, or $68,777) suffer a significant price discount immediately after the storm for being damaged (22 percent). These properties partially recover their values over time though never quite get back to pre-storm (2011) levels. In low-income areas, by contrast, we see only a modest immediate impact on prices, which appears to grow over time and shows no sign of recovery. We see a similar, though delayed and less pronounced, pattern of impacts on low-surge blocks in high- and low-income neighborhoods. These same differences appear when restricting analysis to properties outside the flood zone.

4.4 Buyer composition

We also examine changes in the composition of those interested in investing or buying in Sandy-affected areas. Do the observed price discounts among properties with storm-induced damage lead to different kinds of homebuyers? We use HMDA data to test for changes in characteristics of prospective homebuyers. We test specifically for shifts in the income and race of the households applying for mortgages (using mortgage applicants as a proxy for the universe of homebuyers interested in the neighborhood).[11] Table 4 displays these results. Recall, for these data we cannot identify the parcel or block of the applicant;

[11] Note that effects are qualitatively the same when we analyze shifts in the composition of actual borrowers rather than applicants.

the finest geographic identifier available is the census tract. Thus we create tract-level metrics of storm surge by calculating the average surge level by census tract. The samples are restricted only to sub-borough areas with at least one block that saw storm surge. The results provide evidence of a decline in the income of mortgage applicants in areas that suffered more flooding from the storm but were outside of the FEMA flood zone.[12] Figure 5, however, shows the time path of effects and suggests that some of this reduction in income may have simply been a continuation of a pre-existing trend.

Table 5 and Figure 6 display results from similar models predicting the probability that an applicant is black or Hispanic, controlling for their income.[13] The effects here are stronger, at least in low-income areas. We see evidence that the storm triggered a racial shift in the composition of homebuyers; the likelihood that a borrower is black or Hispanic increases after the storm in neighborhoods that experienced more flooding relative to other nearby neighborhoods. Effects again appear to be just as large in high- and low-surges areas and are concentrated in lower income tracts outside the flood zone. We caution, however, that because we are only capturing those buyers who take out mortgages to finance their home purchases, we may be under-representing more affluent (and possibly white) buyers.[14]

4.4 Exploring Mechanisms

The fact that price impacts and impacts on racial change are similar in high- and low-surge areas suggests that the mechanism may be more about information and risk signaling than

[12] Census tracts within FloodZone are either high-surge or low-surge, and so we do not have the comparison group for sample within FloodZone.
[13] The results are consistent when we do not control for the income.

about actual physical damage (which was presumably greater in high-surge areas).[15] Indeed, when we lower the high/low surge cutoff from 2 feet to 0.5 feet, we still observe significant impacts in the low surge area, and the magnitude is largely unchanged. (See Appendix B.)

To further understand whether price declines are due to changes in risk perception or physical blight, we explore building alteration permits, which we can observe over time. We acknowledge that building permits likely undercount actual repair activity, as some share of alterations will not be formally filed with the City. Nonetheless, as an initial test, we run similar models with the number of alteration permits as the dependent variable (See Figure 7). We see a relative increase in permits in the year after Sandy hit on high-surge blocks, but somewhat surprisingly, the filing activity rises for all surge blocks and then peaks in 2016, four years after the storm.[16] Repairs are concentrated inside the FEMA zone, suggesting that more repairs were made inside the flood zone, perhaps because of the availability of insurance. Further, we only see a post-storm increase in permits outside the FEMA zone in higher income neighborhoods, again suggesting fewer repairs were made in lower-income neighborhoods. In sum, this suggests that some of the persistent price effects may be due to lingering physical damage in the hard-hit areas.

However, the timing is inconsistent with our finding that prices of properties on surge blocks inside the FEMA zone fully recover by 2014 (including those in high-income areas largely recover by then), as the spike in permits isn't visible until 2015 or 2016. Thus we

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16 This timing is consistent with when funding arrived through the Build-it-Back post-Sandy aid program.

are left with somewhat stronger, but certainly not decisive, support for the new information about risk hypotheses as a mechanism explaining the persistent effects.

Furthermore, for areas outside the FEMA zone, we confirm that the distribution of severely damaged properties (i.e. those whose repair may be delayed or more comprehensive than an alteration) is similar across low- and high-income neighborhoods, though we see that the uptick in building permits happens somewhat more quickly after the storm in higher income areas. Again, this does not correspond to an increase in prices, which are persistently depressed in both high- and low-income neighborhoods outside the FEMA zone.

One potential alternative mechanism is that the effects we are seeing outside the flood zone reflect the effect of the new flood zone boundaries that were proposed in 2013 but never adopted. But when we re-estimate our models using the new flood zone boundaries, as shown in Figure 8, we find very similar results; we see price effects on blocks that saw storm surge that are outside both the old and new flood zones. Buyers may view the actual flooding seen in the storm as a better signal of risk than any official flood zones.

In future drafts, we will explore spatially detailed information about insurance coverage and government-subsidized repairs. We will also explore other types of investment, like the construction of new buildings and business openings.

4.5 Robustness

We ran several robustness tests. First, we replicated our models using FEMA's estimate property damage instead of surge level, and obtained very similar results.[17] As shown in Figure 9, the results are similar. Second, we re-estimated our models after excluding properties in Staten Island, as the government buy-out offers were concentrated in Staten Island. We obtained similar results without sales in Staten Island, as shown in Figure 10.

5. Conclusions

In this paper we consider the case of Hurricane Sandy and its impact on real estate prices in New York City. We find significant price discounts after the storm. In the year after the storm, 1-3 family properties on blocks experiencing high surges in the storm saw initial price declines of about 16 percent. On average, values of these properties remained about 12 percent lower than pre-storm levels six years after the storm.

Importantly, we see nearly full recovery in the values of properties that are located inside FEMA zones, perhaps because these areas were already considered risky before the storm so the storm did not provide any additional information, or perhaps because insurance largely covered repair costs. Price for properties outside the FEMA zone drop and remain depressed through 2018.

[17] FEMA determines the damage at the building level based on visible aerial images and surge heights. We categorize a property as damaged if it has any degree of damage (affected, minor, major, or destroyed). We also calculate, for every property, the share of other properties on its block that suffered damage in the storm.

The findings also indicate that properties in higher income neighborhoods that saw high storm surges experienced large initial price shocks but then recovered over time. By contrast, those in lower income areas experienced a delayed response and have exhibited no sign of recovery. Finally, the storm led to a change in the composition of homebuyers in hard-hit areas that were outside the flood zone and/or low-income. After the storm, homebuyers in those areas were more likely to be black and Hispanic.

As for mechanisms, we see similarly persistent effects on low-surge and high-surge blocks, despite the fact that properties on low-surge blocks presumably suffered less damage. While our analysis of building permits finds some evidence that properties within the FEMA zone saw more repairs, the spike in permits occurred two years after prices had recovered. Furthermore, the increase in alteration activity observed in low-surge, high-income neighborhoods outside of the FEMA zone does not correspond with any subsequent price increase. These results together suggests that any persistence in price drops may be due more to changes in information about risk, rather than differences in physical reinvestment.

In short, we find robust evidence that Hurricane Sandy led to substantial and sustained reductions in property values in affected neighborhoods. Six years after the storm, the value of properties in areas hard-hit by storm surges were still depressed. Unlike past research, we uncover considerable heterogeneity in response. Properties on hard-hit blocks inside the flood zone and in higher income areas had largely recovered their value by 2014. Only the properties on blocks located in low-income neighborhoods outside the FEMA flood zone continued to suffer from depressed values. The new information about storm risk appears to have more permanently reduced demand, at least when layered onto weaker sub-markets.

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Table

Table 1: Cross-tabulation of Flood Zone and Surge Heights

1-3 families			
frequency	*HighSurge*	*LowSurge*	*NoSurge*
FloodZone=0	5,174	14,313	174,019
(%)	2.67	7.40	89.93
FloodZone=1	4,168	1,204	271
(%)	74.86	21.34	4.80

Table 2: Price effects for 1-3 family properties

ln(sales prices)	(1) NYC	(2) NYC	(3) NYC	(4) Inside FloodZone	(5) Outside FloodZone
ln(# of units)	0.0318	0.0329	0.0334	-0.0795	0.0379
	(0.0315)	(0.0315)	(0.0315)	(0.161)	(0.0315)
ln(building area)	0.266***	0.266***	0.266***	0.337***	0.262***
	(0.0147)	(0.0144)	(0.0144)	(0.0519)	(0.0148)
# of stories	-0.00431	-0.00414	-0.00421	-0.00145	-0.00547
	(0.00401)	(0.00398)	(0.00396)	(0.00179)	(0.00529)
Building age	-0.00263***	-0.00262***	-0.00261***	-0.00224***	-0.00259***
	(0.000170)	(0.000167)	(0.000167)	(0.000689)	(0.000168)
Building age square	6.35e-06***	6.27e-06***	6.26e-06***	6.25e-06	6.20e-06***
	(1.60e-06)	(1.56e-06)	(1.56e-06)	(7.03e-06)	(1.56e-06)
Building age dummy	-23.85***	-23.51***	-23.46***	-23.08	-23.25***
	(6.393)	(6.263)	(6.263)	(28.43)	(6.264)
HighSurge		0.00915	-0.00884	-0.0593	0.00284
		(0.0200)	(0.0182)	(0.0483)	(0.0215)
*HighSurge*PostSandy*		-0.146***	-0.142***	-0.0906**	-0.142***
		(0.0212)	(0.0179)	(0.0411)	(0.0221)
LowSurge		0.0537***	0.0499***	-0.0241	0.0527***
		(0.0143)	(0.0140)	(0.0508)	(0.0146)
*LowSurge*PostSandy*		-0.113***	-0.112***	-0.0324	-0.116***
		(0.0151)	(0.0146)	(0.0519)	(0.0153)
FloodZone	-0.00926	-0.0437**			
	(0.0195)	(0.0209)			
*FloodZone*PostSandy*	-0.109***	0.00930			
	(0.0189)	(0.0215)			
Constant	11.28***	11.25***	11.25***	15.36***	11.24***
	(0.282)	(0.275)	(0.274)	(2.931)	(0.268)
Observations	199,149	199,149	199,149	5,643	193,506
R-squared	0.251	0.253	0.253	0.314	0.251
Number of tract	1,500	1,500	1,500	114	1,496

Standard errors are clustered by census tract in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Census tract fixed effects, YearQtr dummies, Year*Boro dummies, building classes are controlled.

Table 3: Heterogeneity in Price Effects by Neighborhood Income

ln(sales prices)	(1) Low-income	(2) High-income	(3) Outside FEMA& Low-income	(4) Outside FEMA& High-income
ln(# of units)	0.0387	0.0145	0.0392	0.0235
	(0.0429)	(0.0340)	(0.0426)	(0.0350)
ln(building area)	0.222***	0.300***	0.218***	0.298***
	(0.0203)	(0.0154)	(0.0203)	(0.0161)
# of stories	0.0137***	-0.0102	0.0152***	-0.0202**
	(0.00447)	(0.00698)	(0.00450)	(0.00870)
Building age	-0.00252***	-0.00274***	-0.00256***	-0.00262***
	(0.000311)	(0.000183)	(0.000312)	(0.000182)
Building age square	6.81e-06**	6.27e-06***	6.93e-06**	6.08e-06***
	(2.92e-06)	(1.37e-06)	(2.92e-06)	(1.35e-06)
Building age dummy	-25.98**	-23.29***	-26.49**	-22.52***
	(11.70)	(5.546)	(11.69)	(5.452)
HighSurge	0.00643	-0.0231	0.0183	-0.0191
	(0.0313)	(0.0202)	(0.0324)	(0.0263)
*HighSurge*PostSandy*	-0.210***	-0.0943***	-0.198***	-0.0872***
	(0.0295)	(0.0175)	(0.0311)	(0.0245)
LowSurge	0.0385*	0.0532***	0.0460**	0.0531***
	(0.0201)	(0.0171)	(0.0208)	(0.0178)
*LowSurge*PostSandy*	-0.128***	-0.0967***	-0.133***	-0.0998***
	(0.0230)	(0.0172)	(0.0239)	(0.0180)
Constant	10.55***	10.39***	10.31***	10.20***
	(1.091)	(1.041)	(1.106)	(1.049)
Observations	98,517	100,632	96,582	96,924
R-squared	0.246	0.274	0.246	0.271
Number of tract	951	549	948	548

Standard errors are clustered by census tract in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Census tract fixed effects, YearQtr dummies, Year*Boro dummies, building classes are controlled. The income cutoff is $68,777, which is the median income for the sample.

Table 4: Analysis of Mortgage Applicants' Income

ln(Applicant income)	(1) NYC	(2) Low-income	(3) High-income	(4) Low-income Outside FEMA	(5) High-income Outside FEMA
*HighSurge*PostSandy*	-0.0131	-0.0595***	0.0163	-0.148***	-0.0629*
	(0.0134)	(0.0213)	(0.0169)	(0.0311)	(0.0324)
*LowSurge*PostSandy*	-0.0292**	-0.0350	-0.0263	-0.0604**	-0.0926***
	(0.0148)	(0.0220)	(0.0211)	(0.0286)	(0.0294)
Constant	4.689***	1.975	5.798***	1.083	7.413***
	(1.067)	(1.622)	(1.388)	(2.460)	(1.586)
Observations	413,736	190,129	223,607	160,104	166,925
R-squared	0.023	0.038	0.015	0.041	0.014
Number of tract	1,851	1,208	643	1,070	513

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Borough*Year and SBA dummies are controlled. The median income cutoff is $68,777, which is consistent with price hedonic regressions.

Table 5: Analysis of Mortgage Applicants' Race

Probability of being black or Hispanic	(1) NYC	(2) Low-income	(3) High-income	(4) Low-income Outside FEMA	(5) High-income Outside FEMA
*HighSurge*PostSandy*	0.0256***	0.0416***	0.00953	0.0714***	0.0152**
	(0.00647)	(0.0121)	(0.00621)	(0.0276)	(0.00736)
*LowSurge*PostSandy*	0.0400***	0.0636***	0.0130*	0.0785***	0.0135
	(0.00651)	(0.0105)	(0.00765)	(0.0132)	(0.00938)
ln(income)	-0.0104***	-0.0198***	-0.00474***	-0.0224***	-0.00412**
	(0.00174)	(0.00358)	(0.00167)	(0.00386)	(0.00179)
Constant	0.0877	-1.999*	0.773	-3.289**	1.078
	(0.542)	(1.152)	(0.625)	(1.665)	(0.735)
Observations	335,627	157,273	178,354	132,915	132,787
R-squared	0.005	0.010	0.002	0.012	0.002
Number of tract	1,837	1,200	637	1,064	509

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Borough*Year and SBA dummies are controlled. The median income cutoff is $68,777, which is consistent with price hedonic regressions.

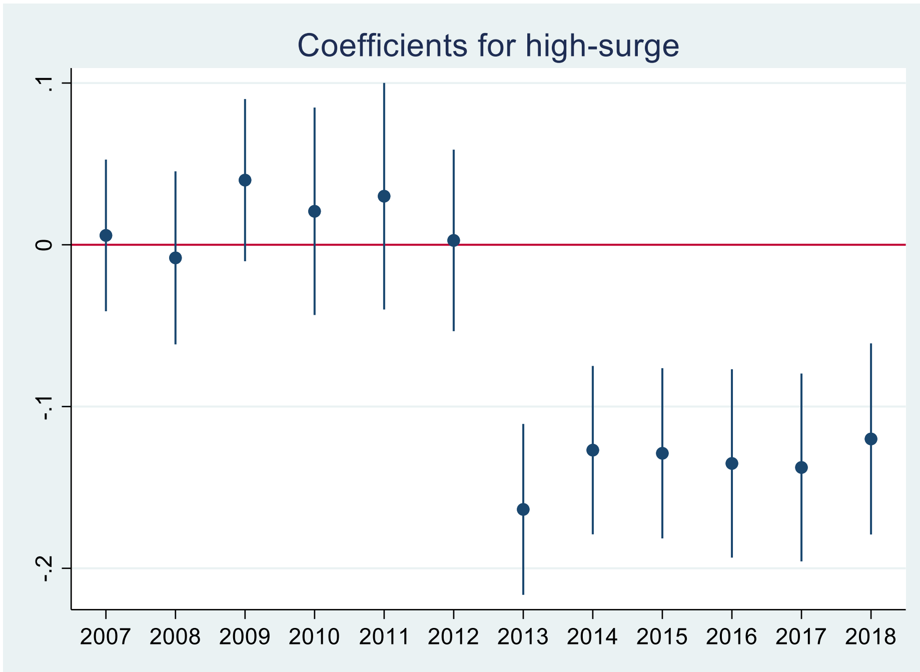
Figure

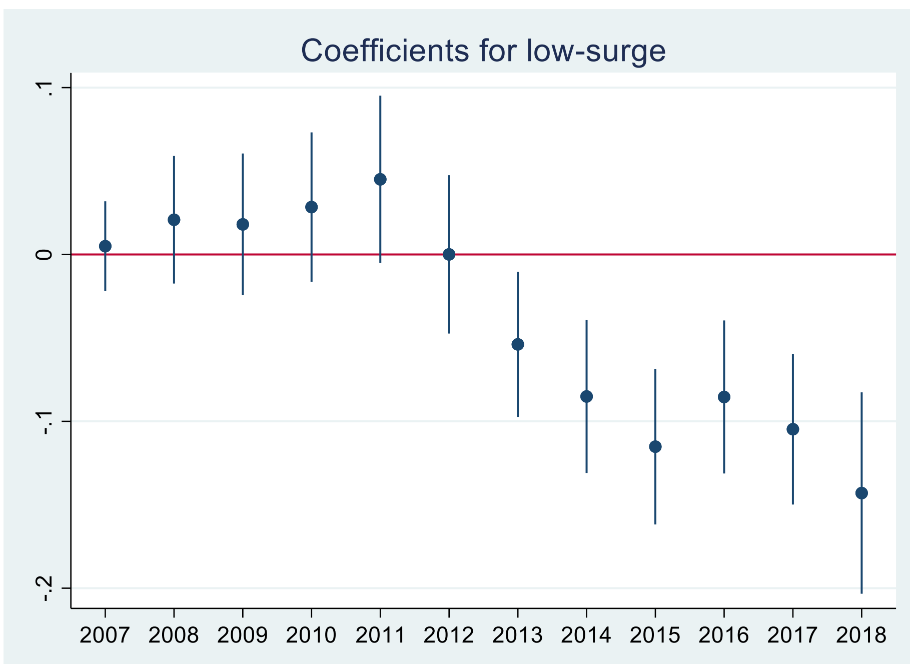
Figure 1: New York City FEMA maps

Note: The left map is FEMA 100-year flood zone as of 2012. The right map shows properties damaged by Hurricane Sandy – black points are "major damaged" or "destroyed", and grey points are "minor damaged" or "affected".

Figure 2: 1-3 family properties sales prices across year

NYC



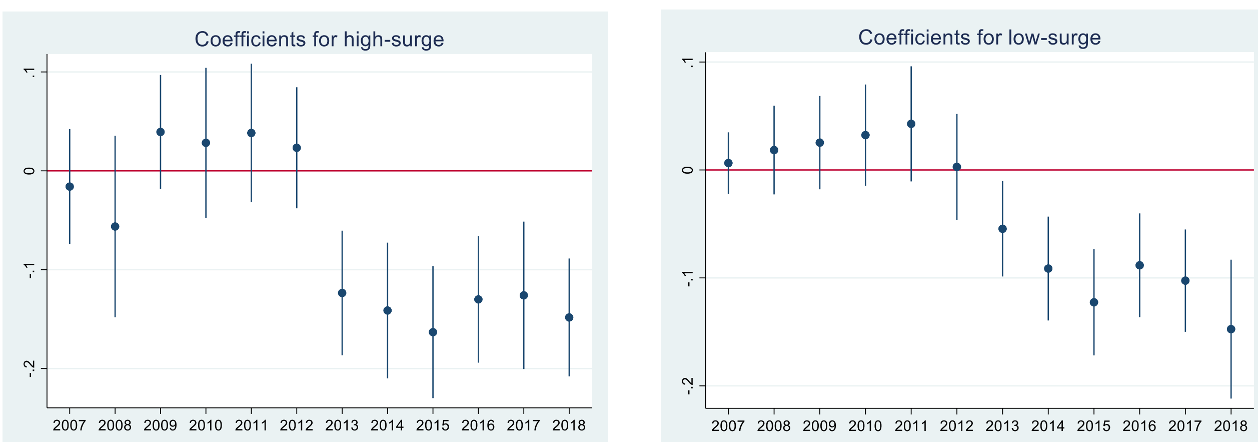


Note: Census tract fixed effects, YearQtr dummies, Year*Boro dummies, building classes and building characteristics are controlled.

Figure 3: 1-3 family properties inside/outside FEMA zone

Inside FEMA zone

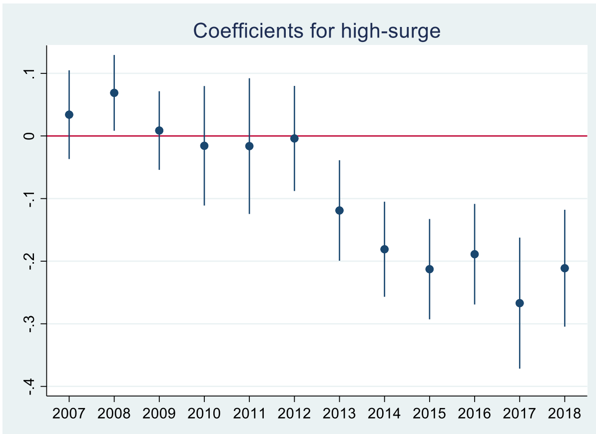
Outside FEMA zone

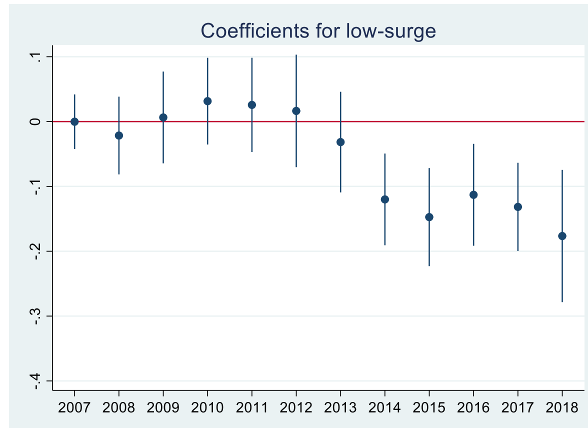


Note: Census tract fixed effects, YearQtr dummies, Year*Boro dummies, building classes and building characteristics are controlled.

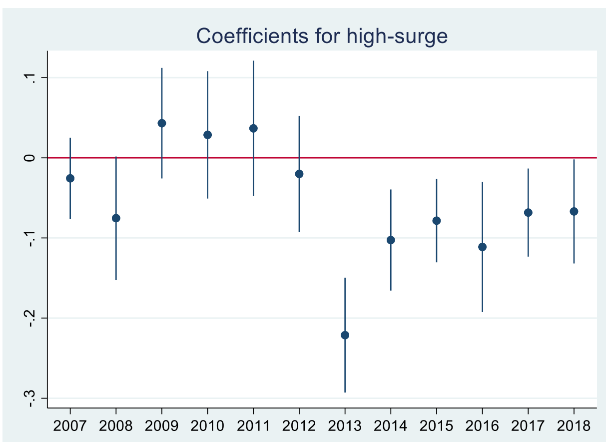
Figure 4: 1-3 family properties by neighborhood income level

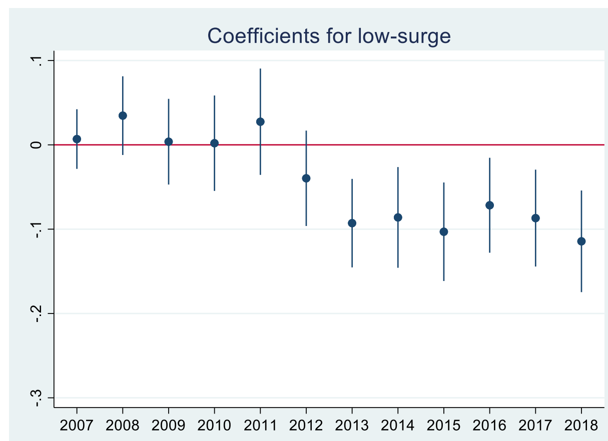
Low-income



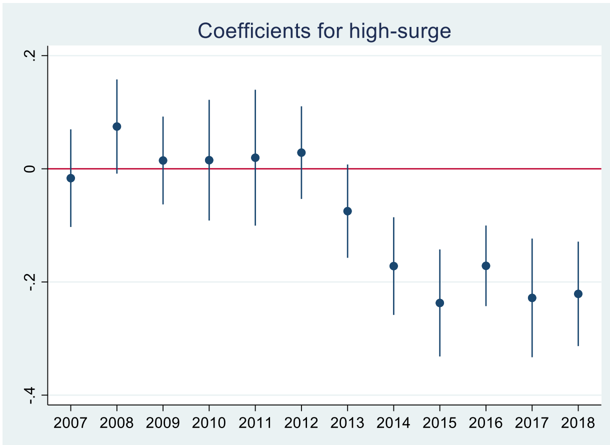


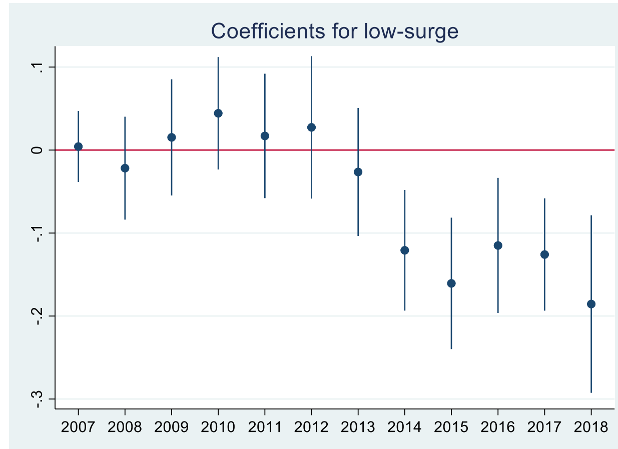
High-income



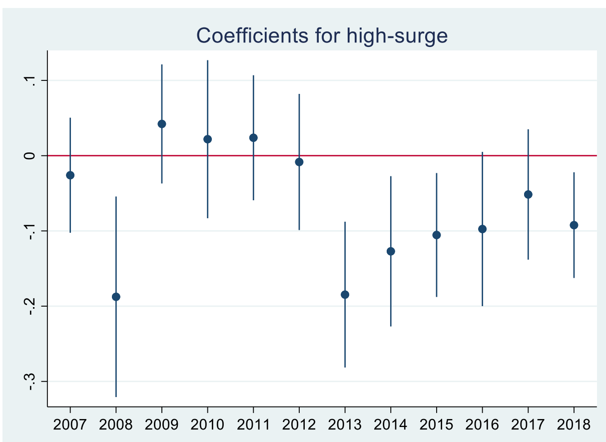


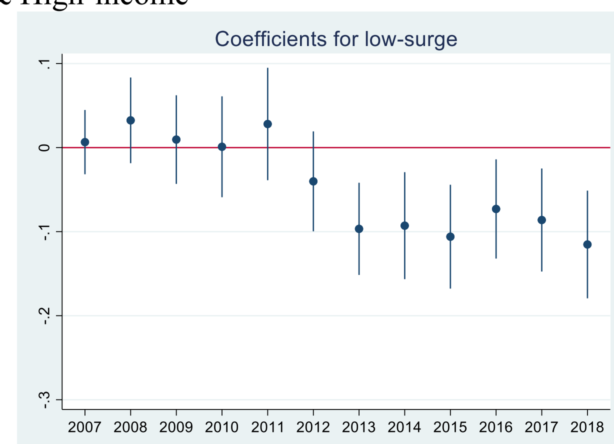
Outside FEMA zone & Low-income





Outside FEMA zone & High-income

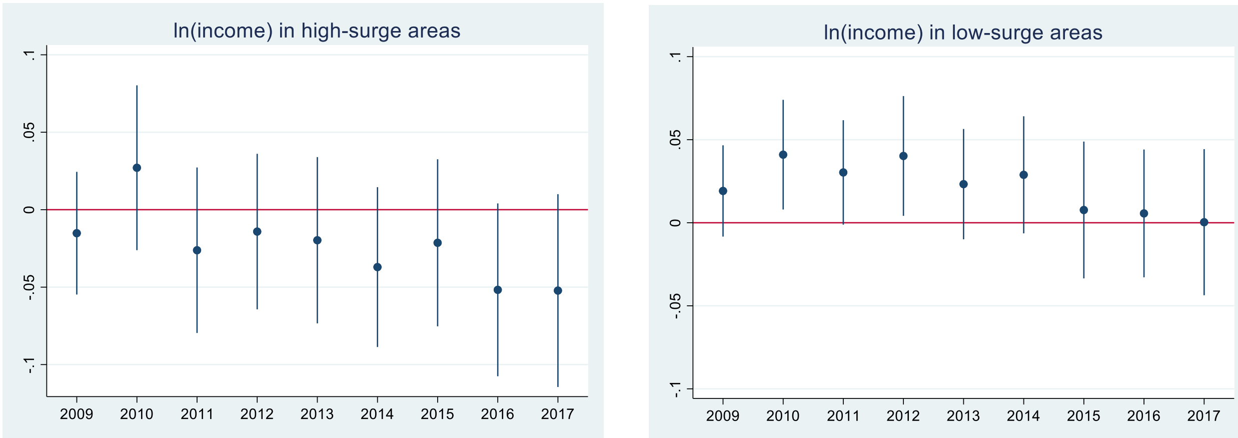




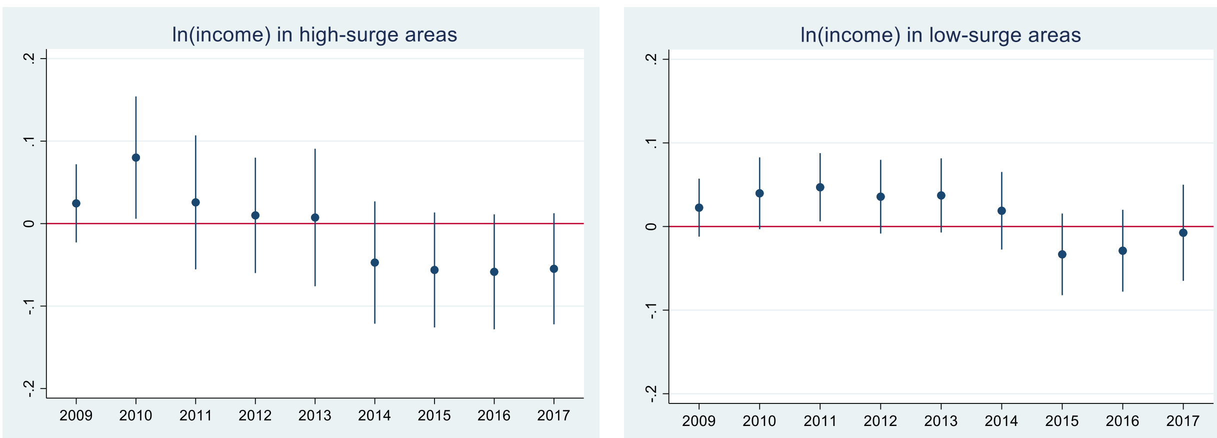
Note: Census tract fixed effects, YearQtr dummies, Year*Boro dummies, building classes and building characteristics are controlled.

Figure 5: HMDA Applicant Income Analysis

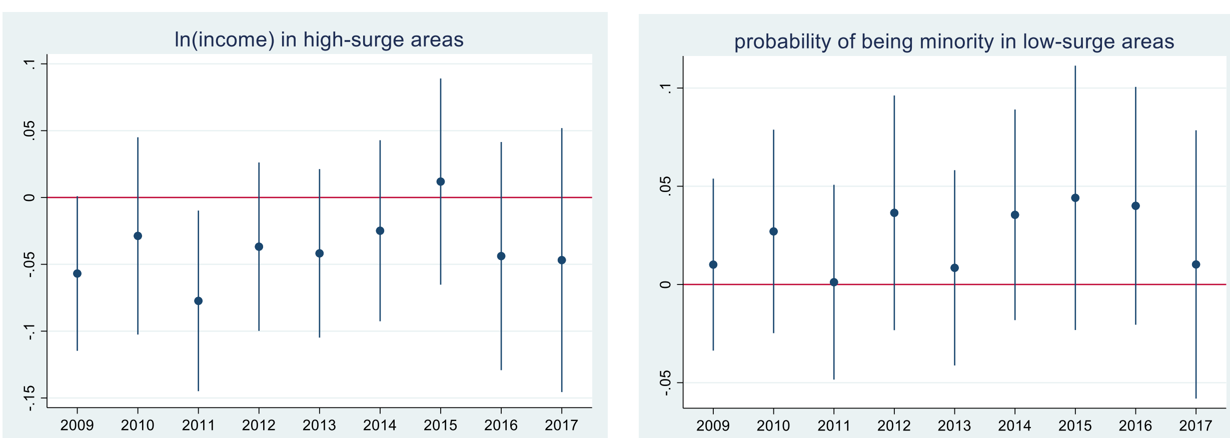
NYC



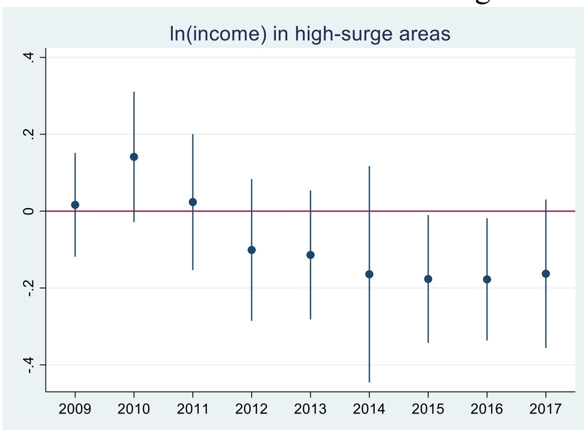
Low-income

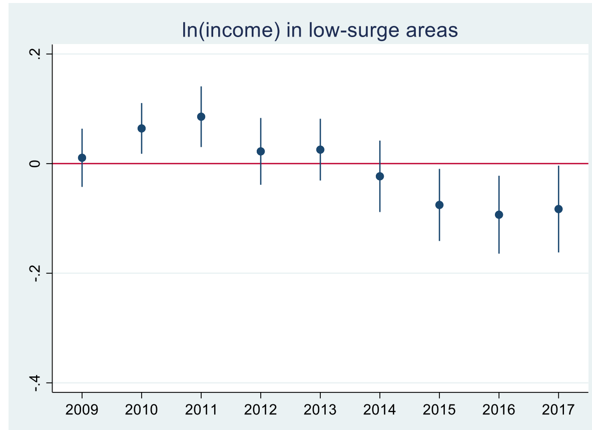


High-income

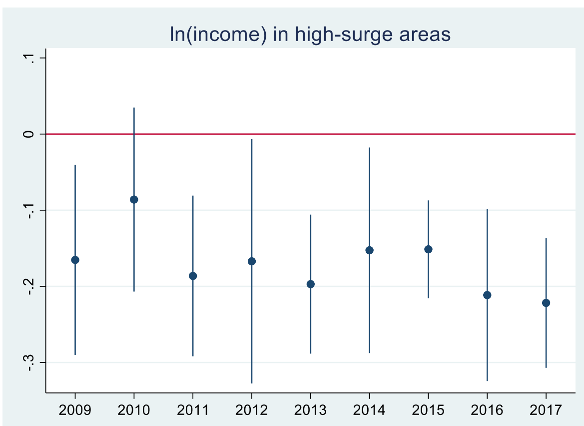


Low-income neighborhoods outside FEMA zone





High-income neighborhoods outside FEMA zone



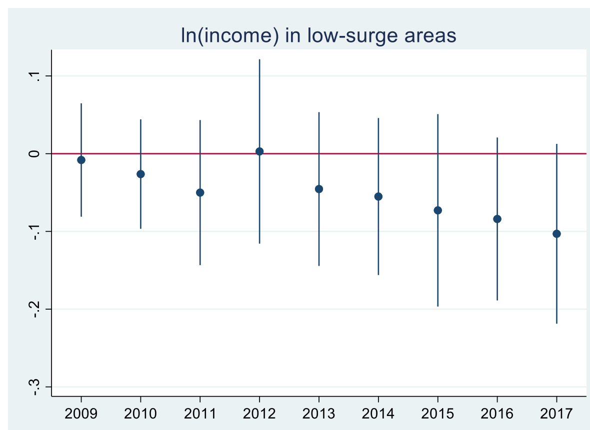
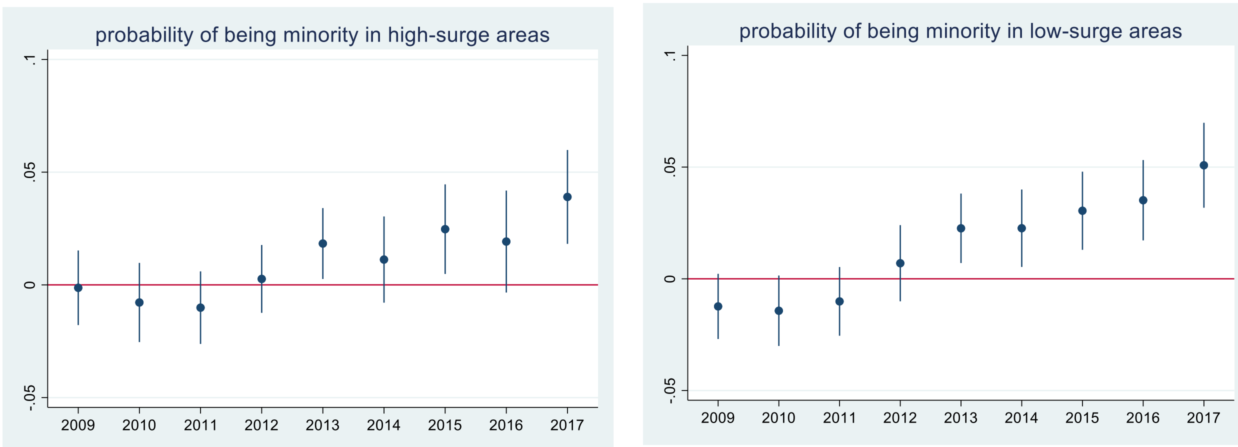
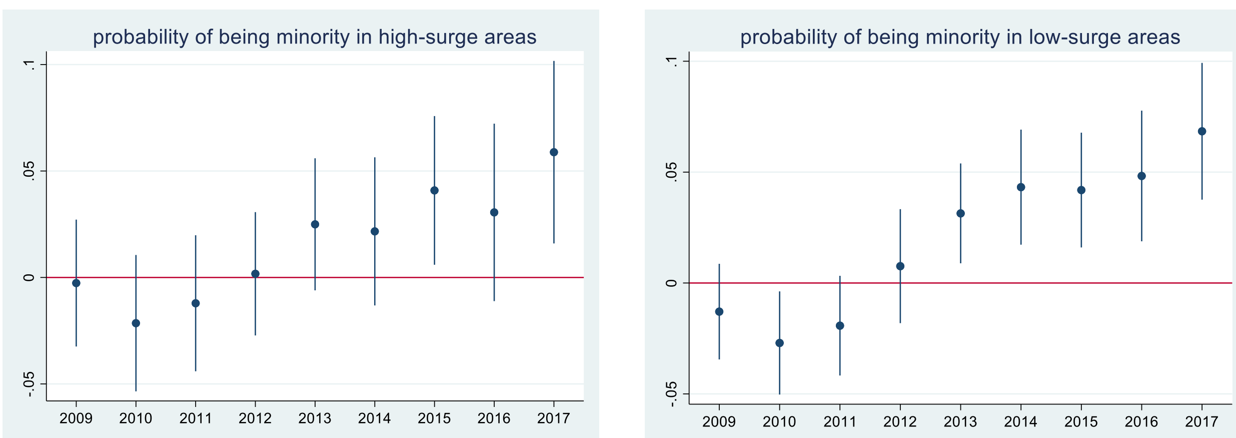


Figure 6: HMDA Applicant Race Analysis

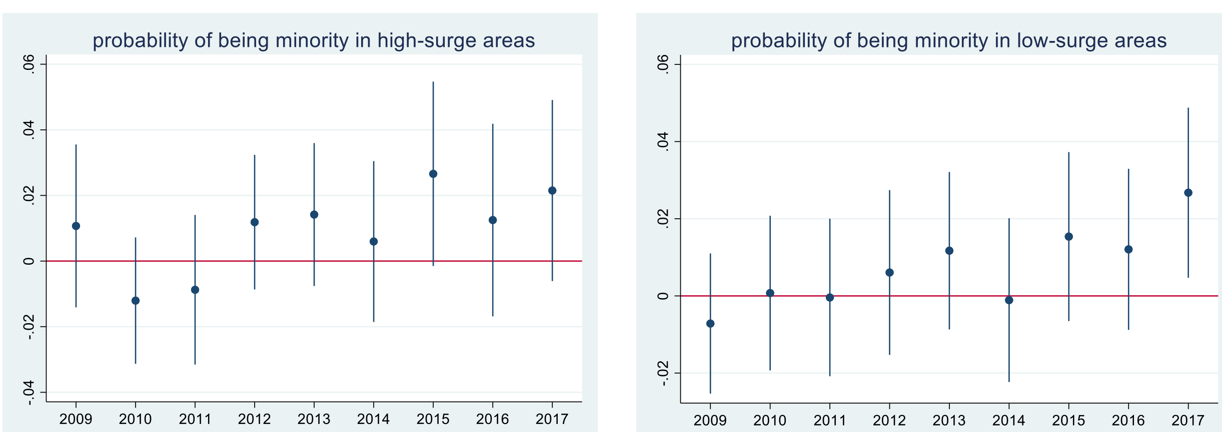
NYC



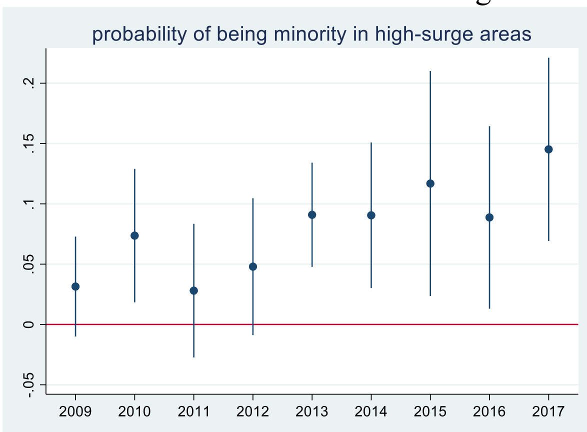
Low-income

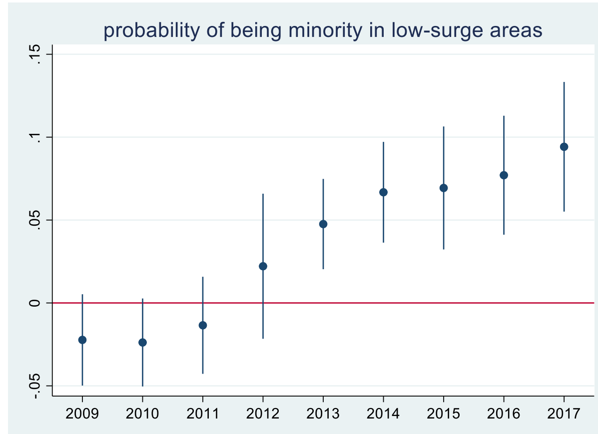


High-income

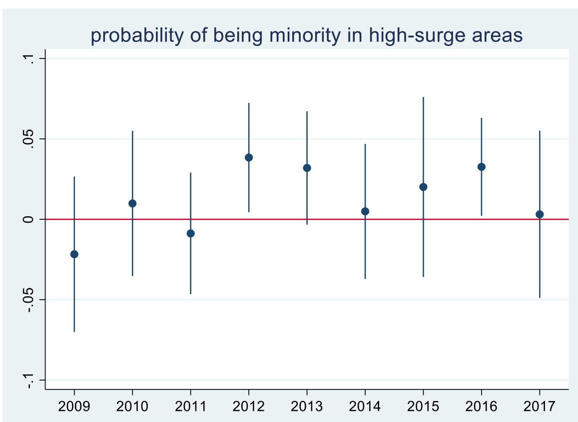


Low-income neighborhoods outside FEMA zone





High-income neighborhoods outside FEMA zone



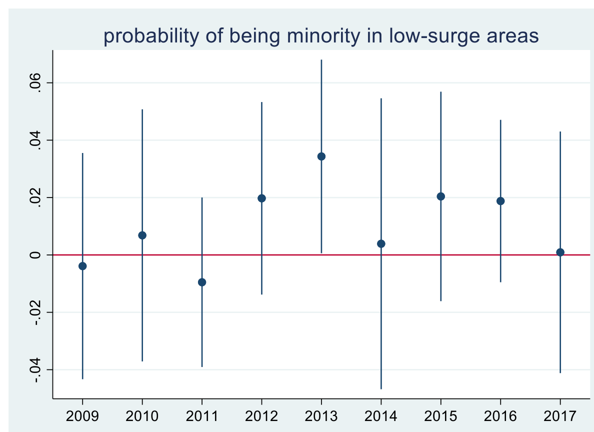
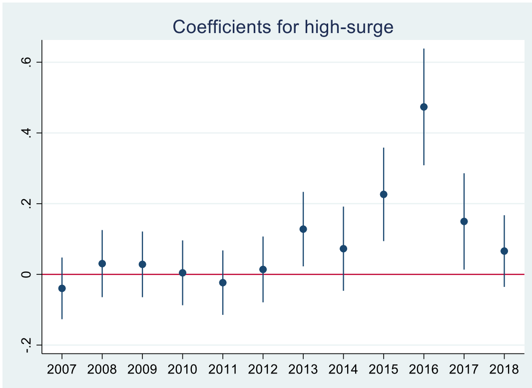
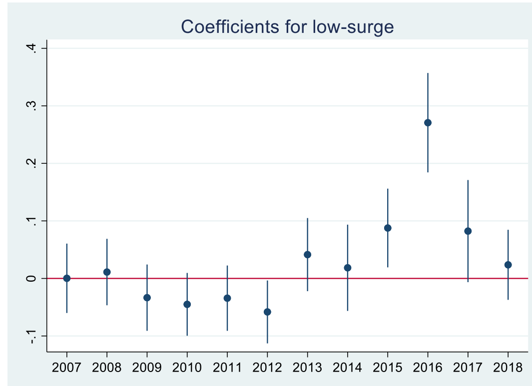


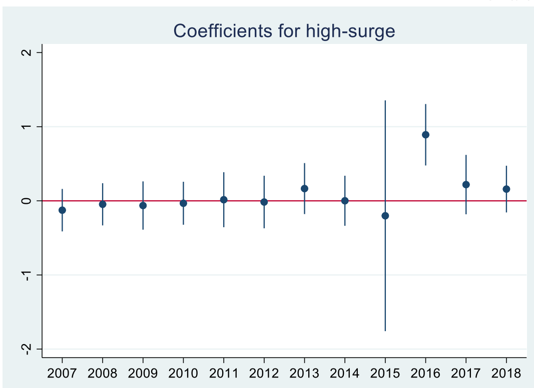
Figure 7: Annual Alteration Working Permits

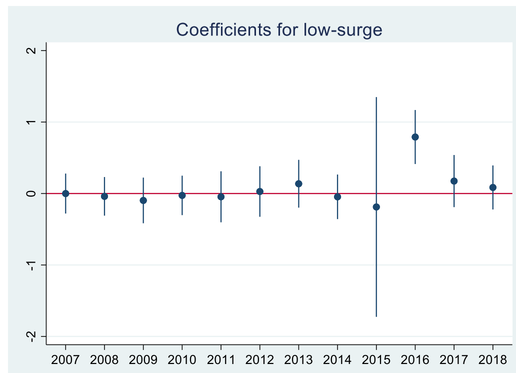
NYC



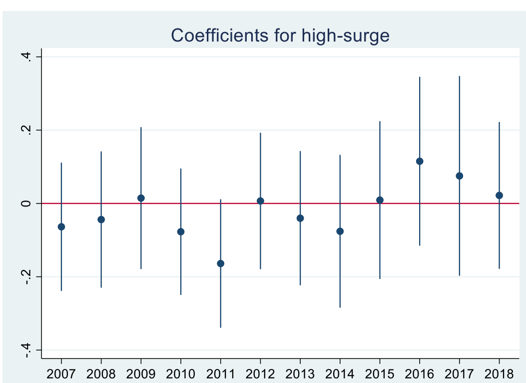


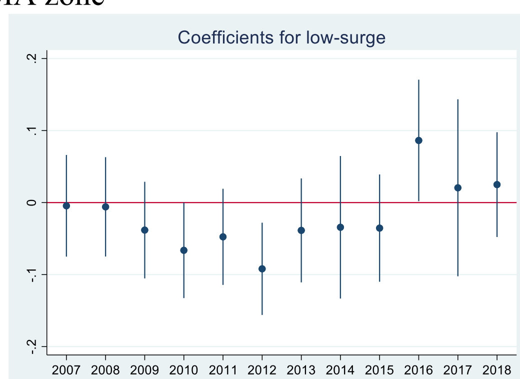
Inside FEMA zone





Outside FEMA zone





Low-income Neighborhoods outside FEMA

High-income Neighborhoods outside FEMA

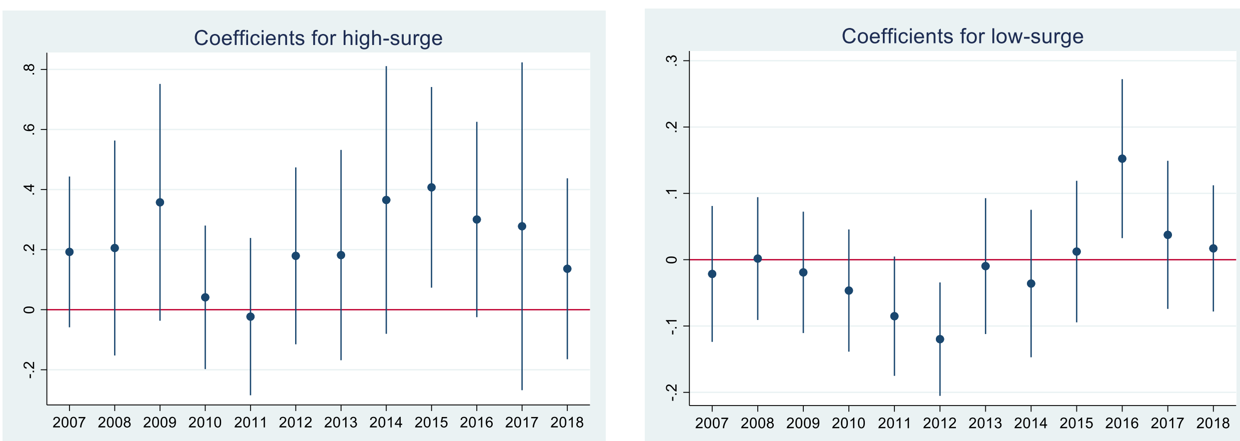


Figure 8: Test the Impact of 2013 Flooding Zone

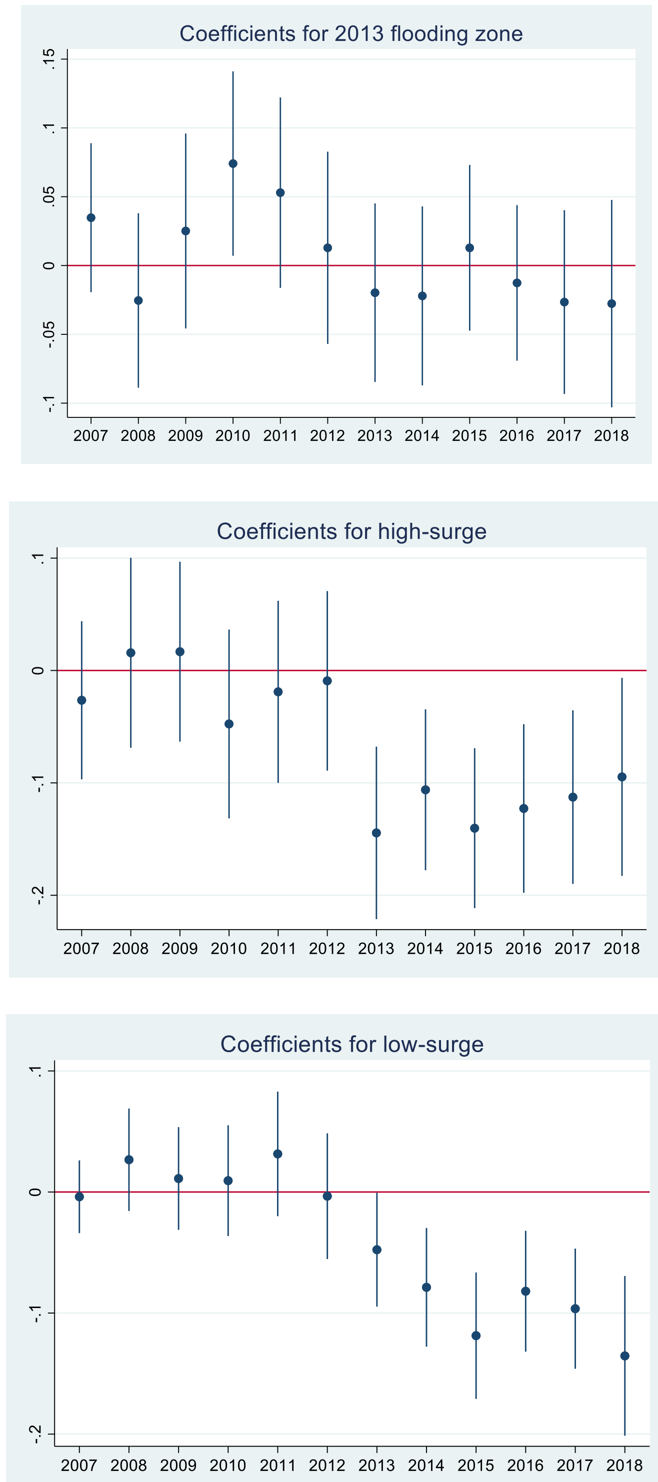


Figure 9: Price Effects using Damage Points

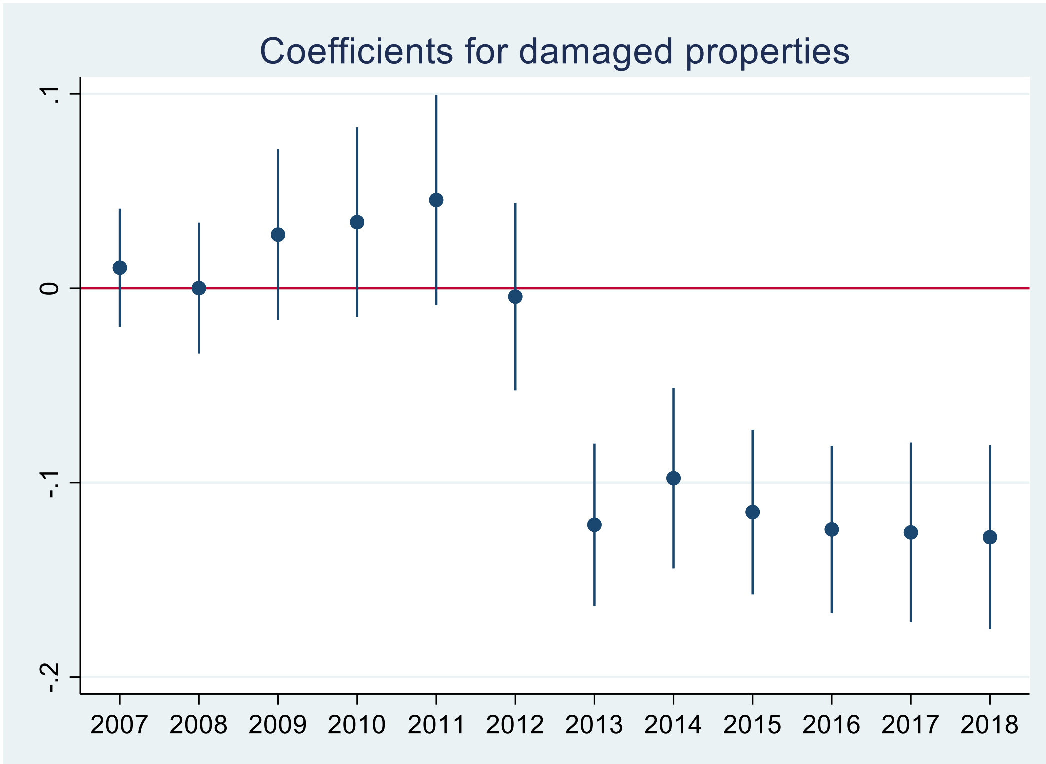
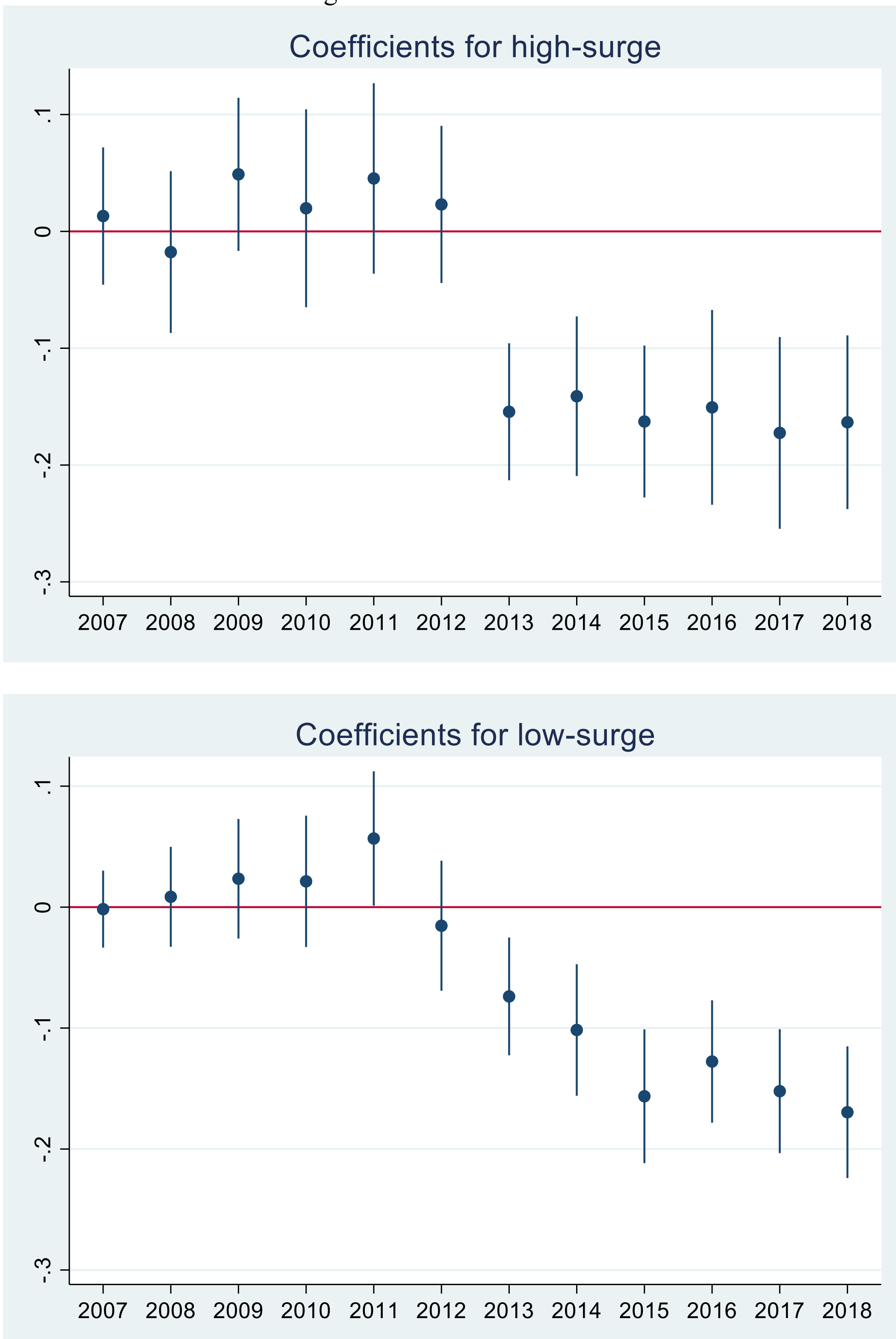


Figure 10: Price Effects excluding Staten Island



Appendix

Appendix A: Price Effects by Property Type

ln(sales prices)	(1) 1-3 families	(2) Condo/coop	(3) Rental buildings	(4) commercial properties
ln(# of units)	0.0334	0.00345	0.565***	-0.0579*
	(0.0315)	(0.0181)	(0.0374)	(0.0317)
ln(building area)	0.266***	0.0840***	0.250***	0.242***
	(0.0144)	(0.00890)	(0.0358)	(0.0227)
# of stories	-0.00421	0.0116***	0.0108	0.00103
	(0.00396)	(0.00147)	(0.00718)	(0.00442)
Building age	-0.00261***	-0.00122***	-0.000346	-0.00338***
	(0.000167)	(0.000385)	(0.00158)	(0.00115)
Building age square	6.26e-06***	9.66e-06***	5.10e-06	5.78e-06
	(1.56e-06)	(9.24e-07)	(8.39e-06)	(4.74e-06)
Building age dummy	-23.46***	-38.94***	-18.70	-22.91
	(6.263)	(3.727)	(34.02)	(19.30)
HighSurge	-0.00884	0.0739	0.0189	0.0142
	(0.0182)	(0.0817)	(0.131)	(0.267)
*HighSurge*PostSandy*	-0.142***	0.0900	-0.184	-0.149
	(0.0179)	(0.0583)	(0.128)	(0.178)
LowSurge	0.0499***	0.0761*	-0.0896	0.0701
	(0.0140)	(0.0402)	(0.0982)	(0.227)
*LowSurge*PostSandy*	-0.112***	-0.0195	0.0194	-0.0134
	(0.0146)	(0.0327)	(0.0689)	(0.224)
Constant	11.25***	11.49***	9.732***	11.11***
	(0.274)	(0.480)	(0.607)	(1.271)
Observations	199,149	182,005	22,750	41,878
R-squared	0.253	0.178	0.508	0.322
Number of tract	1,500	877	1,302	1,552

Standard errors are clustered by census tract in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Census tract fixed effects, YearQtr dummies, Year*Boro dummies, building classes are controlled.

Appendix B: Change the High/low Surge Cutoff from 2 feet to 0.5 feet