The Impact of Natural Disasters on Rents: Evidence from Hurricane Sandy

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Abstract

This paper explores the impact of natural disasters on rental markets and the role of rental subsidies through the Housing Choice Voucher program in the wake of such destructive events. Combining a novel data set of asking rents in New York City with spatial data on flooding incurred by Hurricane Sandy, I estimate the rental impact of the storm in affected neighborhoods using a difference in differences design. In contrast to the literature on home prices, I find initial negative impacts on rents rebound quite quickly. I also find evidence of heterogeneity by neighborhood income: asking rents in above median income neighborhoods increased by 5%, while asking rents in lower income neighborhoods were negatively impacted by 5%. Participants in the HCV program were largely protected from market fluctuations. Voucher rents actually increased by over 5%, benefiting landlords. Programmatic features allowed for the incidence of these increases to fall nearly entirely on the government, protecting the tenants. These results underscore the importance of examining the impact of disasters on rental markets both for understanding the distribution of disaster recovery and its implications for equity, as well as the implicit incentives created by rental subsidies to house vulnerable populations in high-risk areas.

Introduction

As natural disasters grow in frequency and intensity under climate change, understanding how these extreme events affect housing availability and affordability is increasingly important. Most studies examining the impacts of hurricanes on the housing market focus on impacts on property values and have generally found that such storms decrease property prices in the affected areas (Bin and Landry (2013); Bin and Polasky (2004); Hallstrom and Smith (2005); Ortega and Taşpınar (2018); Yi and Choi (2020)). Given that rental data is difficult to obtain, few papers (An et al. (2020)) have been able to focus on rents and theoretically, the impacts of storms on rents might differ from home prices. The incidence of increased user costs of housing differs for renters than for homeowners which has implications for both the demand and the supply sides of the market. Renters do not have to bear the costs of repairs to the structure of their home, or need to consider the long-term value of the property, while owners do. Therefore, there is less reason to think that storms will reduce rental demand (and rents) for units in affected neighborhoods. In fact, supply adjustments may predict rising rents as landlords may be more apt to remove some rental units from supply or make investments in repairs that raise properties to the next price tier. In addition, if the hurricane damage prompted new development, units in new buildings may rent at higher levels.

Examining the role of rental subsidies in the aftermath of a hurricane can shed light on how, due to the nature of the subsidy, this market of renters can experience different impacts of such shocks. The subsidized market includes a third actor, the government, that can shoulder some of the incidence of increased user costs of housing, generating an interesting theoretical trade off. While there is ample evidence showing that low-income and minority neighborhoods are typically more vulnerable to the harmful impacts of natural disasters (Cutter et al. (2012); Van Zandt et al. (2012)), low-income households may also be shielded from market fluctuations by subsidies they receive. Landlords may be able (required) to renovate their properties earlier than other low-income landlords, and programmatic features may allow them to recoup renovation costs through rents without risk of losing their tenants if the government subsidizes some of the rent increases. What are the implications if rents are not tightly bound to market forces in the subsidized segment

of the low-rent market? What incentives are created to house at-risk populations in neighborhoods especially susceptible to such damage? To understand the ways in which government intervention is altering impacts for those it supports, examining the population of existing rental subsidy recipients is critical.

In this paper, I first examine the localized effect of Hurricane Sandy on rental markets in the affected neighborhoods in New York City and examine several dimensions of heterogeneity in the impacts. I then turn to questions surrounding the role of government rental subsidies through the Housing Choice Voucher program in affecting the rental impacts for low income households. Hurricane Sandy (2012) is an ideal storm to study these questions because it was a large and sudden event that caused substantial damage across the city, but the storm surge affected the city in locally unpredictable ways. This meant that neighboring city blocks experienced wide variation in damage from the storm, providing plausibly quasi-exogenous variation across otherwise similar, small geographic areas.

Exploiting this variation, this paper is able to make two main contributions to the existing literature on housing markets in the wake of disasters. First, by combining a new and unique data set of unit-level asking rents from StreetEasy listings with city block level information on storm surge heights, I am able to assess the impacts of the storm on market rents by comparing smaller geographic areas than the one other paper on rental impacts by (An et al. (2020)) which uses ZIP code level variation in storm exposure. Using an event study methodology, I find that, in the 14 months immediately after the hurricane, rents in affected areas experienced a negative impact relative to non-affected areas within in the same ZIP code of 5 percent ($219). This drop likely reflects a dis-amenity effect from the blight and damage incurred, further supported by the fact that no such drop occurred in low surge areas. It is also consistent with the work of Meltzer et al. (2021), which found that retail businesses on blocks with high storm surge levels experienced a change in closure rate that was twice as high as that for establishments in areas without any surge. The effects were also particularly pronounced in the years immediately following the storm.

However, rents rebounded quite quickly. Two years after the storm (by 2014), quality-adjusted asking rents in high surge areas had recovered substantially and by four years post-storm they had returned to rent levels in non-surge areas. This result is in contrast to both my own estimation of

the impact on home prices in the same city blocks, and to the literature on home prices that shows persistent 11-22% price discounts for at least 6 years after Hurricane Sandy (Ellen and Meltzer (2022), Ortega and Taşpınar (2018)). This difference has implications for the price to rent ratio in affected areas. A rough estimate of the average price to rent ratio across high and no surge blocks over time suggests that after the hurricane, it did become more affordable to purchase rather than rent in high surge areas relative to no surge areas. However, both areas have price-to-rent ratios of between 15-20 for most of the period suggesting it is still "typically better to rent than buy[1]."

Yet the average impacts mask heterogeneity in response by neighborhood income. Quality-adjusted rents in above median income neighborhoods increased by roughly 5% more on high surge blocks than no surge blocks after the hurricane, while quality-adjusted rents for below median rent units decreased by roughly 5%. Ellen et al. (2022) also find that above median income neighborhood home prices recovered more quickly than below median income neighborhoods. These findings are consistent with some literature that finds that higher income households are more likely to stay in their units in the wake of a disaster and invest in protection against future storms rather than move (Smith et al. (2006)). Residents of these neighborhoods have more resources, and they appear to have renovated their properties more quickly. I find evidence that these differential impacts may be driven by the timing of renovations: while above median income neighborhoods appear to begin renovations in the year after the storm, below median income neighborhoods do not experience an increase in renovation permits until around 2016/2017, when the city's recovery funds were distributed.

The second contribution of this paper, is to examine the sub-market of households receiving Housing Choice Voucher subsidies in affected areas, to understand how their rental impacts may have differed from those in other low-income neighborhoods. While there is considerable literature documenting the distortions created by explicit subsidization of disaster relief through insurance (Kousky (2010); Gregory (2017); Gallagher (2014)) and a burgeoning literature on the implicit subsidization of development and habitation of areas prone to damage from climate change (Ostriker and Russo (2022); Baylis and Boomhower (2019); Wagner (2022)), little work has examined

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[1]https://www.forbes.com/sites/greatspeculations/2010/11/02/rent-ratio-tells-you-whether-renting-or-buying-is-the-better-deal/?sh=4096cc6e9d08

the role of existing, non-disaster specific subsidy programs in distorting impacts after disasters. Programmatic features of the subsidy distributed through the Housing Choice Voucher program, and the government's explicit desire to keep these vulnerable populations housed, provide reason to think that rents in this sub-market may behave differently than the low end of the rental market over all. Given the increasing frequency of climate-related disasters and the enormous scale of the devastation they inflict, the question of the degree to which existing subsidy programs alter disaster-related rental impacts for these households is crucial.

In the Housing Choice Voucher (HCV) program, the local housing authority pays the difference between the rent charged and 30 percent of a tenant's income, up to the rent ceiling. Therefore, as long as the rents landlords charged to voucher holders remain below the allowable rent ceilings (payment standards), rent increases will be paid for by the housing authority[2].

Due to institutional features of the HCV program, impacts on voucher-rented units might differ from other units in low-income neighborhoods in two important ways. First, voucher rents might be "sticky" downward for sitting voucher units, meaning they will be resistant to downward pressure from decreases in demand. Local housing authorities conduct rent reasonableness assessments when new tenants lease a unit, and when a landlord requests a rent increase. Therefore voucher landlords may have been protected from the negative impacts experienced by other units in low-income neighborhoods. Second, the government as a voucher landlords might be able to avoid liquidity constraints on making repairs that other low-income landlords experience if the housing authority acknowledges improvements to their units through rent increases. Voucher landlords may have been able to, or required to, make repairs to their units earlier, knowing that they could recoup the costs through rent increases without the risk of losing their tenant. This could have been possible if housing authorities adjusted payment standards to prevent additional rent burden on the tenants, or if original rents were below the payment standards to begin with. Housing authorities may have prioritized keeping tenants in their units at a vulnerable and chaotic time, over disagreements with landlords over rent hikes.

I analyze the change in rents charged to voucher holders with the same event study methodology

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[2]When households first enter contract on a new apartment with a voucher subsidy, the program requires that the tenant pay no more than 40% of their income to rent, but no such official limitation exists as the voucher holder remains in the unit.

using administrative records from HUD's housing choice voucher program, and, in contrast to the broader findings, I find a steady relative increase in voucher rents in high surge areas compared to non-surge areas. Voucher rents do appear to have been "sticky" downward, with no average decrease in the years immediately after the storm. In addition, voucher landlords were nearly 10% more likely to file for renovation permits in 2013 than non-voucher landlords in low-income neighborhoods and rents increased for these buildings. Within three years of the storm (by 2015), voucher rents had increased by 3 percent ($45) in high surge areas relative to non-surge areas and by 2017 they had increased by 5.2% percent ($87) more in high surge areas than no surge areas. I also find differential increases in rents in low surge areas compared to non-surge areas, which, though noisy, appear to be of similar magnitude to the changes in high surge areas.

It appears landlords were able to capitalize quality improvements into rents so quickly because the government bore a substantial amount of the incidence of increased user costs of housing. I find that the incidence of these Sandy-induced rent increases for subsidized households fell nearly entirely on the government such that voucher tenants were shielded from the rent increases by the housing authority. There was virtually no increase in the portion of rent paid by voucher holders in high surge areas compared to no-surge areas in the same ZIP code, and the payments from the housing authority mirror the increases in the contract rents. Whether voucher landlords chose to, or were required to, renovate their properties earlier, they did not face the same risk of losing their tenants to rental increases that other low income landlords would. This may reflect a willingness on the part of the housing authority to accommodate voucher landlords' renovation of damaged properties while keeping voucher holders in their units.

Together, the results in this paper imply that when considering the impacts of climate change on the housing market, we should consider both the home sales and rental markets, as the impacts may differ between the two. In the case of Hurricane Sandy, while considerable research suggests the hurricane lead to a persistent decrease in home sales prices, I find evidence that while hedonic rents decreased initially, they rebounded much more quickly than home sales prices. Average effects on quality-adjusted rents can mask considerable heterogeneity in disaster recovery across neighborhood income. These results have important implications for the distribution of disaster recovery, how it may lead to changes in the composition of the population and the economic development of

neighborhoods, and have longer-term effects on equity.

The fact that the nature of the subsidy created different rental impacts in the Housing Choice Voucher sub-market should also prompt discussion about the role of existing rental subsidies in the wake of natural disasters. The housing voucher program appears to have shielded both landlords and tenants from broader market fluctuations by shouldering additional costs. This additional level of "insurance" afforded to landlords might encourage participation in a program plagued by low landlord engagement. However, it may also mean that rental subsidies create an implicit incentive for housing vulnerable populations in neighborhoods at high risk of disaster-induced damage.

This paper is organized into two sections. Section A focuses on documenting the impact of the storm on asking rents, and details theory and background, data and empirical strategy, results and mechanisms related to this question. Section B turns to the government's role in insuring low income tenants and their landlords against the rental impacts of climate change, and describes the background and data on the Housing Choice Voucher program, a few small modifications on the empirical strategy, and the results and mechanisms for this question. I then discuss some robustness checks pertaining to both sections. Finally, the paper concludes with a discussion of the two sections and the policy implications.

A. The Impact of Hurricane Sandy on Market Rents

1   Theory and Background

Although considerable work has has focused on the impacts of natural disasters on house prices, the theoretical impacts on rents are ambiguous because the incidence of the increased user costs of housing differs across homeowners and renters. On the one hand, rents may decrease if demand for rental housing in these areas decreases due to blight or information shocks. However, rents may increase if there is a substantial reduction in the rental supply due to the disaster, or changes in the composition of the rental stock due to rebuilding or renovations. A priori, it is not clear which effects should dominate.

1.1 Hurricane Sandy

Hurricane Sandy hit the east coast of the US in October of 2012 and provides an ideal setting for studying the impact of natural disasters on rental markets for two reasons. First, the hurricane caused considerable damage across a fairly large geographic area. In New York City, it inflicted roughly \$19 billion in damages and damaged over 69,000 residential properties. The storm surge affected nearly 9 percent of residential units in the city (NYC.gov).

To distinguish areas that experienced higher levels of damage from lower levels of damage, I follow previous work of Ellen and Meltzer (2022) and designate areas as high surge if they experienced more than 2ft of surge and low surge if they experienced 0-2ft of surge[3]. Figure 1 shows a map of ZIP codes across the city, with blocks shaded by this storm surge designation. Naturally, most of the high surge areas are along the coast, though notably many blocks along the coast line experienced low or no surge. The surge also covered all five boroughs of New York, generating substantial variation in the populations and neighborhoods affected.

Second, the storm surge was somewhat unpredictable and varied substantially, creating exogenous variation in storm exposure across neighboring city blocks. Figure 2 provides an example of an Upper East Side neighborhood where the surge levels vary considerably across neighboring blocks, as well as across the flood zone boundary, depicted in grey. High, low, and no surge blocks are contiguous and cross in and out of the flood zone, creating plausibly exogenous "treatment" and "comparison" groups across small geographic areas.

1.2 Potential Rental Effects of Storms on Housing Markets

Reduction in Rents

Damage from a hurricane makes affected neighborhoods less desirable, either because of the blight incurred or because of new information about the riskiness of the neighborhood. Research has shown evidence of such a negative demand shock in the homeownership market. Several papers document negative effects of hurricane and flooding risk on residential property prices ((Bin and Po-

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[3]This categorization is discussed in more depth in both Sections 2.1 and 2.3.

lasky, 2004); Ortega and Taşpınar (2018); Gillespie et al. (2020); Hennighausen and Suter (2020)). Many of these papers also find that new information about the relative riskiness of neighborhoods is a strong driver of the decrease in demand in the longer term. Hallstrom and Smith (2005) find that prices decreased in counties that did not experience damage from Hurricane Andrew, but where the hurricane would have conveyed risk information to the homeowners. Ellen and Meltzer (2022) find evidence that after Hurricane Sandy, while housing prices decreased in areas affected by the storm across the board, prices remained depressed for a longer period of time outside the flood zone than inside the flood zone. They suggest that prospective buyers of properties outside the flood zone received new information about the relative riskiness of the properties that was already known to buyers within the flood zone through the requirement to purchase flood insurance and that this outweighed any existing supply effect. Kousky (2010) shows a similar effect in Missouri, where property prices in 100-year floodplains did not change significantly after a 1993 flood of the Mississippi River, but prices in the 500-year floodplains significantly declined where home buyers would not have initially been informed about their property's flood risk. Tanaka and Zabel (2018) are able to isolate the effect of risk information from disaster impacts themselves by examining changes in house prices near US power plants after the Fukushima nuclear disaster in Japan and find significant (and temporary) declines in house prices.

It is not clear, however, how strong we should expect the negative demand effect to be for renters because of the differing incidence of increased housing user costs from homeowners. Renters experience the same dis-amenity effect of blight as homeowners, but renters do not have the same long-term stake in property. Renters care about the use-value of housing, and are not concerned with the long term asset value of the unit. In addition, they are not required to purchase flood insurance and are less likely to need to pay for repairs if damages are incurred. Flood zone and surge level boundaries are likely to be less salient borders to renters for these reasons and renters have less reason to be discouraged by potential long-term outcomes of property in these areas.

That said, renters may have less initial information about flood risk than homeowners since they are not required to purchase flood insurance, and thus storms may provide a larger information shock to renters. While they are not likely to incur large repair costs to the unit, they may suffer damage to personal property. In addition, if enough displaced households join the rental market

in nearby, non-damaged blocks, this could lead to rental increases in unaffected areas (relative negative impacts in affected areas).

Increase in Rents

On the other hand, supply adjustments might lead to an increase in rents. The damage inflicted by the storm might initially considerably reduce the supply of rental housing, with fewer habitable properties leading to a rise in rents for the remaining stock (Vigdor (2008)). In the case of Hurricane Sandy, which damaged but did not completely destroy many properties, the supply of viable rentals in surge areas could arguably be more elastic than the supply of owner-occupied homes. It may be too costly for smaller landlords to maintain rental units in at-risk areas. These landlords may remove their damaged units from the market entirely, particularly in the case of basement apartments, while continuing to occupy higher floors of their buildings. This could lead to a considerably larger reduction in the supply of rental units than owner-occupied properties.

In addition, other factors may alter the composition of the rental stock. Damages may lead landlords to renovate or rebuild their properties, potentially improving quality and pushing their units into the next tier of the rental market. New development to replace damaged properties might lead to newer units driving up rents. It's also possible that older, damaged buildings were removed from the rental stock altogether, creating a younger rental supply in affected areas, which is strongly correlated with higher rents.

At the intensive margin, ownership may play a role. It's possible that, if landlords are constrained by their ability to recoup renovation costs, they might choose to sell their buildings after the hurricane. This may be particularly true for smaller landlords who may have more liquidity constraints. Heightened turnover may bring in a set of new owners with different business models, which may lead to a change in rents. Even if the volume of sales is unchanged, it's possible that buyers who are willing to take on the risk of a rental property in an area susceptible to damage may be larger, and more resourced. These buyers may be more sophisticated in their knowledge of the market and more aggressive in increasing rents to the maximum the market can bear. Even if ownership does not change, reactions to the hurricane may vary by landlord type. Indeed a working paper by Verbugge and Gallin (2017) suggests that rents are stickier for small landlords than for

larger landlords, who are less affected by the costs incurred from losing a tenant.

Heterogeneity by Sub-market

Finally, the overall impacts on rents in affected areas might mask important heterogeneity across several dimensions. Several papers have explored the impacts of disasters on home prices stratified by neighborhood income, with mixed results. Smith et al. (2006) find that higher income households are more likely to stay in their homes and invest in preventing further damage, while lower income households prefer to move to more affordable housing. Cohen et al. (2021) and Ellen et al. (2022) actually find larger initial impacts in higher income neighborhoods, but the latter find that these neighborhoods recover more quickly. They suggest their results may reflect that residents of higher income neighborhoods have more resources to repair damage and blight, and to ensure themselves from damage from future disasters. On the other hand, higher income renters are likely to be much more mobile than lower income renters, so we might expect a larger response in demand in higher income areas.

Ultimately, since the theory suggests the possibility of a variety of countervailing forces, the question of the impact of the hurricane on rents in affected neighborhoods is an empirical one.

2 Empirical Strategy

I estimate the impact of Hurricane Sandy on rents using a difference-in-differences design that compares blocks that experienced higher levels of storm surge to blocks that experienced no storm surge within the same ZIP code. To do this, I gather a rich data set of spatially detailed data on the storm surge from the hurricane, market rents and administrative data from New York City.

2.1 Data

FEMA Surge and Flood Maps

I use FEMA's surge map to capture the impact of the storm through water inundation. The FEMA Modeling Task Force (MOTF), a group that uses statistical modeling and on the ground

surge sensors and field observations to regularly update flood impacts, uses high-water marks and surge sensor data to interpolate water surface elevation after the storm. They report surge levels at one or three square meters but following previous work, I collapse these interpolated micro estimates to the block level (Ellen and Meltzer (2022)).

I categorize surge heights to facilitate a comparison between areas that were clearly impacted by the storm and those that were not. In Figure 3, I examine the relationship between surge heights and FEMA's estimate of "major damage"[4], aggregated to the block level, to find an appropriate surge-level threshold to identify blocks that were severely affected by the storm. The main goal of identifying a surge-level cut off is to capture as many blocks that experienced major damage due to the storm as possible, while excluding properties that were likely damaged due to other, potentially endogenous, factors, like the quality of the structure. The red line indicates a block level average of 2ft, this paper's threshold for categorization as a "high surge" block. Using the 2ft threshold, properties that did not experience any surge but still incurred a substantial amount of damage, and properties that experienced low levels of surge and damage are excluded from being categorized as highly affected by the storm. While 2 feet appears to be a reasonable threshold, I do experiment with other surge thresholds, as discussed more in section 2.3.

With a 2ft threshold for "high surge" areas, "low surge" areas are designated as experiencing flooding, but with less than 2ft of water and no surge blocks did not experience any storm surge. I also use the boundaries of the 100-year flood zones in effect at the time of Hurricane Sandy and categorize areas into high-risk areas (flood zone = 1) and low risk areas (flood zone = 0).

Asking Rents

To examine the impact of the hurricane on asking rents, I use unit-level asking rent data from 2010-present from StreetEasy, provided through a partnership with the Furman Center. The data includes the asking rent for the unit, the number of bed and bathrooms in the unit, whether the unit listing required a broker fee, the date of the posting, the address and geolocation.

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[4]I choose to use surge heights rather than FEMA's plot level estimates of damage because surge heights are a major factor that goes into FEMA's damage calculation and surge heights are more likely to be exogenous to rental changes than damage. This follows other papers on Hurricane Sandy (Ellen and Meltzer (2022) and Meltzer et al. (2021)).

Historically, it has been quite difficult to obtain data on asking rents which, in part, explains why there is such limited research on the subject. Asking rents are an ideal data source for examining market fluctuations because they respond quite quickly to changes in market dynamics. For these reasons, this data from StreetEasy provides a novel opportunity to examine a largely unexplored topic. However, like most rental data, it is not without its limitations.

Since StreetEasy started in 2006, by 2010 it was still relatively nascent. While at present, StreetEasy is ubiquitous in rental searches in New York City, at the time of Hurricane Sandy StreetEasy listings were concentrated in high rent neighborhoods and buildings. Figures 4a and 4b show the composition of the sample over time across borough and type of building, respectively. Listings are concentrated in Manhattan, especially in the early years, though Brooklyn and, to a lesser extent Queens, gain listings over time period. Listings are predominantly in elevator buildings, condo buildings or walk-ups or 3 or more units, initially, though the share of listings in walk-ups increases dramatically from 2010-2015. By the end of the period walk-ups make up a greater share of listings than elevator buildings.

Figures 5a and 5b show the geographic distribution of listings in the sample by surge area, first in 2011, and then across the whole time period. They reflect the same initial concentration in Manhattan and subsequent spread to other boroughs, across all three surge designations. The same apartments do not appear often enough in the sample to attempt a repeat-rent model, however it is noteworthy that, while the increase in listings is clear over time, most listings are concentrated in ZIP codes that contained listings before the storm. This means that limiting the sample to ZIP codes that appear in 2010 and 2011 still captures over 90% of listings in the entire sample.

Overtime, the sample across all three surge areas increases in the number and variety of listings. Plotting the average asking rents over time misleadingly indicates a decrease in rents over the time period as more lower-rent units are added to the sample. Figure 6 plots the average block level change in rent from the prior year, holding constant the number of bedrooms, over time. It is clear that around the time of the hurricane there is more volatility on high surge blocks than low and no surge blocks, with almost no increase in average rents the year after the hurricane, and then increasing by more than $200 in 2015 compared to an increase of around $100 in low and no surge areas. This volatility is particularly notable given how closely the trends track each other later in

the period. However, it is important to note that over much of the time period, with the most dramatic exception in 2020 when the COVID-19 pandemic first hit, rents were increasing each year across all three surge groups. As discussed in more detail under Section 2.3, the impacts found in this paper are relative to the comparison group and do not reflect absolute changes in rents.

Building permits

To observe whether rent changes are associated with new building permits, demolition permits, or renovation permits for damaged properties, I include Department of Buildings (DOB) data on jobs permits during the time period. This data is collected by the city for all job applications submitted through the Borough offices since January of 2000. Jobs are classified as "new building", "demolition" or "alteration". Alterations are further classified as "A1", for "a major alteration that will change the use, egress, or occupancy of the building", "A2" for "an application with multiple types of work that do not affect the use, egress, or occupancy of the building" and "A3" for "one type of minor work that doesn't affect the use, egress, or occupancy of the building." Of the renovation permits in the sample filed within four years of the storm (2013-2016), 65% were categorized as "A2", 33% as "A3" and only 2% were categorized as "A1".

PLUTO

To identify characteristics of buildings, I use the city's publicly available Primary Land Use Tax Lot Output (PLUTO) building data from 2007 - 2021. This data includes annual extensive land use information at the tax lot level. I match on the tax lot number (BBL) to retrieve the number of units in the buildings, the number of floors, and the age of the building.

Building Sales

I use data from the Department of Finance (DOF) combined with the Automated City Register Information System (ACRIS) to obtain information on property records and deeds from 2004 -2019. Among the information included in this data is address, the date of sale, and the price. I use this data to estimate the impact on the hurricane on home prices, observe the number of sales over time

in affected areas, and identify whether there is heterogeneity in the rental impacts by landlord turn over (whether an arms-length sale occurred).

2.2   Summary Statistics

To identify whether rents changed in neighborhoods impacted by the hurricane, I limit my sample to ZIP codes that have at least one city block that experienced some level of surge.

Table 1 reports the number of individual listings, city blocks, and ZIP codes in the StreetEasy sample in 2011, one year prior to the hurricane, and for 2017. In 2011 there were 2,070 listings in 110 blocks that would experience high levels of surge across 56 different ZIP codes. As noted previously in section 2.1, in 2011 StreetEasy was a relatively new service in earlier years of the time period so the sample grows over time.

Table 2 shows baseline (2011) summary statistics for StreetEasy units by surge level. Units in high surge areas tend to look fairly similar to those in the comparison group, no surge areas, though notably the buildings they are in are about 10 years younger, the neighborhoods are slightly whiter with slightly lower median neighborhood rents. Low surge units tend to be in substantially larger and newer buildings, with higher baseline average rents.

2.3   Estimation

I estimate the impact of Hurricane Sandy on rents in the affected neighborhoods using a difference in differences methodology that compares census blocks that experienced high and low levels of surge to census blocks within the same ZIP code that experienced no surge before and after the hurricane. I begin with following standard difference in differences equation

$$y_{ht} = \sigma_{z(h)} * \tau_t + \sigma_{z(h)} * surge_{b(h)} + \sum_{s \in S} \beta_s Post_t \times 1(s(b(h)) = s)$$

$$+\gamma_1 floodzone_h + \theta X_{ht} + +\varepsilon_{ht}$$

(1)

Where y is the log of asking rent in \$2021, for housing unit h, in time t. Within the summation, *Post*, an indicator for years post 2012, is interacted with a set of dummy variables indicating the

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surge level, s(b(h)) of the block, b, on which the housing unit is located, so the set s is defined as $S = high, low$. High surge blocks experienced storm surge levels of more than 2ft of water, and low surge blocks experienced surge levels of less than 2ft. As discussed in Section 2.1, I experiment with other thresholds and find qualitatively similar results, shown in Appendix Table B.2.

Importantly the equation contains ZIP code by year $(\sigma_{z(h)} * \tau_t)$ and ZIP code by surge level fixed effects $(\sigma_{z(h)} * surge_{b(h)})$ to remove variation from time trends in the ZIP code and baseline differences between surge levels in the ZIP code. I choose to cluster my analysis within ZIP codes because while census tracts are often considered to be the best proxy for neighborhoods, the limitations on rental data coverage discussed in Section 2.1 mean the sample includes very little variation in surge within tracts[5]. As a robustness check, I do re-estimate the main results with census tract fixed effects rather than ZIP codes and results look very similar. See Figure B.2.

This empirical strategy allows for the interpretation of the coefficients of interest, β_s, to be the changes in rents in high and low surge areas, relative to non surge areas within the same ZIP code, before and after the hurricane.

I include a vector of housing unit characteristics, (X_{ht}), which include, the number of bedrooms and bathrooms, and whether the unit required a broker fee. I also include building level controls including the number of units in the building, units squared, the age, age squared and the number of floors, and whether the unit is located in a building with subsidized or controlled rents, where regulations might have prohibited rental increases.

In addition, I include an indicator for whether the unit is located in the the flood zone. Standard errors are clustered at the ZIP code by block level.

I also estimate the impact on rents using an event study specification that takes the following form

$$y_{ht} = \sigma_{z(h)} * \tau_t + \sigma_{z(h)} * surge_{b(h)} + \sum_{\tau=2010}^{2021} \sum_{s \in S} \beta_{\tau,s} 1\left(t - 2012 = \tau, s\left(b(h)\right) = s\right)$$
$$+ \lambda X_{ht} + \gamma_1 floodzone_h + \varepsilon_{ht}$$

(2)

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[5]Only 25% of census tracts include listings on blocks with more than one type of surge, compared to 95% of ZIP codes.

Here, the indicator variable in the summation interacts event years τ, from 2010-2021, rather than the simple $Post_t$ variable, with the dummy variables indicating the unit's block's surge level, s(b(h)). Since the event study allows for a better understanding of the dynamics of rental changes over time, it is the preferred specification.

One caveat of this empirical strategy is that it ignores general equilibrium effects: both equations 1 and 2 estimate the local effects of the hurricane on rents. It is possible that Hurricane Sandy affected rents in the city more broadly. For instance, a reduction in the rental supply in the affected areas could have lead to an increase in rental demand in other areas of the city and rents may have increased city-wide. This estimation strategy will not be able to capture those broader effects.

In addition, I am not able to rule out the possibility that some of the mechanisms discussed here could spillover into non-surge blocks. As mentioned previously, it is possible that displaced homeowners join the rental market on non-surge blocks, which could increase demand and increase rents in these areas. That is to say, with this empirical strategy, I am only able to pick up the difference in rental changes between surge and non-surge areas, and the results do not imply that rents remained unchanged in non-surge areas or that they were completely unaffected by broader consequences of the storm.

Finally, to estimate heterogeneous differences in the impacts by age, rent level, height and renovation permits, I estimate an event study with a triple difference which takes the following form

$$
\begin{aligned}
y_{ht} = \sigma_{z(h)} * \tau_t + \sigma_{z(h)} * surge_{b(h)} + \sum_{\tau=2007}^{2019} \sum_{s \in S} \sum_{r \in R} \beta_{\tau,s,r} 1(t - 2012 = \tau, s\,(b(h)) = s, r(b) = r) \\
+ \lambda X_{ht} + \gamma_1 floodzone_h + \varepsilon_{ht}
\end{aligned}
\tag{3}
$$

where the double summatory from equation 2 is now interacted with an indicator for the measure of heterogeneity. The coefficients $\beta_{\tau,s,r}$ then depict the differential changes across surge level and time for rents in buildings that are newer, taller, higher rent or that filed for renovations as a result of the storm. These measures of heterogeneity are discussed in more detail in their respective results sections below.

3 The Impact of Hurricane Sandy on Asking Rents

I begin by first estimating a simple version of equation 1 without controlling for any building or unit characteristics, except for the number of bedrooms. Column 1 of Table 3 shows that raw rent expenditures on high surge blocks increased by 5.3% more than on non-surge blocks. Yet, this difference disappears as I begin to add building and unit quality controls. In Column 2, I add controls for building age and building age squared, and the point estimate decreases considerably and becomes insignificant. In Column 3, I add the rest of the controls, reflecting the preferred specification for quality-adjusted rents. The results change very little, and continue to reflect no significant change in quality-adjusted rents. Rather, it appears that the change in raw neighborhood rents is driven by the age of the building. Throughout all three specifications, there appears to be no impact on rents in low surge areas [6].

Figures 7a, 7b, and 7c confirm the high surge block results from columns 1-3 in Table 3 in the event study framework of equation 2. However, they also reveal that the simple difference in difference estimation does mask some heterogeneity over time. Initially, in the period immediately after the storm (late 2012 and 2013) rents were negatively impacted in high surge areas relative to no surge areas by roughly 5% ($219), likely reflecting a dis-amenity effect due to blight. This finding is consistent with previous work on the impact of Hurricane Sandy on commercial establishments (Meltzer et al. (2021)), which found an 11 percentage point increase in the annual closure rate for retail businesses after the hurricane, with the strongest effects in the years immediately following the storm. It is also consistent with Figure 8 which shows a binscatter plot of the growth rate in the number of block level rental listings in StreetEasy. The pronounced growth in listings in 2013 in high surge areas suggests that more rental units were available at the time, likely due to vacancies, bringing down rents.

However, across all specifications, by 2014 rents in high surge areas began to rebound. Four years after the hurricane (by 2016), quality adjusted rents (Figure 7c), had rebounded back to non-surge block levels. Toward the end of the period they appear to be increasing relative to non-

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[6]Results are remarkably similar using continuous measures of surge, as well as different thresholds for high surge. See Table B.2.

surge blocks. This finding is in direct contrast to the 11-22% house price discounts that persist for at least 6 years after the hurricane (Ellen and Meltzer (2022), Ortega and Taşpınar (2018)), despite the fact that over half the households that requested FEMA assistance, indicating their dwelling was damaged, were renters (Furman Center for Real Estate and Urban Policy (2013)). These differing results provide evidence of substantially different responses to natural disasters across owner-occupied and rental markets.

Much of this house price literature finds larger negative effects outside the flood zone, which they interpret as evidence of a strong information effect causing a decrease in demand. Unfortunately, the data from StreetEasy has a limited sample of listings in non-surge areas within the flood zone, especially in the pre-period, so I am not able to conduct the same stratified analysis for rents. Results for properties outside the flood zone, presented and discussed more fully in Appendix A (Figure B.8a), do indicate slightly larger negative impacts on rents than for the full sample, but rents still rebound by 2016-2017. This provides suggestive evidence that while information may play a small role for renters, it is capitalized into home prices to a much greater degree than rents, particularly in the longer term. However, caution is encouraged in interpreting these results since the analogous comparison for properties within the flood zone cannot be estimated.

3.1 Price to Rent Ratio

To further investigate the difference in impacts across rents and home prices, I estimate a version of equation 2 to identify the impact on sale prices on the same blocks for which I have rental information. Roughly half (51%) of all sales in ZIP codes that experienced any surge from 2010-2021 occurred on blocks on which I also have rental listings in that year[7]. Very similar to what has been found in previous literature, I find persistent 10-20% price discounts on high surge blocks after the hurricane. Figure 9 shows the impact estimates for prices next to the same impact estimates for rents from Figure 7c, on the same scale to highlight the contrast.

The difference between the impacts across tenure in the housing market suggest there may have been a change in the relative affordability of purchasing compared to renting across high and

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[7]The geographic overlap increases to roughly 72% if I do not restrict both data sets to having transactions on the same block within the same year

no surge blocks. To try to examine this, I create a measure of the price/unit to rent ratio at the block level by dividing the median annual price/unit by the median annual rent. Since prices appear to have fallen more, and remained more depressed than rents, this would imply a larger drop in the numerator than the denominator, so we would expect to see a larger decrease in the ratio on high surge blocks compared to no surge blocks, implying purchasing has become relatively more affordable in high surge areas than no surge areas. Though I am not powered to estimate a regression on the price/unit to rent ratio, Figure 10 shows the average ratio across high and no surge blocks over time. While the ratio is increasing over time across both groups, it is clear there is a divergence in the trend on high surge blocks around 2014-2015, when rents appear to have rebounded on these blocks while prices did not. This reflects suggestive evidence that it may have become more affordable to buy than rent in high surge areas relative to no surge areas after the hurricane. However, the ratio remains between 15-20 for most of the period in both groups, so while the change in trend is clear, it may not indicate a difference qualitatively in the favorability of buying vs renting.

3.2 Heterogeneity in Rental Impacts

In this section I discuss the evidence for heterogeneous effects by neighborhood income, and voucher status. In Appendix A, I also explore heterogeneity along building height, renovation permits and landlord turnover and find no evidence of any significant differences in rents along these three measures individually.

Neighborhood Income

To examine whether the impacts on quality adjusted rents differ by neighborhood income, I estimate a version of equation 3 where the measure of heterogeneity in the triple interaction is whether the unit is in a census tract where the tract median income is above the sample median income in that year. This measure accounts for the endogeneity in tract income levels after the storm by allowing the distribution to adjust each year, and holding constant the threshold (median) in the distribution. Figures 11a and 11b show that quality-adjusted rents increased for above median income neighborhoods and decreased for lower income neighborhoods[8].

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[8]Coefficients for the difference in difference estimates from equation 1 can be found in Table B.1

These results are consistent with Smith et al.'s (2006) that higher income households are more likely to stay in their homes in the wake of a storm, and Ellen et al.'s (2022) that higher income neighborhood home prices rebounded quicker than lower income neighborhoods. If buildings are of better quality in higher income neighborhoods, they may have experience less blight to begin with. While average surge heights were roughly 3.5 ft in both above and below median income neighborhoods, buildings in below median income high surge blocks were roughly 5 years older in 2011 than those in above median income neighborhoods, so they may have been more susceptible to storm damage. The buildings in higher income neighborhoods are also slightly taller than those in lower income neighborhoods, although building/unit height does not appear to have been a significant factor independent of neighborhood income, as is shown in Appendix A.

Rather, landlord resources appears to have played a larger role in the heterogeneity in rental impacts. Landlords in higher income neighborhoods are more likely to have the liquidity available to quickly make repairs. Indeed, while I find no clear differential impact by renovation status (see Figures B.4a and B.4b), suggesting renovated buildings are not driving rent increases, I do find different patterns in the frequency of renovations across higher and lower income neighborhoods. Figures 12a and 12b show that in higher income neighborhoods, there was an immediate increase in renovation permits, while in lower income neighborhoods, the increases do not appear until around 2016 and 2017, when as Figure 13 shows, substantial amount of the city's "Build it Back" recovery funds were disbursed[9]. Despite this evidence of differential recovery, I do not find that the rental increases were concentrated in buildings that renovated (Figures B.4a and B.4b)) Rather, these results suggest the possibility of a different channel. If recovery began nearly immediately in higher income areas, they may have avoided the initial drop in demand due to blight. Amenities may have recovered faster in these neighborhods, consistent with research from LeSage et al. (2011) on the aftermath of Hurricane Katrina. The quicker recovery may also have led to an increase in demand from renters of neighboring areas that view the rental stock as more storm-resistant or the neighborhood as rebounding.

Rent Stabilization

A concurrent explanation for the differential rent impacts across above and below median income

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[9]https://www.nyc.gov/content/sandytracker/pages/build-it-back

neighborhoods is the share of units that are rent stabilized. In New York City, almost half of all apartment units are rent stabilized, a form of tenant protection that limits the annual amount a landlord can increase rents. Over 30% of units in the sample in lower-income neighborhoods are in buildings with more than 75% of their units rent stabilized, compared to only 20% in higher income neighborhoods. One theory is that landlords with large shares of rent stabilized units may have had less of an incentive to renovate and improve damaged properties if they knew they were not able to capitalize those costs into higher rents. Figure 14 does show some slight differences in rental impacts across buildings with different shares of units under rent stabilization (less than 25%, 25-75%, and more than 75%). Buildings with lower levels of rent stabilization appear to have slightly more positive rental impacts compared to buildings with higher levels of rent stabilization, but all coefficients remain insignificant.

To examine how the inclusion of buildings with higher shares of rent stabilized units may be generating differential results across neighborhood income, I rerun the heterogeneity analysis across above and below median income neighborhoods solely for buildings with less than 25% of their units rent-regulated. In Figure 15a, I find that these buildings actually experience larger negative impacts in below median income neighborhoods than the more heavily rent stabilized stock. Indeed, landlords of rent stabilized units may have had a strong incentive to not lower rents to avoid putting their units on a lower rent path, limited by how much their rents can raise when the market rebounds. I also find, on average, they the owners of these buildings still did not file for renovation permits until 2016/2017 (Figure 16a), suggesting that rent stabilization was not the primary factor preventing renovations in these areas.

Voucher Status

Recipients of Housing Choice Vouchers tend to occupy the lower end of the rental market. Since StreetEasy listings tend to be higher rent units, only 5% of the listings in the sample are in buildings that had a voucher holder in that year. Interestingly, however, stratifying the results by buildings that had at least one voucher holder in that year indicates, as Figure 17 shows, that, if anything, rents in voucher buildings actually increased in high surge areas relative to non-surge areas after the storm. This could simply reflect the fact that voucher buildings in the StreetEasy data are not representative of the broader voucher population, since only 9% of voucher holder buildings in

New York City appear in the StreetEasy data, but the results provides suggestive evidence that the sub-market of voucher holders may have responded differently to the shock of the hurricane than the rest of the low-income market, which is explored in detail in the next section.

B. The Role of Government Subsidies

In this section, I turn to the question of the role of government subsidies in protecting low income households and their landlords from these market fluctuations. The nature of the Housing Choice Voucher program's housing subsidies may distort the low income rental market, leading to differing impacts for this population and questions surrounding the government's subsidization of climate risk.

4 Why HCV Program Impacts Might Differ

Government rental subsidies might shield vulnerable, low-income households, typically those at highest risk of climate-induced destruction (Van Zandt et al. (2012)), from market fluctuations in the wake of disasters. The Housing Choice Voucher program is the largest rental subsidy program in the country, providing assistance to over 5 million people in approximately 2.3 million households nationally (Center for Budget and Policy Priorities, 2021), and over 100,000 households in New York City. Voucher households are expected to pay 30% of their income toward rent, and the housing authority subsidizes the rest of the rent to the landlord as long as the rent falls below a specified payment standard, generally a percentage of the area Fair Market Rent. If rent exceeds the payment standard, the voucher household is responsible for the remaining difference. Such subsidies mean that the hurricane's impacts on the voucher rental market may differ from the rest of the lower income rental market in two important ways.

First, sitting voucher rents may be "sticky" downward. Housing authorities typically conduct "rent reasonableness" assessments to ensure that the rents charged to voucher holders are comparable to other rents for similar units in the area. However, they generally only conduct these assessments when a voucher tenant is moving into a new unit or when the landlord requests a

rent increase. Therefore, sitting voucher landlord rents may have remained stable rather than responding to the acute negative rental shock found in Section A that other units in lower-income neighborhood experienced.

Second, voucher landlords may not have been subject to the same resource constraints as other low-income landlords. If voucher landlords knew they would be able to recoup renovation costs through higher rents without risking losing their tenants, they may have been able to renovate sooner than other landlords in low-income neighborhoods. Voucher tenants would not have borne the incidence of these rent increases if rents were initially below the payment standard in affected neighborhoods, where voucher landlords could raise rents up to that payment standard and have the housing authority cover the difference. In addition, housing authorities have the ability to create payment standard accommodations, which adjust the percentage of the FMR that is designated as the payment standard. Ordinarily, we would not expect housing authorities to make household level accommodations beyond those for households with disabilities, but it is possible that in the wake of the hurricane, housing authorities were primarily concerned with keeping vulnerable populations housed under adequate conditions and facilitated that through the tools at their disposal.

The question of the role of housing subsidies in disaster mitigation, contributes to a growing body of literature on the ways that the explicit and implicit government subsidies distort incentives and market outcomes in regard to the development and habitation of areas at high risk of climate change. A number of studies have focused on behavioral changes with flood insurance and rebuilding in the wake of damaging flood events (Kousky (2010), Gregory (2017), Gallagher (2014)), and several find that these policies actually encourage rebuilding and renovation in high-risk areas.

The topic has been explored in the context of wildfires too. Baylis and Boomhower (2019) and Olmstead et al. (2012) both find that government attempts at wildfire mitigation create implicit subsidies for homeowners and encourage development in fire-prone areas. The former's estimates suggest that the implicit subsidy from firefighting mitigation can reach up to 20% of the home's value.

Few papers, however, have taken into account the role of existing social safety net programs when estimating the costs of government subsidization and mitigation of climate risk. The research that does exist suggests that omitting existing program transfers from analysis on government

spending on disaster relief can lead to a gross underestimate. Deryugina (2017) shows that affected counties receive extra transfers through non-disaster social insurance programs such as income maintenance payments, unemployment insurance, and public medical benefits, that average about $780–$1,150 per capita on top of on average $155–$160 per capita of official disaster aid. Therefore, if we are interested in understanding the extent to which the government subsidizes climate risk, examining the impact of disasters on existing programs is important.

The Housing Choice Voucher program provides an excellent setting for contributing to this literature. By examining the impacts on rents for households receiving vouchers, I am able to consider the role of housing subsidies in disaster mitigation both explicitly through shielding low income households from market fluctuations, and implicitly by subsidizing the rent setting behavior of landlords renting to low income households in at risk areas.

5   Data and Sample

In addition to the data listed in section A, I use annual administrative data on all housing choice voucher households and their landlords in New York City from 2007 through 2019, which housing authorities are required to submit to HUD for program analysis and monitoring. This restricted-use data set includes a household ID and building address which has been geocoded to include a Borough Block Lot (BBL) identifier, census tract and block identifiers which I use to match to other data sets. Importantly, it includes the total rent charged for the unit, the payment standard, the total tenant payment (TTP) to the landlord, and the housing assistance payment (HAP) which is the payment made by the housing authority to the landlord to cover the balance of the rent. It also provides demographic information on the household head such as the race and ethnicity, age, number of children and income as well as the number of bedrooms in the unit. Finally, the data set includes the name and masked Tax Identifier Number (TIN) of the landlord.

Table 4 shows the sample of voucher households across surge levels and Table 5 shows summary statistics for all voucher holders living in surge and non-surge areas in 2011. Unsurprisingly, voucher holder rents are much lower than StreetEasy in the same areas, and the census tracts they live in are poorer with a higher share minority households than the StreetEasy listings.

While voucher holders, their buildings and neighborhoods look similar across surge levels, there are some modest differences. Voucher holders in surge areas are slightly more likely to be white and less likely to be Hispanic. They are older, and slightly less likely to have children. They are charged slightly higher rents, though their average neighborhood rents are lower. Interestingly, while a similar proportion of voucher holders have rents above the payment standard in 2011 across the three groups, a much larger percentage of voucher holders in high surge areas have rents that are exactly the same as the payment standard (38%), even though average census tract rents are lower in these areas. This may reflect a strategy of voucher landlords in lower rent neighborhoods, to take advantage of the subsidy by charging rents above neighborhood market rents. However, since in high surge areas, voucher holders live in newer buildings, this may also reflect that they live in higher quality buildings than the average voucher holders in unaffected areas. The differences between these samples underscore the importance of using a difference in differences methodology, but I also control for these baseline differences to ensure they are not driving the identified impacts.

6   Estimation

Since most differences between surge and non-surge areas in the voucher sample move in the same direction as the differences in the StreetEasy sample, I use the same estimation strategy as equation 2 with a couple modifications: the voucher sample is from 2007-2019, rather than 2010-2021 and the number of bathrooms in the unit is not available in the voucher data, so it is not included as a control.

When turning to the incidence of the rent changes, I estimate equation 2 with two additional changes. First, since tenant payments are dependent on the household's income, I include income as a control when estimating the impact on the tenant's portion of the rent. Second, when households first enter contract on a new apartment with a voucher subsidy, the program requires that the tenant pay no more than 40% of their income to rent (the 40% rule) but no such official limitation exists as the voucher holder remains in the unit. If there were differential rates of moving over time between surge and non-surge areas, and thus differential rates of households subject to the "40% rule", estimates equation 2 of the change in tenant payment might be biased toward the group

with fewer restricted households. For this reason, I include an indicator for whether the household was new to the building in that year. This indicator covers those households that are new to the program as well as those that simply moved to a new unit with their voucher.

7   The Impact on Voucher Unit Rents

For comparability to the StreetEasy sample, the first set of results estimates the rental impacts on the full repeated cross section of voucher units. Table 8 reports key coefficients from the difference in difference estimation for the four specifications of equation 1 presented using the StreetEasy data in Section A. Column 1 omits all controls except for the number of bedrooms, column 2 adds the age of the building, column 3 adds the rest of the controls. Unlike in the StreetEasy results, the impact on voucher rents is remarkably robust to the addition of controls. While the coefficients are insignificant, they indicate a relative increase in rents of roughly 3% in high surge areas compared to non-surge areas.

Estimation of equation 2 provides a clearer picture of the results. As Figure 18a shows, there is a clear increasing trend in rents in high surge areas compared to no surge areas, and by 2016, voucher rents in high surge areas were roughly 5% higher relative to voucher rents in non-surge areas[10]. Most notably, though not statistically significant, Figures 18c and 18d clearly show that voucher rents increased in both lower income and higher income neighborhoods, in contrast to the broader market which saw negative impacts in lower income neighborhoods[11].

7.1   The stickiness of voucher rents

The dynamic figures also highlight an additional difference in the rental response of the voucher sample compared to StreetEasy asking rents: voucher rents do not adjust to market conditions in the years following the hurricane. Rather, voucher contract rents were "sticky" downward, and increase gradually in the areas that experienced damage due to the storm. This is perhaps

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[10]While the estimates in low surge areas are slightly larger and more significant in Table 8, the figures show that the trend is relatively similar and if anything, noisier.

[11]Key coefficients for the simple difference in differences estimation of Equation 3 can be found in Table B.1

unsurprising when considering the mechanism through which rents are assessed in the voucher program. Rent reasonableness assessments are conducted when a voucher holder moves into a new unit, or when a landlord requests an increase. If neither happen, we actually should expect to see this stickiness in voucher rents for sitting landlords that do not have a new tenant, and that rents for new tenants in the years immediately following the hurricane experience the negative impact found in the broader market, particularly in lower income neighborhoods. Figures 19a and 19b confirm this hypothesis. Figure 19a displays the impact of the hurricane on rents for a repeated cross section of sitting voucher units, omitting any observations where a tenant newly moves into a unit. Figure 19b shows the impact on the repeated cross section of units in the year they have a new tenant. It is clear that sitting voucher rents did not experience a drop after the hurricane, and instead remained relatively constant, while "new" voucher rents did adjust to the broader market in 2012, 2013 and 2014.

7.2   Exploring the mechanisms for voucher rent increases

Though standard errors are large, the results thus far not only suggest that sitting voucher rents did not experience the same negative impacts as other units in lower income neighborhoods, but they also appear to have increased. Since the heterogeneous effects across neighborhood income in the broader sample appear to be driven by differential recovery, one testable theory is that voucher landlords were able to, or required to, renovate their buildings earlier than other low-income landlords. As the results in Section A showed, on average lower-income landlords did not invest in renovations until the Build it Back funds were largely being dispersed in 2016 and 2017. Yet, voucher landlords need their units to pass inspections to continue to house voucher holders, so the public housing authorities may have required these landlords renovate their properties earlier. They may have readily acknowledged the improvements made by the landlords, allowing them to recoup their investments quite quickly through rental increases. While non-voucher landlords run the risk of losing their tenants through rent increases, voucher tenants might not bear the marginal cost of these rent increases if rents were below the payment standard initially, or if housing authorities made payment standard accommodations to keep tenants in their units.

7.2.1 Renovations

I begin by showing, in Figures 20a and 20b that voucher landlords were significantly more likely to file for renovations in lower income neighborhoods in the year after the hurricane (2013), than other low-income landlords. While Figure 20a looks quite similar to the previous results (Figure 12b) that showed lower income landlords waiting to file for renovation permits until 2016 and 2017, Figure 20b shows that voucher buildings were around 8% more likely to file for renovations in 2013.

Whether these renovations were required by the housing authority, or initiated by the landlords, they appear to have lead to an increase in rents. Figure 21b shows the impact of the hurricane on rents for voucher buildings that did not file for renovations in 2013, and Figure 21a shows the β coefficients from an estimation of equation 3, which depict the differential impact of the storm on rents in high surge ares for buildings that filed for a renovation permit in 2013. The rental increases in high surge areas for units occupied by voucher tenants appear to be driven by units where landlords filed for a renovation permit in the year after the hurricane. These increases are consistent across all three alteration types (Figure B.7) and are robust to extending the permit filing period out to 2016, though they are strongest for those that filed immediately after the hurricane[12].

If voucher rents increased, it is then critical to understand whether the pass-through of renovation costs into rents fell on the voucher holders themselves. Ordinarily, we would expect that if lower income landlords capitalize renovation costs into rents, they would be at risk of losing tenants that cannot afford the higher rent increases. However, with the government involved as a third actor that bears some of the marginal cost of rental increases, voucher landlords may not be bound to the same market constraints.

7.2.2 Voucher Rent Incidence

To estimate the incidence of the rent increases for voucher tenants, I estimate the impact of the storm on the portion of rent that is paid by the tenant and the portion of rent that is paid by the

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[12]In high surge areas, the vast majority of these permits were filed for properties that were damaged to some degree by the storm, according to FEMA's damage assessment (Table 7), but it is difficult to tell from the data whether the renovation led to a quality improvement or was simply repairing the existing damage. Roughly 36% of these permits were "A3", whose minor update could be as small as moving the location of the generator.

housing authority using equation 2.

In high surge areas, Figures 22a and 22b show that the rent increases are not reflected in rental burden on the voucher tenants. Figure 22a shows, if anything, a very slight increase in in TTP payments over time in high surge areas relative to non-surge areas. By contrast, the changes in the HAP payments in Figure 22b are large and statistically significant, mirroring the pattern for voucher contract rents. Consistent with the fact that voucher tenants are not paying larger amounts toward rent though rents are increasing, housing assistance payments for voucher holders living in high surge areas increased by over 6.6% by 2014 and over 10% by 2017.

There are multiple ways the program could have shouldered the majority of the rent increases. If voucher rents were below the payment standards originally, raised rents may have simply closed the gap between the rent and the payment standard. For households whose rents were at or above the payment standard, public housing authorities may have been able to use exception payment standards, or payment standard accommodations to adjust payment standards across specific geographic regions that were impacted by the storm. The largest housing authority in the sample has stated that at the time, they used a metropolitan wide payment standard and did not increase the payment standard in response to the hurricane. However, the data shows that in practice there were a variety of different payment standards used for units with the same number of bedrooms which calls into question the reliability of the payment standard variable for this analysis. Therefore, for now this paper stops short of a comprehensive analysis of the exact mechanisms by which the housing authorities subsidized the majority of rent increases.

8 Robustness Checks

I run several robustness tests. The key identifying assumption of the analysis presented in this paper is that absent the hurricane, rents on blocks that experienced surge would have trended in the same way as rents on blocks that did not experience surge. Since I am limited in my ability to establish pre-trends in the market rent data, I attempt to validate this assumption using a few strategies.

8.1   Pre-trends in related measures

First, while I cannot establish robust evidence of no pre-trend in rents across surge and non-surge areas, I can show evidence of no pre-trend in other, related measures. As Figures 23a, 23b and 23c show, there are no differential pre-trends in construction across high and no-surge areas via the share of lots that received new building, demolition or renovation permits prior to the storm. In addition, I am able to replicate the high and low surge results from Ellen and Meltzer (2022)in Figures 24a and 24b using the same high, low and no-surge designation, as well this paper's ZIP code level fixed effects and various controls used in their paper. These figures show no differential pre-trends in sale prices across the surge designations. If there were no pre-trends in various measures of construction, or home prices across surge and non-surge areas, the assumption that this extends to rents as well seems credible.

8.2   Other Rent Data Sets

Rental data is difficult to obtain, which makes the StreetEasy listings a particularly novel data set. However, since the data does not begin until 2010, I attempt to validate the results using available, but highly imperfect sources of rent information. Once such source are Notices of Present Value (NOPV), issued by the The Department of Finance (DOF). The DOF issues NOPVs annually to inform homeowners of market and assessed values of their property. These statements estimate the gross rental income as reported by the property owner. Li (2022) was able to scrape this data from the publicly available PDFs, from which I use the data from 2005. The Furman Center was able to gain access to more recent years of data, from which I use 2016. However, I am missing critical years in between so I am only able to conduct a longer term difference in differences estimation, rather than a full event study specification.

The data has a few other important caveats: it only covers buildings with 6 or more units, and the approximation of rental income includes commercial rents. However, on average, only 2.5% of units in rental buildings are commercial (Li (2022)). I calculate the average monthly rent per unit for each building and as Table 9 shows, the NOPV estimated rents are much more similar to the ACS median rents in Table 2. However, the characteristics of buildings across the NOPV and

StreetEasy samples are comparable.

I estimate equation 1 on the log average monthly rent per unit, controlling for the age of the building, the number of floors and whether the building is in the flood zone. Initially, as Column 1 Table 10 shows, I find, a similar near zero, insignificant effect on quality-adjusted rents. In Column 2, when I stratify the sample by neighborhood income level, results remain insignificant but move in the same direction as the estimates in the StreetEasy data: I find a positive association for higher income neighborhoods and a negative association for lower income neighborhoods.

8.3   Randomly Generated Treatment and Comparison Groups

Another concern might be that the effects I find are spurious, and not due to the hurricane. If this were true, then I would expect to see similar differences in rental impacts between treatment and comparison groups where the distinction between them is orthogonal to the hurricane. To test this, I randomly split the comparison group and run the same analysis comparing the two groups in each instance. I simulate this process 100 times and plot the point estimates of all 100 estimations in Figures 25a and 25b. As the figures show, I find no evidence of any differences between these randomly generated groups, providing support for the assumption that any differences we see between surge and non-surge areas is due to the differential impact of the hurricane on these blocks.

8.4   Spillovers

It is worth noting that the identification strategy in this paper identifies *relative* impacts across high and no surge blocks, but does not address the possibility of spillovers. Indeed, since the units of analysis are such small geographies, it is possible that many of the mechanisms contributing toward asking rent impacts addressed in this paper may have also affected no surge blocks. If anything, we would expect the existence of such spillovers to attenuate any differential impacts on rents between high and no surge blocks. To explore this, I compile a secondary comparison group comprised of ZIP codes along the coast, and therefore presumably comparable to other coastal areas, that did not experience any flooding. Figure 26 shows that the impacts in the StreetEasy

sample are quite similar to the main results, providing limited evidence of strong spillover effects on original comparison blocks.

Another way to address the possibility of spillovers is to run the analysis clustered at different levels of geography. Census tracts are a common level of geography used to approximate neighborhoods in the urban economics literature. However, census tracts are particularly small in New York, and many did not experience much variation win flooding, which is why the main analysis clustered analysis at the ZIP code level. Still, replication of the results using census tract fixed effects does yield similar results (Figure B.2).

9   Discussion

In this paper, I find evidence that hedonic rents in high surge areas of New York City experienced a negative impact in the years immediately after Hurricane Sandy relative to those that experienced no surge but, contrary to home prices, rebounded quite quickly and returned to levels comparable to non-surge areas 3 years after the storm. Stratifying the results by neighborhood income reveals heterogeneity in quality adjusted rental impacts: rents for higher income neighborhoods increased, while rents for lower income neighborhoods decreased. These results appear to reflect that landlords in higher income neighborhoods had more resources to begin renovations and restoring the neighborhood earlier than lower income neighborhoods.

Importantly, I find that rents in the Housing Choice Voucher market behaved differently than the rents for other low income units. The program appears to have protected both landlords and tenants from market fluctuations. Voucher rents were "sticky" downward, so that voucher landlords did not have to reduce their rents in response to market conditions. In fact, voucher rents increased, prompted by renovations to their units. The government subsidized these renovations, so that rental increases did not fall on the tenants themselves.

A few important implications emerge from this work. First, it is worth stressing that the relative impacts in rents of Hurricane Sandy clearly differ from those found for house prices in the wake of hurricanes, which appears to reflect the different incidence in increased user costs of housing cross renters and homeowners. Since one-third of the population rents and roughly

40% of the occupied rental stock is located in areas at moderate risk of damage from natural disasters (The Joint Center for Housing Studies (2022)), ensuring that housing market research accounts for the differences between the owner-occupied and rental markets is critical for policy making. Additionally, differential recovery across tenure and by neighborhood income has broader implications for equity and the demographics of these neighborhoods over time. Future work will explore how the population in these neighborhoods may have changed due to the storm-induced rental market dynamics.

In a similar vein, as rental housing costs continue to rise, there have been national discussions of increasing the scale of the voucher program. In light of these results it feels important to consider the implications of such an expansion in areas at high risk of damage due to natural disasters. On the one hand, vouchers appear to shield low income tenants from the fluctuations of the broader market and potentially enable landlords to improve the quality of their units. The Housing Choice Voucher program is plagued by low landlord participation, and if this sort of "insurance" acts as an incentive for participation, the increased costs to the government may have additional positive consequences. On the other hand, this level of "insurance" may be explicitly subsidizing and therefore unintentionally encouraging the housing of vulnerable, low-income households in areas at high risk of climate change-induced damage. This creates important questions for policy makers as to the role of existing rental subsidies and their potential unintended consequences in light of the increasingly frequent and destructive events caused by climate change.

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10 Figures

Figure 1: New York City ZIP codes by Storm Surge Level
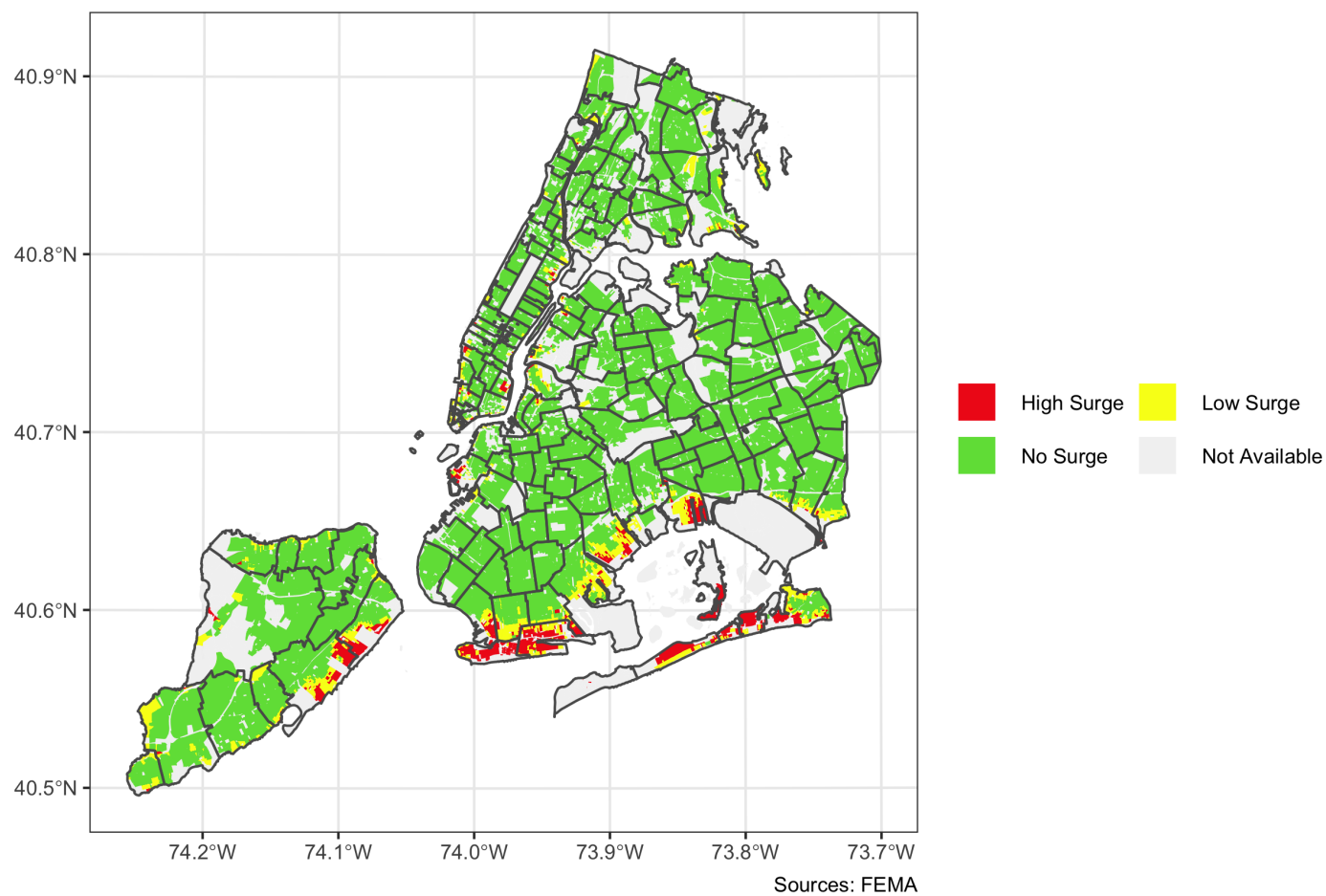
Figure 2: High, Low and No Surge Blocks across the Flood Zone
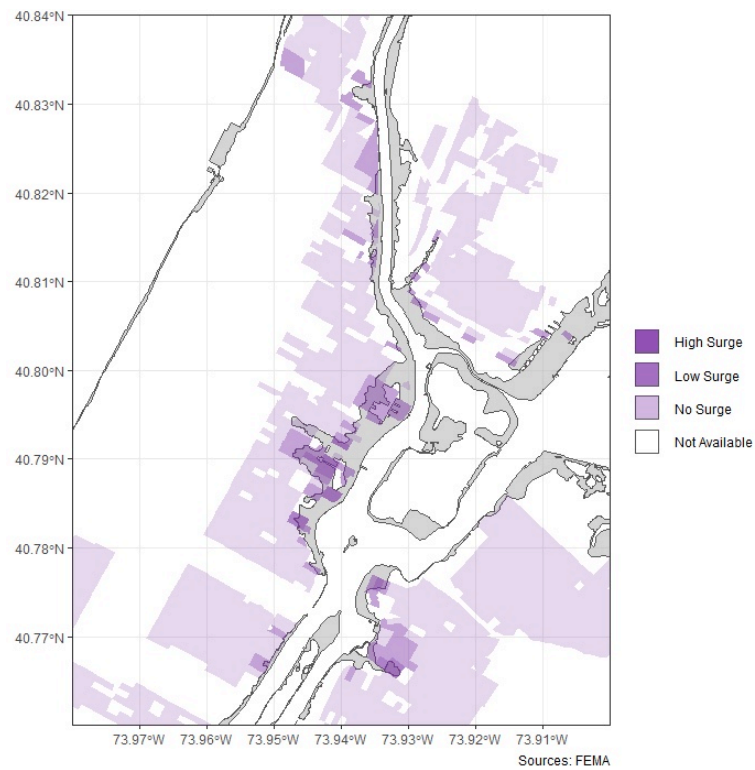
Figure 3: Percentage of Plot Incurred Major Damage by Surge Height
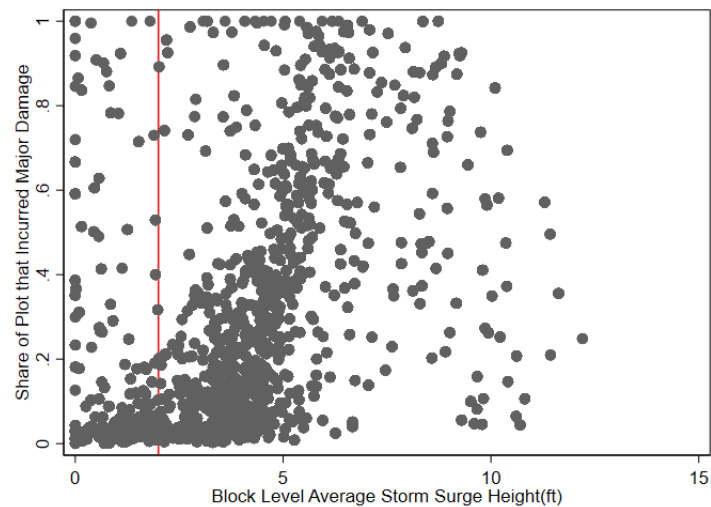
Note: Red line indicates cut off of 2ft of surge height for high surge areas.

Figure 4: Composition of StreetEasy Sample over Time

(a) Number of Listings by Borough over Time
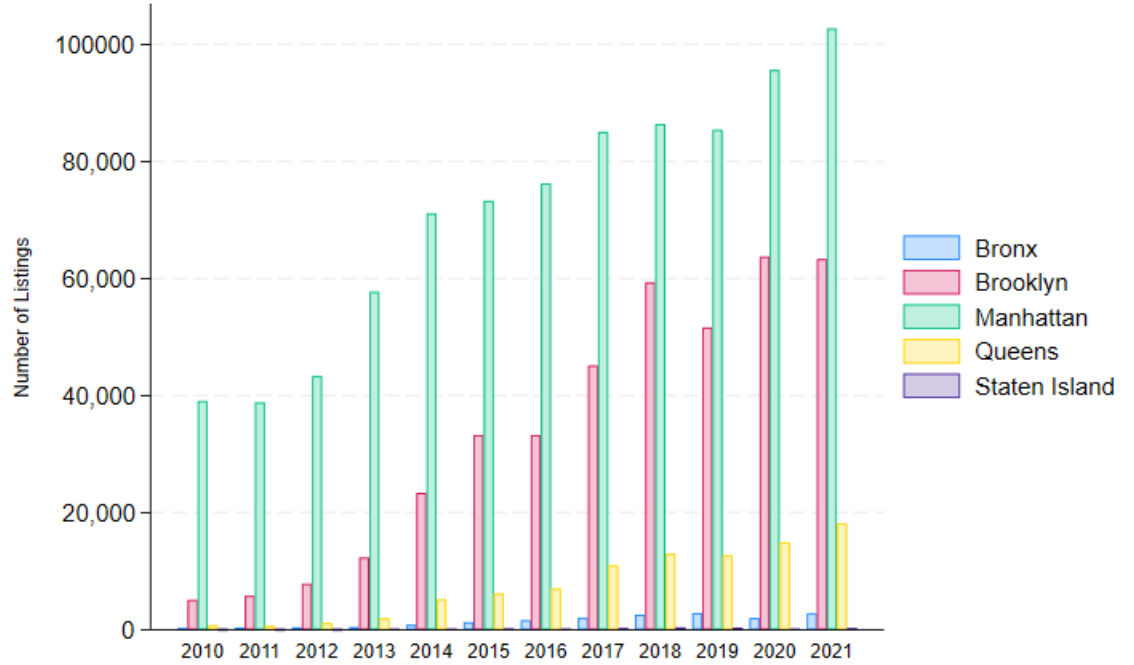
(b) Share of Listings by Building Type
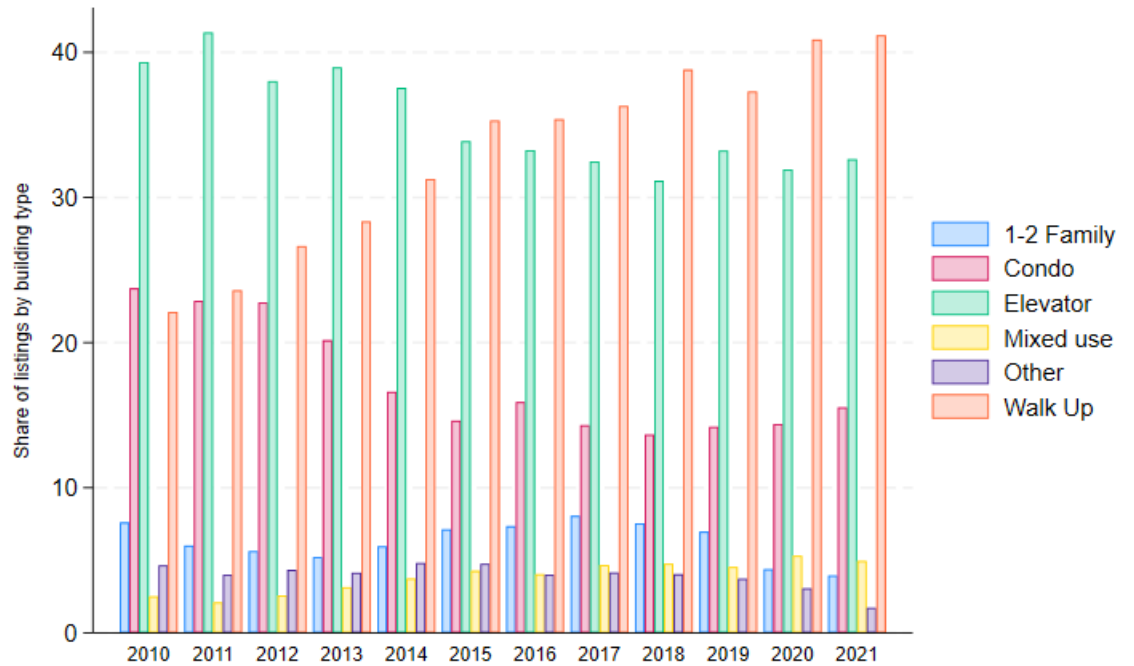
Figure 5: Dispersion of StreetEasy Sample over Time

(a) StreetEasy Sample in 2011

High Surge   Low Surge   No Surge   Not Available

Sources: FEMA
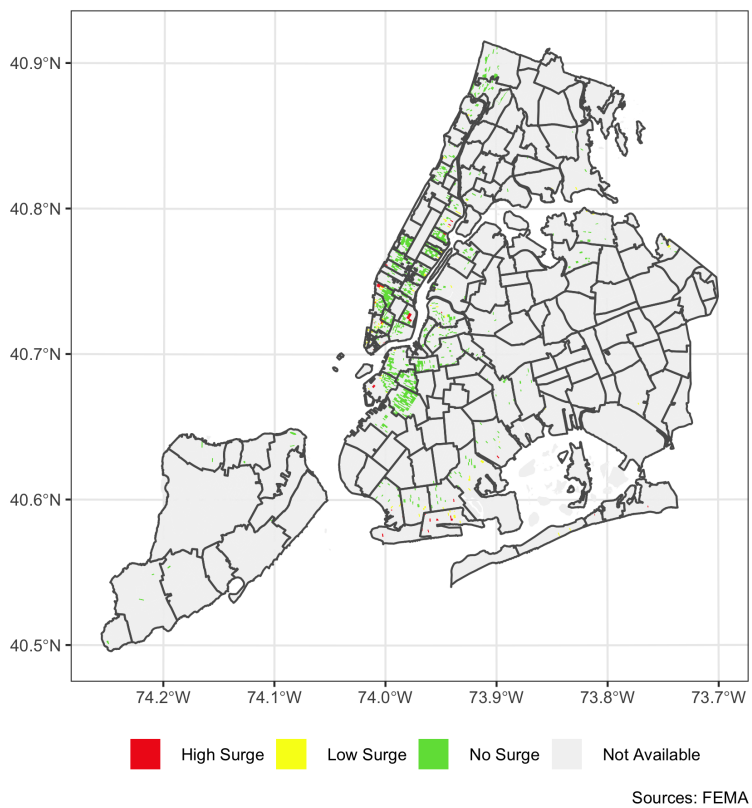
(b) StreetEasy Sample Across Full Time Period

High Surge   Low Surge   No Surge   Not Available

Sources: FEMA
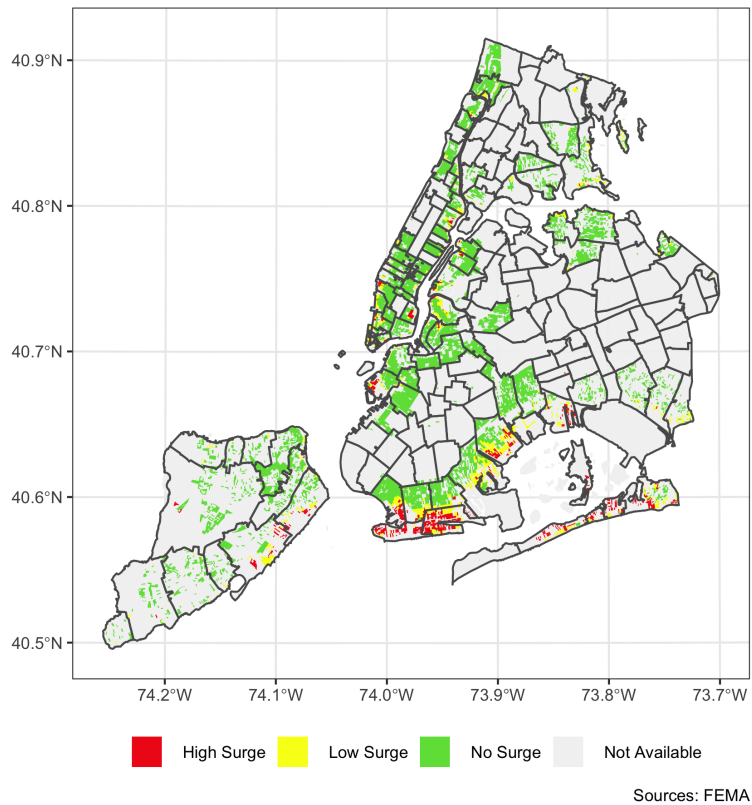
Figure 6: Annual Change in Average Rents Over Time

Figure 7: Impact of Hurricane Sandy on Asking Rents

(a) Average Rents in High Surge Areas (Table 3, Column 1)
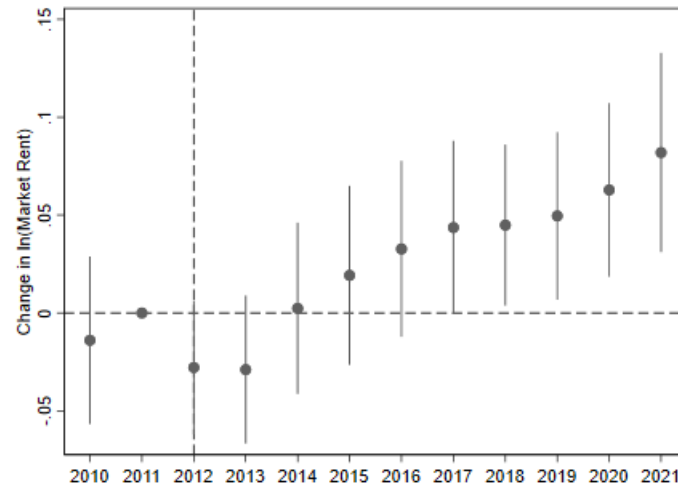
(b) Average Rents in High Surge Areas, controlling for age of building (Table 3, Column 2)
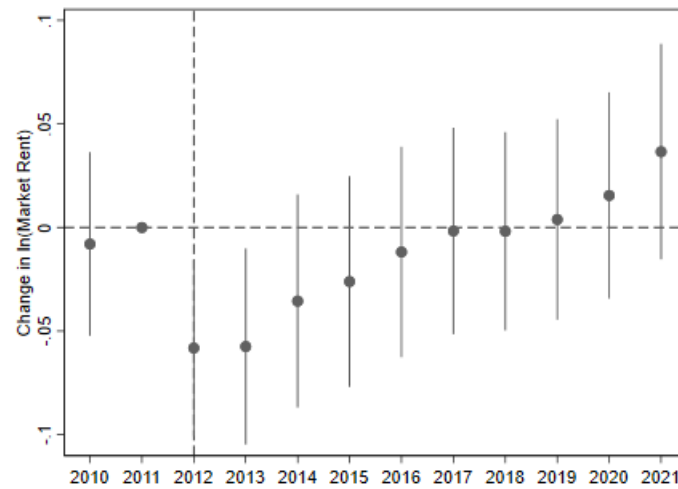
(c) Average Rents in High Surge Areas, all controls (Table 3, Column 3)
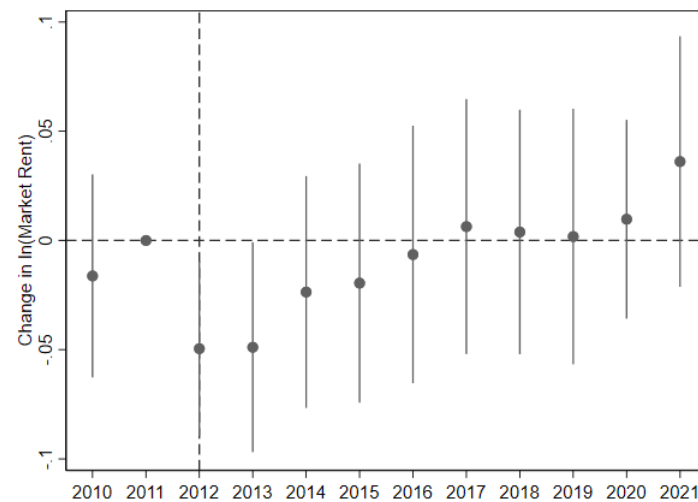
Figure 8: Annual Block-Level Growth Rates in Number of Listings by Surge Level
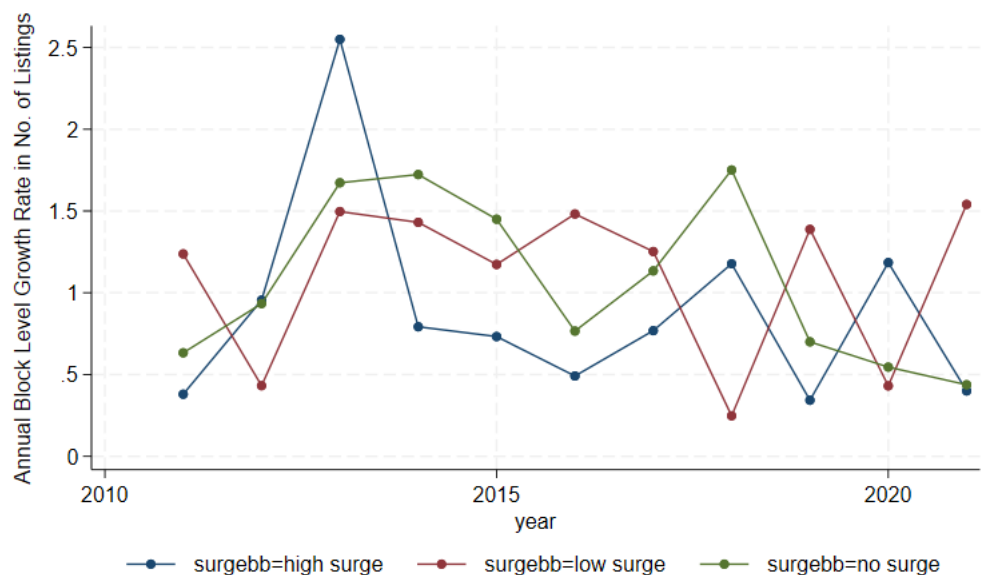
Figure 9: Impact of Hurricane Sandy on Rents and Home Prices
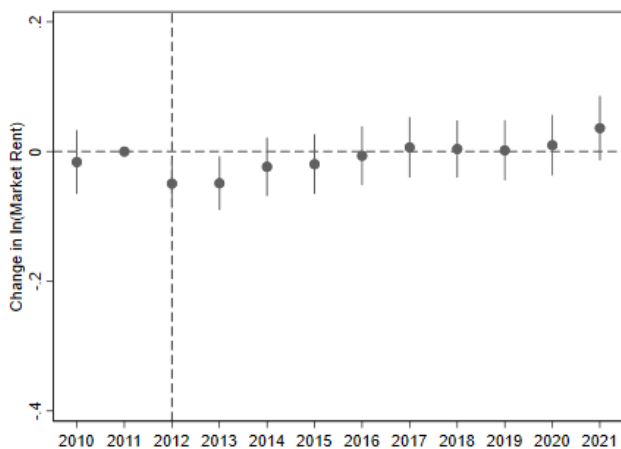
(a) Rents   (b) Home Prices
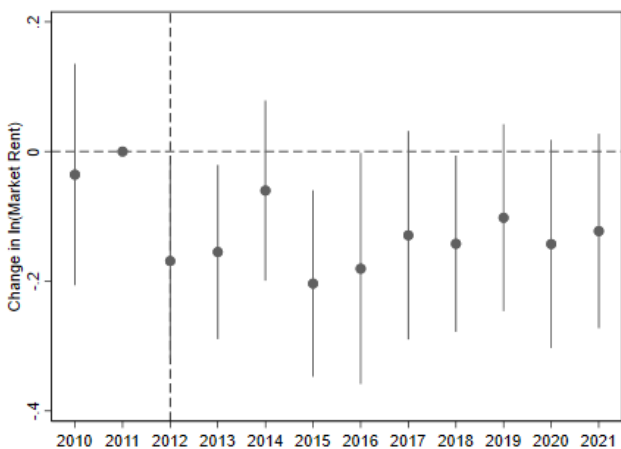
Figure 10: Average Price/Unit to Rent Ratio Over Time
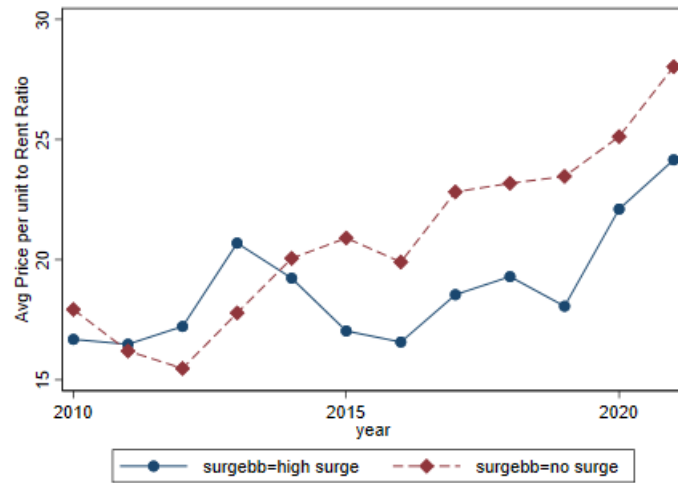
Figure 11: Quality-adjusted Rent Impacts by Neighborhood Income

(a) At or Below Median Income
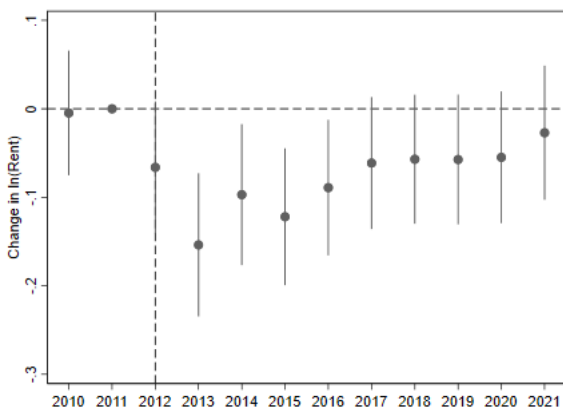
(b) Above Median Income
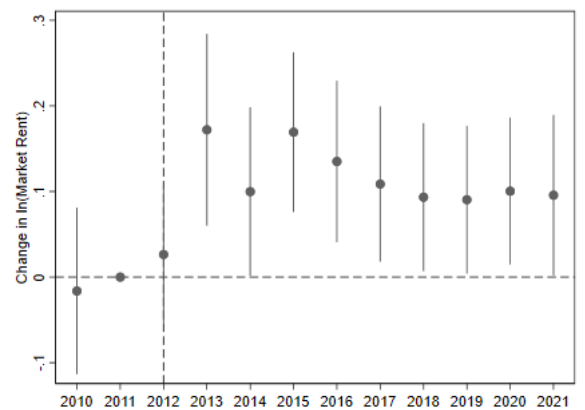
Figure 12: Impacts on the Share of Lots with Renovation Permits by Neighborhood Income

(a) At or Below Median Income

(b) Above Median Income
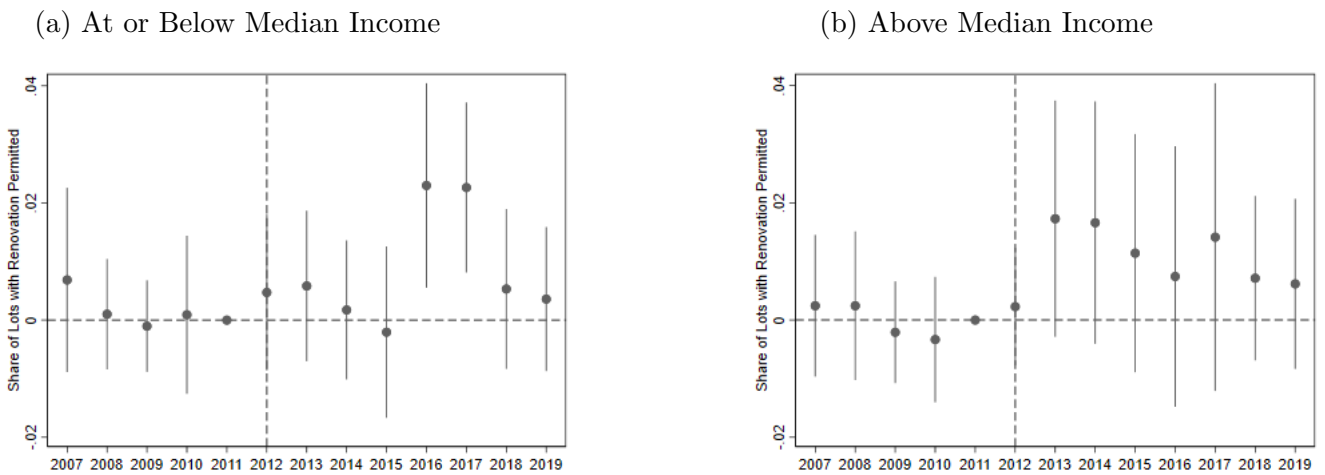
Figure 13: Build it Back Recovery Funds Distribution for Manhattan and Brooklyn
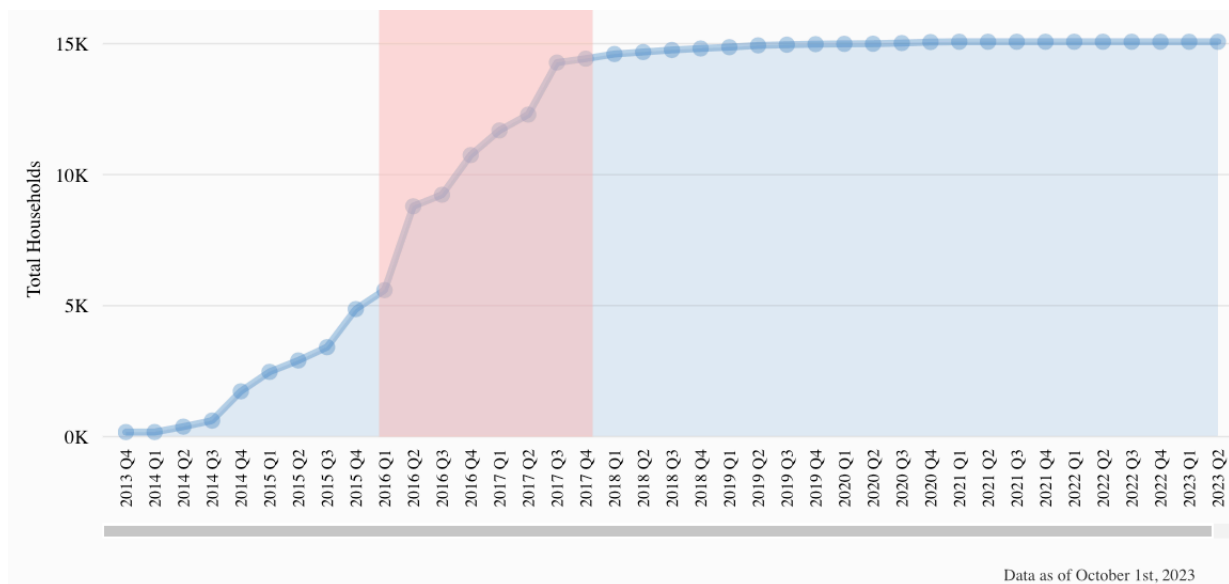
Notes: https://www.nyc.gov/content/sandytracker/pages/build-it-back. The red section indicates the time period with an increase in renovation permits in below median income neighborhoods.

Figure 14: Impacts on High Surge Rents by Share of Building Units Rent-Stabilized

(a) Less than 25% Rent-Stabilized
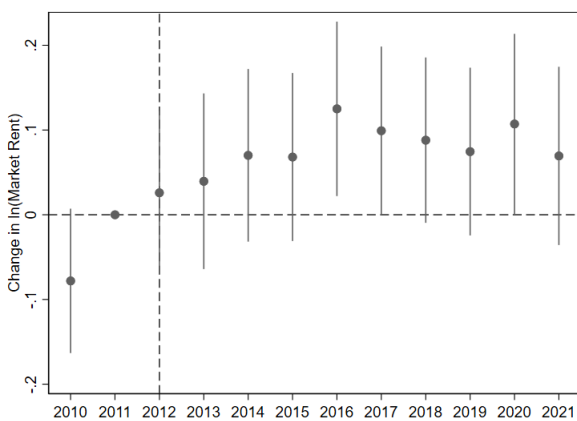
(b) 25-75% Rent-Stabilized
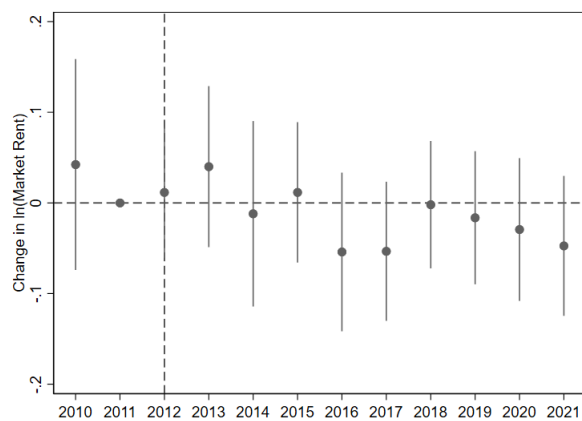
(c) More than 75% Rent-Stabilized
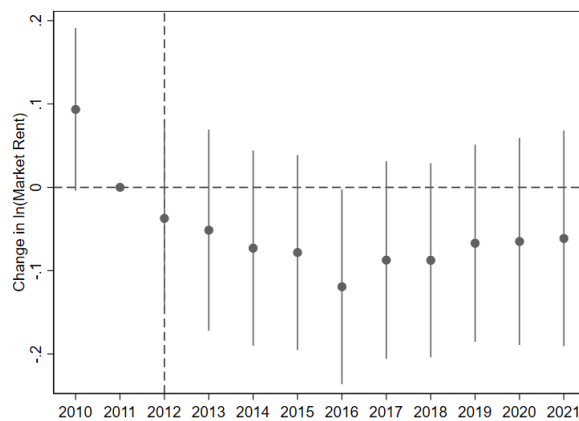
Figure 15: Impacts on Rents for Buildings with Less than 25% of Units Rent-Stabilized by Neighborhood Income

(a) At or Below Median Income

(b) Above Median Income
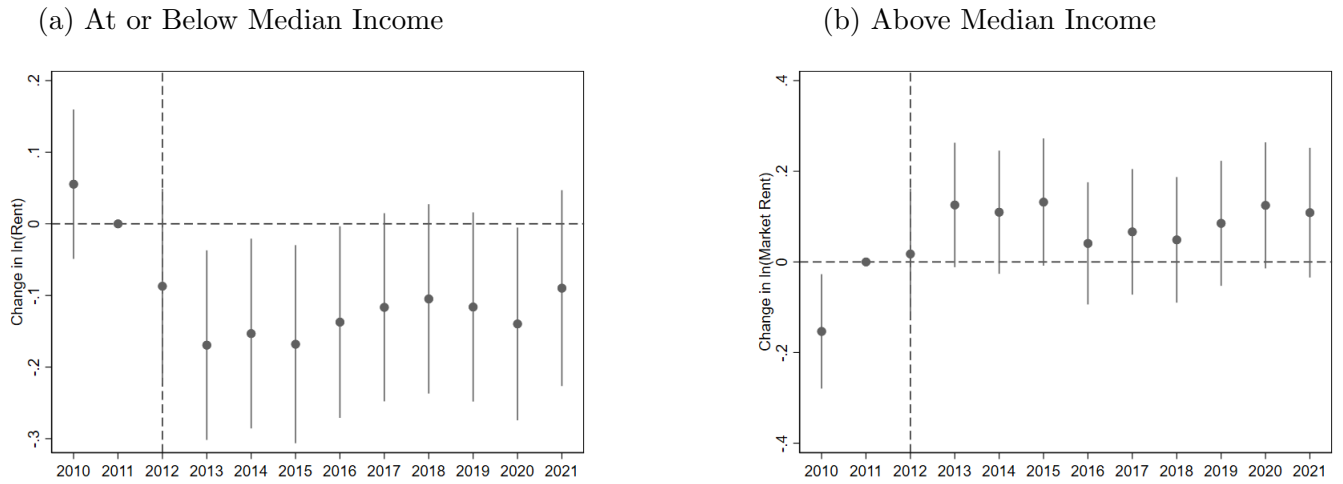
Figure 16: Impacts on the Share of Lots with Renovation Permits for Buildings with Less than 25% of Units Rent-Stabilized by Neighborhood Income

(a) At or Below Median Income

(b) Above Median Income
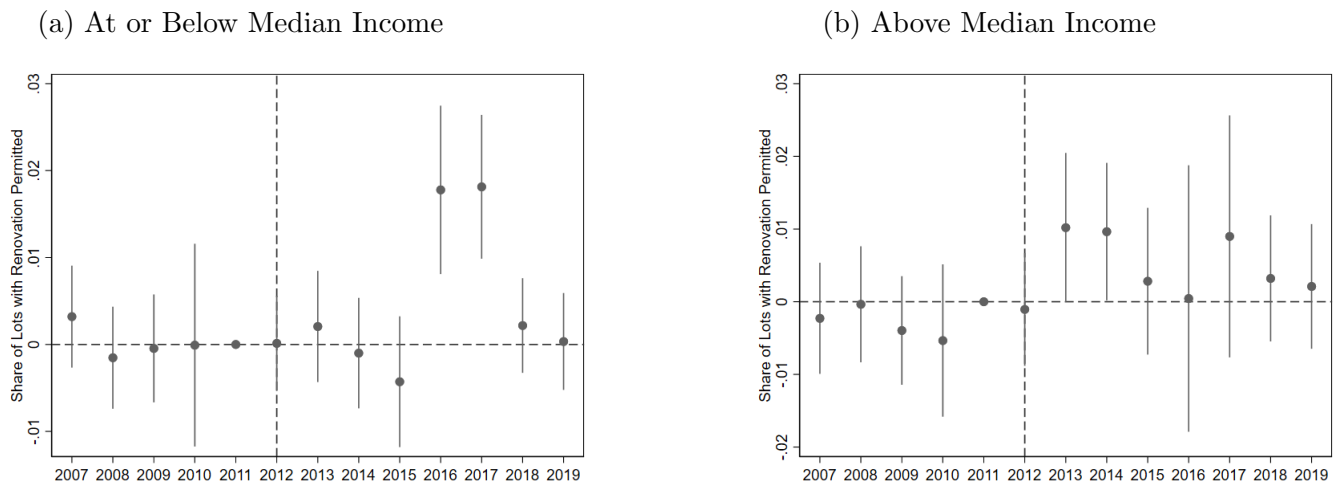
Figure 17: Quality-adjusted Rental Impacts for Voucher Buildings
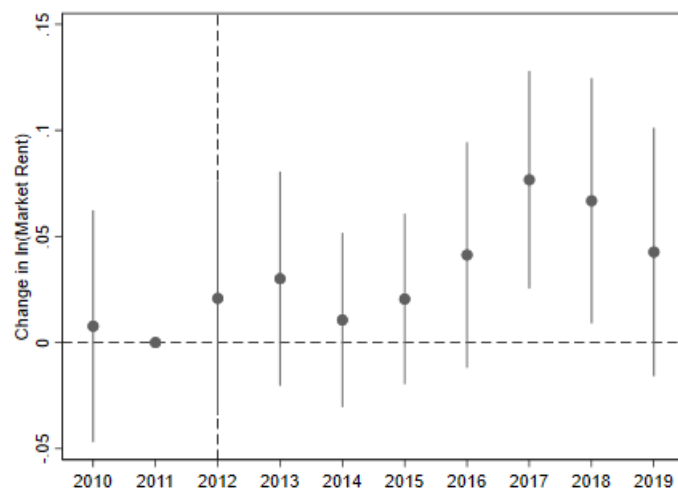
Figure 18: Impact of Hurricane Sandy on Voucher Rents

(a) High Surge Areas
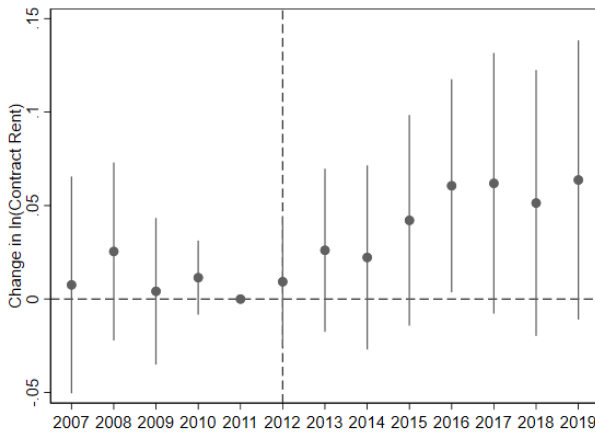
(b) Low Surge Areas
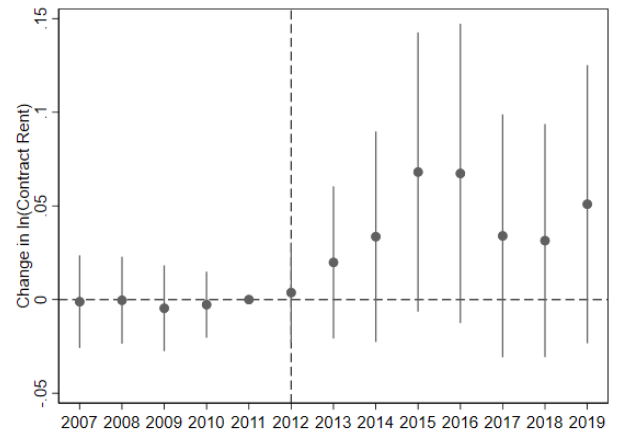
(c) High Surge, At/Below Median Income Neighborhoods
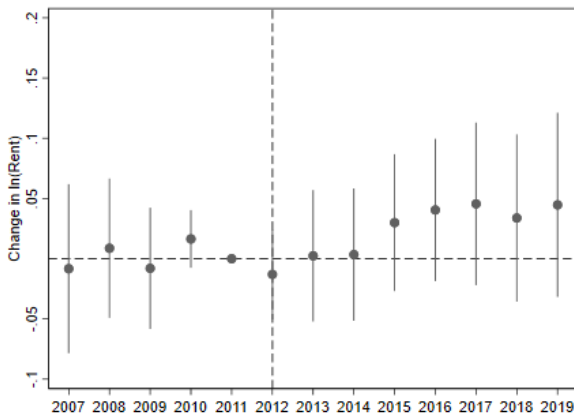
(d) High Surge, Above Median Income Neighborhoods
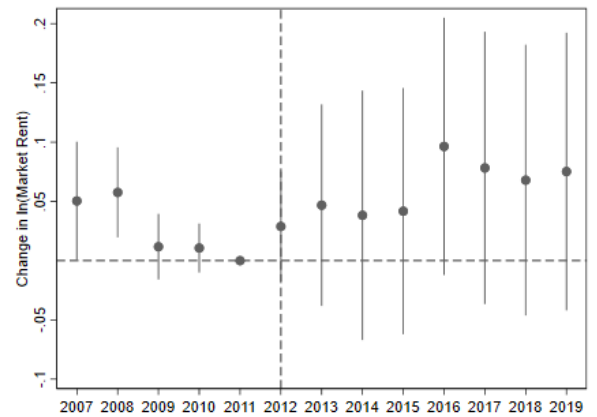
Figure 19: High Surge Voucher Rental Impacts by Tenure

(a) Sitting Voucher Units
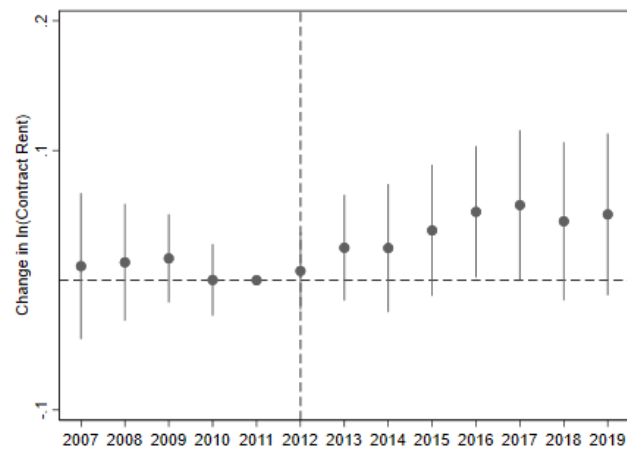
(b) "New" Voucher Units
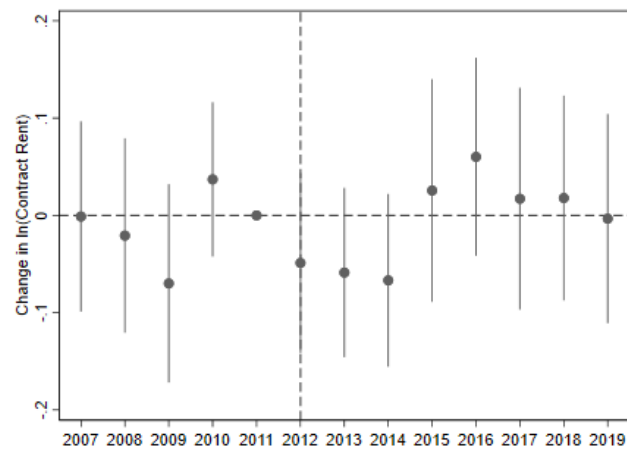
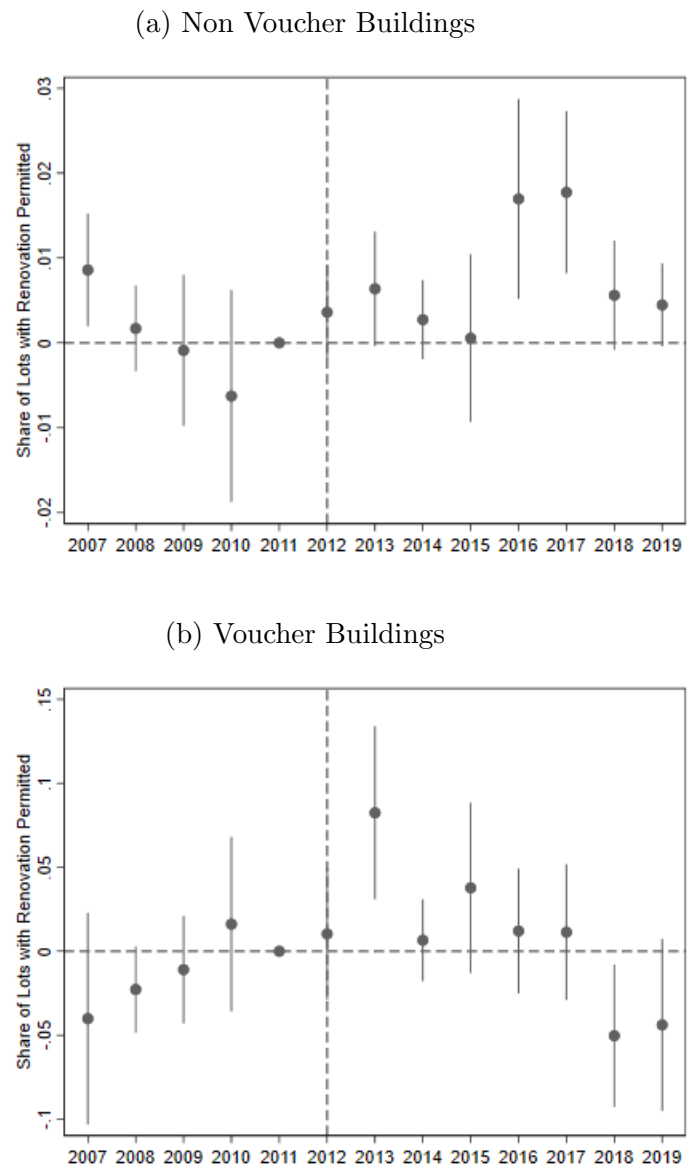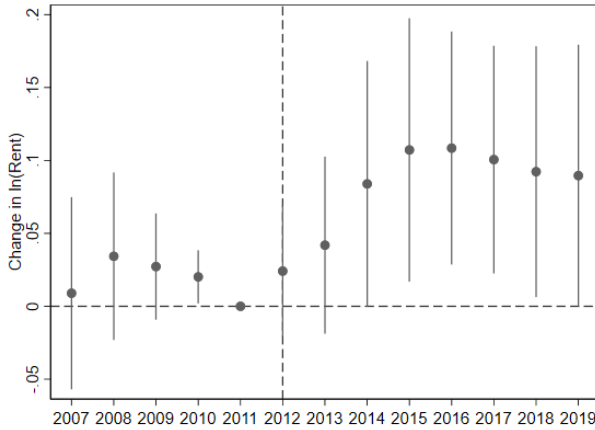Figure 20: Share of Lots that Filed for Renovation Permits in Below Median Income Neighborhoods

(a) Non Voucher Buildings

(b) Voucher Buildings

Figure 21: Differential Voucher Rental Impacts for 2013 Job Filings

(a) Buildings that filed for 2013 renovation permit
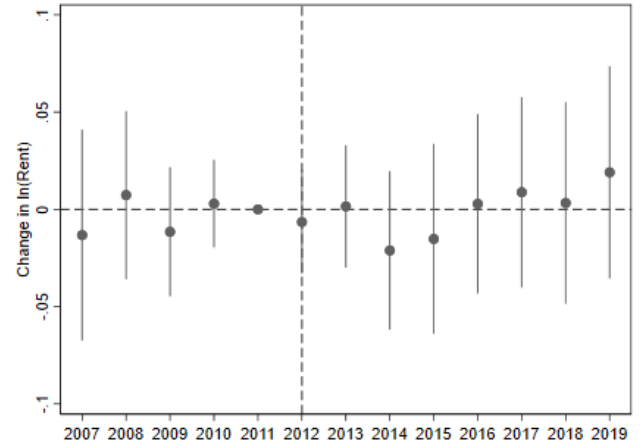
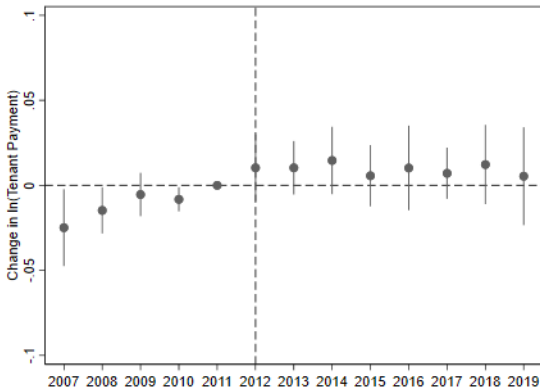(b) Buildings that did not file for a 2013 permit

Figure 22: Impacts on Tenant and Housing Assistance Payments in High Surge Areas

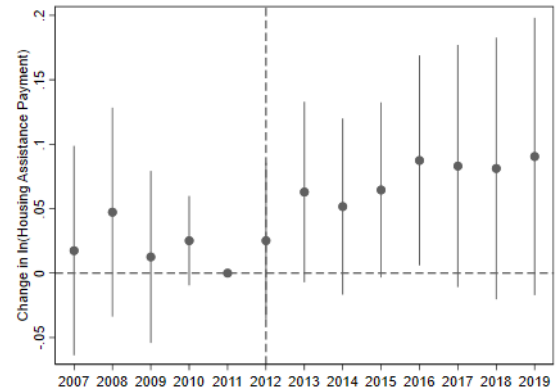(a) Voucher Tenant Payments

(b) Housing Assistance Payments

Figure 23: Impacts on the Share of Buildings with Demolition, New Building and Renovation Permits
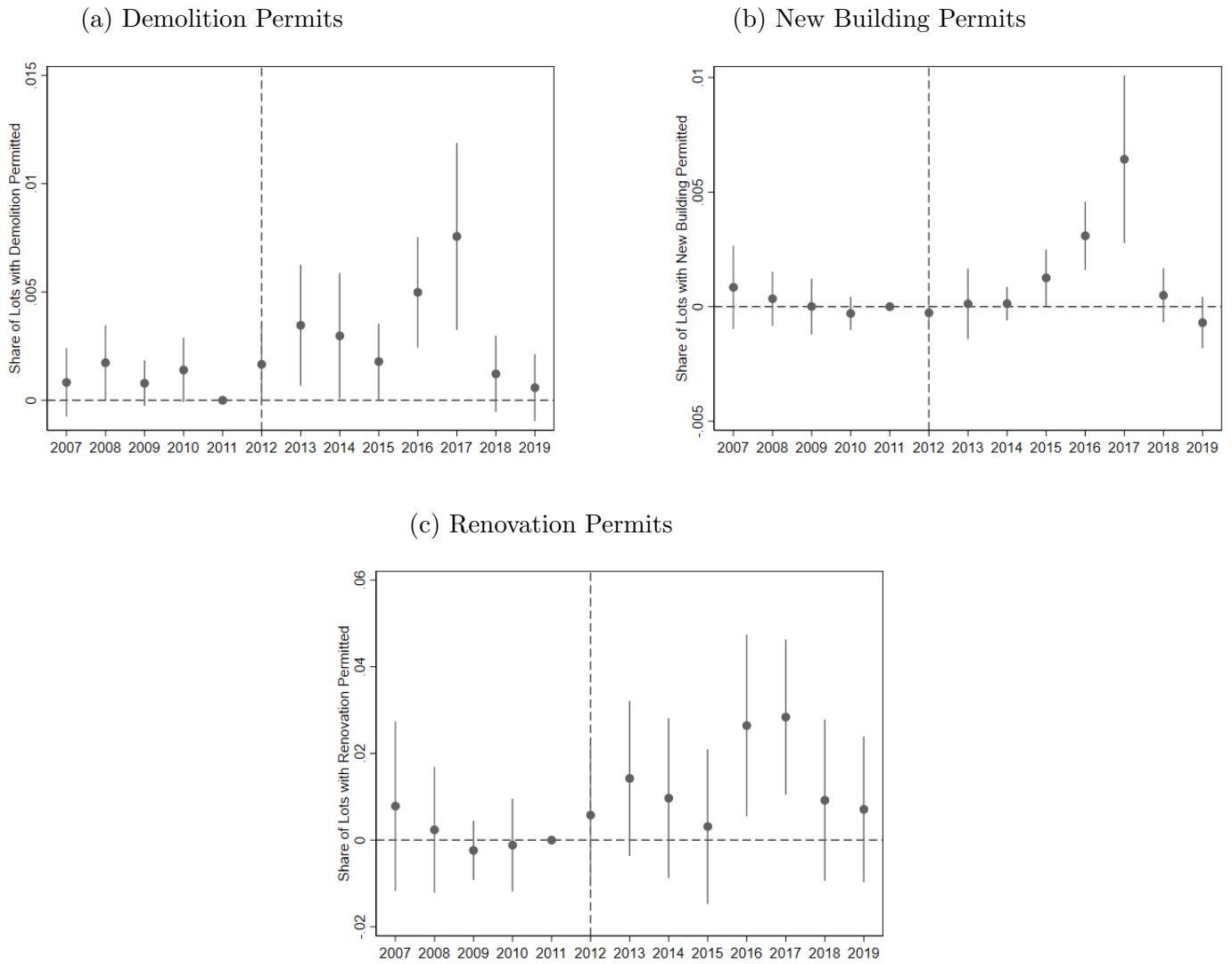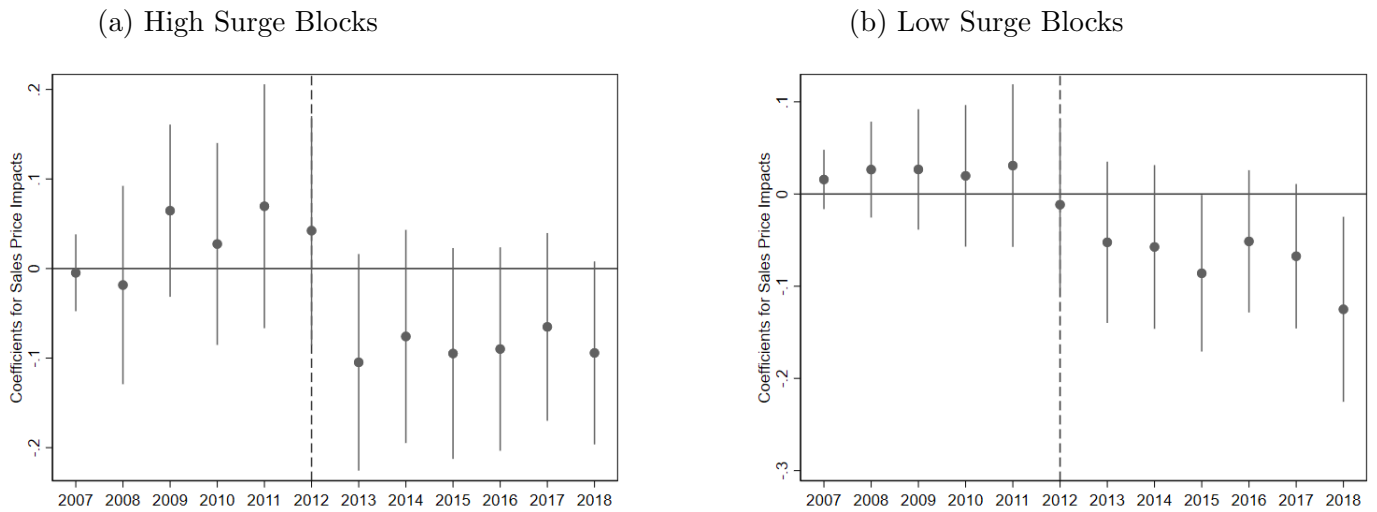
(a) Demolition Permits

(b) New Building Permits

(c) Renovation Permits

Figure 24: Impacts on Sales Prices

(a) High Surge Blocks

(b) Low Surge Blocks

Figure 25: Rental Impacts of Randomly Split Comparison Group
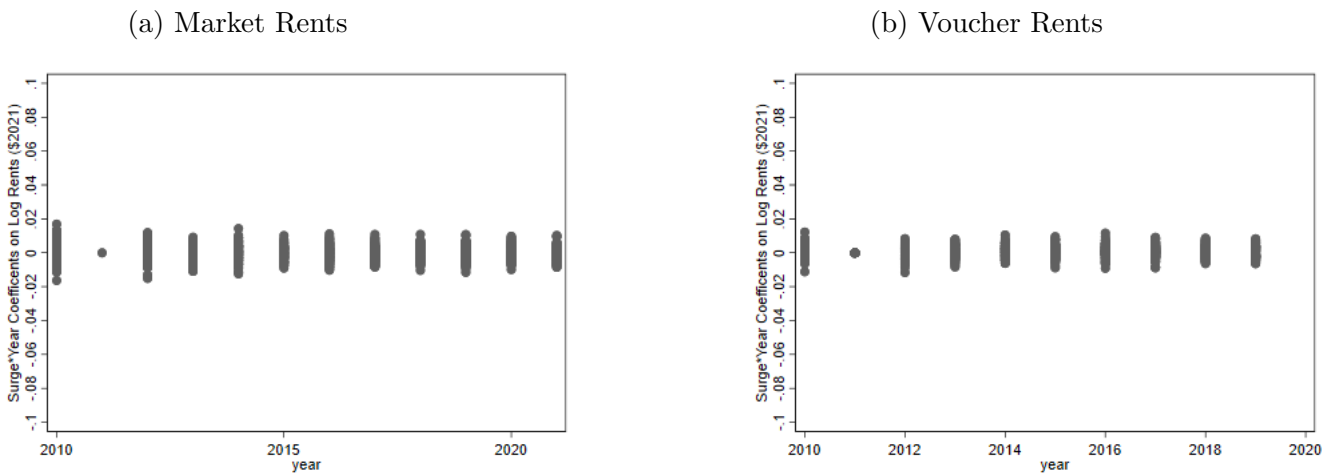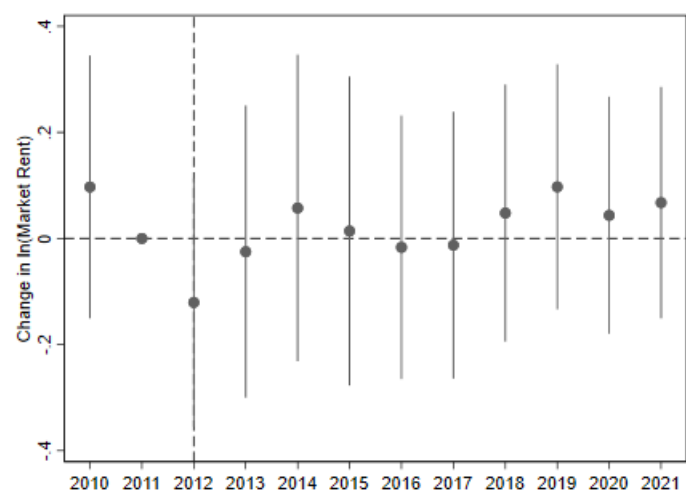
(a) Market Rents

(b) Voucher Rents

Figure 26: Rental Impacts with Non-affected Coastal ZIP code Comparison Group

11 Tables

Table 1: Sample of Asking-Rent Listings by Surge Area

2011	High Surge	Low Surge	No Surge	Total
Listings	2,070	6,078	37,647	45,795
Blocks	110	222	2,043	2,375
ZIP codes	30	60	81	93
2017	High Surge	Low Surge	No Surge	Total
Listings	6,042	16,265	123,306	145,613
Blocks	330	501	3,900	4,731
ZIP codes	45	79	88	98

Table 2: Summary Statistics for Market Units in 2011 by Surge Level

	High Surge	Low Surge	No Surge
Unit Level			
No. Bedrooms	1.36	1.25	1.25
	(0.97)	(0.89)	(1.02)
No. Bathrooms	1.25	1.33	1.22
	(0.53)	(0.64)	(0.59)
No fee	0.44	0.60	0.31
	(0.50)	(0.49)	(0.46)
Rent (in 2021)	4377.28	5364.10	4390.90
	(3313.40)	(9058.12)	(4460.26)
Building Level			
No. Res. Units	47.83	80.44	41.39
	(109.32)	(197.59)	(132.69)
Building Age	74.86	68.72	84.66
	(40.78)	(41.28)	(32.44)
Tract Level			
Tract Pov Rate	0.17	0.14	0.18
	(0.08)	(0.12)	(0.13)
Tract Share White	0.53	0.49	0.46
	(0.26)	(0.29)	(0.30)
Tract Share Black	0.11	0.16	0.15
	(0.19)	(0.24)	(0.23)
Tract Share Hispanic	0.16	0.22	0.25
	(0.14)	(0.20)	(0.23)
Tract Share Asian	0.17	0.10	0.12
	(0.13)	(0.12)	(0.15)
Tract Share College Degree	0.26	0.24	0.25
	(0.11)	(0.12)	(0.13)
Tract Share Foreign Born	0.44	0.34	0.32
	(0.18)	(0.15)	(0.15)
Tract Med Rent (in 2021)	1371.39	1518.26	1517.39
	(467.23)	(479.22)	(499.75)

Table 3: Impact of Hurricane Sandy on Market Rents

	(1) Log Rent (2021)	(2) Log Rent (2021)	(3) Log Rent (2021)
No. Bedrooms	0.165*** (0.017)	0.170*** (0.018)	0.168*** (0.018)
high surge × post=1	0.053*** (0.018)	0.018 (0.021)	0.021 (0.020)
low surge × post=1	0.010 (0.022)	0.010 (0.019)	0.016 (0.020)
Building Age		-0.005*** (0.000)	-0.004*** (0.000)
Building Age Sq		0.000*** (0.000)	0.000*** (0.000)
No. Bathrooms			0.012 (0.011)
No Broker Fee			0.006 (0.005)
No. Res Units			-0.000 (0.000)
Res Units Sq			0.000 (0.000)
Subsidized housing			-0.016 (0.014)
Number of Floors			0.008*** (0.001)
Flood Zone			0.046** (0.019)
Constant	7.886*** (0.025)	8.122*** (0.025)	7.931*** (0.028)
N	1371538	1371538	1371536
Age Controls		X	X
Zipcode * Year		X	X
Zipcode * Surge	X	X	X

Notes:Regressions on log asking rents in \$2021. Column 1 includes on control for number of bedrooms, Column 2 adds age, Column 3 includes all controls. All models include zipcode by year and zipcode by surge level fixed effects.. Clustered standard errors in parentheses. * p < 0.10 ** p < 0.05 *** p < 0.01

Table 4: Sample of Voucher Holders by Surge Area, 2011

2011	High Surge	Low Surge	No Surge	Total
Voucher Holders	6,136	4,749	40,829	51,174
Blocks	394	499	4,093	4,986
ZIP codes	37	79	92	96

Table 5: Summary Statistics for Voucher Units in 2011 by Surge Level

	High Surge	Low Surge	No Surge
Unit Level			
HH Head Black	0.03	0.05	0.04
	(0.16)	(0.22)	(0.20)
HH Head Hispanic	0.18	0.22	0.25
	(0.38)	(0.41)	(0.44)
HH Head White	0.48	0.35	0.38
	(0.50)	(0.48)	(0.49)
HH Head Over 65	0.46	0.33	0.28
	(0.50)	(0.47)	(0.45)
Has Children	0.28	0.36	0.39
	(0.45)	(0.48)	(0.49)
Contract Rent (in $2021)	1483.59	1605.83	1449.96
	(546.51)	(844.68)	(488.48)
HH Income/10000 (in $2021)	1.97	2.16	1.85
	(1.39)	(1.51)	(1.18)
Housing Assistance Payments (in $2021)	1026.11	1126.68	1065.66
	(506.63)	(808.20)	(475.51)
Tenant Rent Portion (in $2021)	490.37	532.59	445.97
	(352.43)	(383.85)	(289.28)
Share Above Payment Standard	0.04	0.05	0.07
	(0.20)	(0.22)	(0.25)
Share At Payment Standard	0.38	0.23	0.13
	(0.48)	(0.42)	(0.33)
Share 0-5% Below PS	0.06	0.09	0.12
	(0.25)	(0.29)	(0.32)
Share 5-10% Below PS	0.08	0.11	0.13
	(0.27)	(0.31)	(0.34)
Share 10-50% Below PS	0.37	0.48	0.51
	(0.48)	(0.50)	(0.50)
Share 50	(0.24)	(0.21)	(0.20)
Building Level			
No. Res. Units	389.41	1193.76	142.83
	(471.68)	(2413.30)	(342.67)
Building Age	49.54	55.75	70.41
	(21.68)	(29.30)	(29.96)

Table 6: Summary Statistics for Voucher Units in 2011 by Surge Level (Continued)

	High Surge	Low Surge	No Surge
Tract Level			
Tract Poverty Rate	0.25	0.23	0.27
	(0.11)	(0.15)	(0.13)
Tract Share White	0.42	0.30	0.27
	(0.34)	(0.31)	(0.31)
Tract Share Black	0.30	0.31	0.24
	(0.25)	(0.28)	(0.23)
Tract Share Hispanic	0.20	0.31	0.40
	(0.15)	(0.26)	(0.27)
Tract Share Asian	0.06	0.06	0.08
	(0.09)	(0.10)	(0.12)
Tract Share College Degree	0.17	0.17	0.15
	(0.09)	(0.09)	(0.09)
Tract Share Foreign Born	0.42	0.34	0.35
	(0.19)	(0.14)	(0.14)
Tract Median Rent (in $2021)	1009.00	1182.58	1197.20
	(349.23)	(312.86)	(334.01)

Table 7: FEMA Damage Assessment by Type of Alteration

	A1	A2	A3	Total
Major Damage/Destroyed	0.02	21.61	10.24	31.87
Minor Damage	0.01	39.33	10.01	49.36
Affected	0	3.17	8.78	11.95
No damage	0	0.20	6.61	6.82
Total	0.04	64.31	35.65	100.00

This table shows the percentage of voucher holders in high surge areas by the FEMA Damage Assessment classification and the type of alteration permit the building filed for in 2013.

Table 8: All Voucher Rent Results

	(1) Log Rent (2021)	(2) Log Rent (2021)	(3) Log Rent (2021)
No. Bedrooms	0.160*** (0.004)	0.160*** (0.004)	0.156*** (0.004)
high surge × post=1	0.028 (0.019)	0.029 (0.020)	0.026 (0.020)
low surge × post=1	0.042** (0.021)	0.039* (0.022)	0.042* (0.023)
Building Age		-0.002*** (0.001)	-0.002*** (0.001)
Building Age Sq		0.000 (0.000)	0.000 (0.000)
No. Res Units			-0.000*** (0.000)
Res Units Sq			0.000*** (0.000)
No. of Floors			0.007** (0.003)
Subsidized housing			-0.096*** (0.022)
Flood Zone			-0.088* (0.048)
Constant	6.961*** (0.009)	7.060*** (0.016)	7.074*** (0.022)
N	681247	680663	680663
Age Controls		X	X
All Other Controls			X
Zipcode * Year	X	X	X
Zipcode * Surge	X	X	X

Notes: Regressions estimated on repeated cross-section of all voucher units
in the program during the time period. *Standard errors in parentheses.* * p
< 0.10 ** p < 0.05 *** p < 0.01

Table 9: NOPV Summary Statistics (2005)

	High Surge	Low Surge	No Surge
Building Age	74.53	76.92	80.49
	(26.81)	(24.38)	(19.73)
Number of Res. Units	61.60	54.94	28.04
	(142.31)	(325.42)	(85.97)
Number of Floors	6.03	5.34	4.89
	(4.50)	(4.68)	(3.28)
Monthly Rental Income/Unit ($2021)	1768.16	1658.86	1618.50
	(1232.35)	(1568.16)	(1396.65)
Number of buildings	687	1639	29,562

Table 10: Key Coefficients for NOPV DID High Surge Estimates

	(1) Log Avg Inc/Unit	(2) Log Avg Inc/Unit
high surge × post=1	-0.018	-0.035
	(0.014)	(0.028)
high surge × post=1 × high_inc=1		0.016
		(0.051)
Zipcode * Year	X	X
Zipcode * Surge	X	X
N	311827	311827

*Notes: These regressions show key coefficients for the impact on log average rental income per unit. The model also includes controls for the age and size of the building, whether it includes affordable housing, and whether it is located in the flood zone. Clustered standard errors in parentheses. * p < 0.10 ** p < 0.05 *** p < 0.01*

A   Appendix

Below I discuss the results for further measures of heterogeneity associated with building age.

A.0.1   Building Height

Since units on lower floors were more likely to be damaged by the storm surge than units on higher floors, it's possible that taller buildings and/or units on higher floors experienced different rental impacts. There is some evidence this is true in Figures B.2a and B.2b where, though not statistically significant, rents appear to have increased in buildings above median height (6 floors) and decreased in buildings below median height. However, I find no differential impacts for ground floor apartments, based on a rough approximation of the unit's floor. (Figure B.3) [13].

A.0.2   Renovations

Since neighborhood income heterogeneity in rental impacts appears to be related to the timing of renovations, I explore in the StreetEasy sample whether the renovated buildings in particular are driving the rent impacts. If landlords conducted renovations to repair damage and return their unit to its initial quality, we would not expect landlords to be able to pass on renovation costs into rents. However, some research suggests that landlords enjoy monopoly pricing power power in New York City (Watson and Ziv (2021)), and, in the wake of a disaster, they may enjoy even more abnormal market power. In addition, if the landlord took the opportunity to improve the unit beyond its original condition, a well functioning market would allow those costs to be passed onto rents.

Figure B.4b plots the relative rental impacts for buildings in high surge areas that did not file for renovation permits in 2013 (r = 0) and B.4a plots the $\beta(s = high, r = 1)$ from equation 3 which represent the differential impact for buildings that did file for permits in 2013-2015. Interestingly, while rents decreased initially for buildings that did not file for renovation permits in the 3 years after the hurricane, and slightly increased for those that did, neither impact is persistent throughout the period. The fact that the buildings that filed for renovation permits do not drive the rental increases lends more credibility to the argument that their ability to recover faster lead to an increase in demand, and therefore rents, in those neighborhoods.

A.0.3   Building Ownership

Given the evidence that prices fell in affected areas (Ellen and Meltzer (2022), Ortega and Taşpınar (2018)), it is possible that certain buyers aimed to take advantage of the price discounts, bought rental properties and adjusted management practices to alter rents. Consistent with Ellen and Melter (2022), I find no evidence of an increase in the share of lots or units sold in the years immediately after the hurricane (Figure B.5). In addition, the main results are unaffected by dropping listings from properties that were sold during this time period (Figure B.6).

A.0.4   Information

While the flood zone is less likely to be a salient boundary for renters than homeowners, as discussed in Section 1, it is still possible that households outside of the flood zone were less aware

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[13]The sample does not include enough basement apartments to isolate the impacts on these units, which are most likely to be affected by flooding

of the level of flood risk of their neighborhoods and that after the hurricane, renters in these neighborhoods updated their preferences accordingly: toward newer buildings they viewed as less prone to flood damage. The StreetEasy listings data is not powered for a full comparison of the impacts within and outside of the flood zone because in the pre-period there are less than 10 listings each year in the flood zone that did not experience surge[14]. However, roughly half of the listings in high surge areas are outside of the flood zone.

When limiting the sample to those listings outside the flood zone, Figure B.8a shows that the relative negative rental impacts between high surge and no surge areas are larger. However, rents do still recover back to non-surge levels by 2016. Stratifying the results by higher and lower income neighborhoods also shows more dramatic impacts: rents increased by more in higher income neighborhoods (Figure B.8b) and experience larger negative impacts in lower income neighborhoods (Figure B.8c) than for the full sample. It is difficult to fully interpret these results without the analogous comparisons of listings within the flood zone, however they offer suggestive evidence that climate risk information may play a small, short term role in housing decisions for renters, but a marge larger role for home owners.

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[14]There are a substantial number of blocks that were in the flood zone that did not experience surge, but the buildings on these blocks do not appear to use StreetEasy.

B   Appendix

Table B.1: Key Rental Impact Coefficients for High Surge Heterogeneity by Neighborhood Income

	(1) Street Easy	(2) Vouchers
high surge × post=1	-0.055	0.030
	(0.034)	(0.022)
high surge × post=1 × high_inc1=1	0.117***	-0.005
	(0.042)	(0.049)
N	1370102	680663
All Controls	X	X
Zipcode * Year	X	X
Zipcode * Surge	X	X

*Notes:*This Table presents key heterogeneity coefficient for the broader market and voucher sample. Column 1 presents results from estimation with Street Easy sample and Column 2 with voucher sample. Full heterogneity interactions are included in the regressions, as well as standard unit, building, flood zone controls. *Standard errors in parentheses.* * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

Table B.2: Key Quality Adjusted Rental Impact Coefficients using Continuous Surge and Different Thresholds for High Surge

	(1) Log Rent)	(2) Log Rent	(3) Log Rent	(4) Log Rent	(5) Log Rent	(6) Log Rent	(7) Log Rent	(8) Log Rent
post=1 × surge	0.003 (0.007)	-0.017** (0.008)						
post=1 × high_inc1=1 × surge		0.045*** (0.014)						
high surge (1ft) × post=1			0.027 (0.027)	-0.072* (0.040)				
high surge (1ft) × post=1 × high_inc=1				0.122** (0.054)				
high surge (2ft) × post=1					0.021 (0.020)	-0.058* (0.034)		
high surge (2ft) × post=1 × high_inc=1						0.120*** (0.042)		
high surge (3ft) × post=1							-0.003 (0.024)	-0.073** (0.036)
high surge (3ft) × post=1 × high_inc1=1								0.118** (0.048)
Zipcode * Year	x	x	x	x	x	x	x	x
Zipcode * Surge	x	x	x	x	x	x	x	x
N	1371537	1371537	1371537	1371537	1371536	1371536	1371537	1371537

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure B.1: High Surge Rent Impacts with Census Tract Fixed Effects

(a) Quality Adjusted Rents
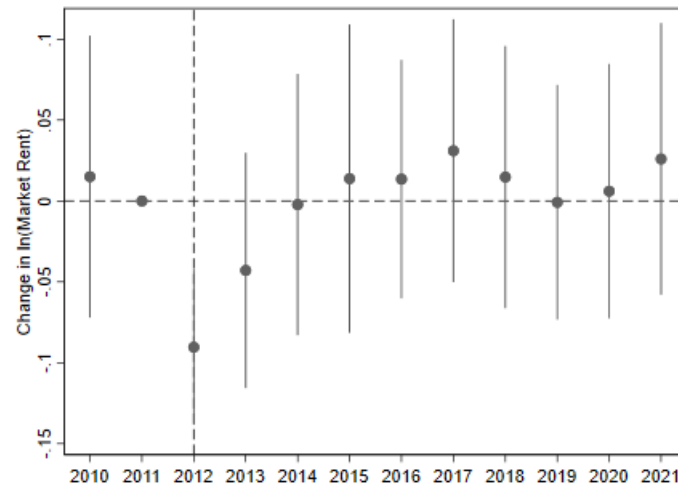
(b) Average, non-adjusted Rents
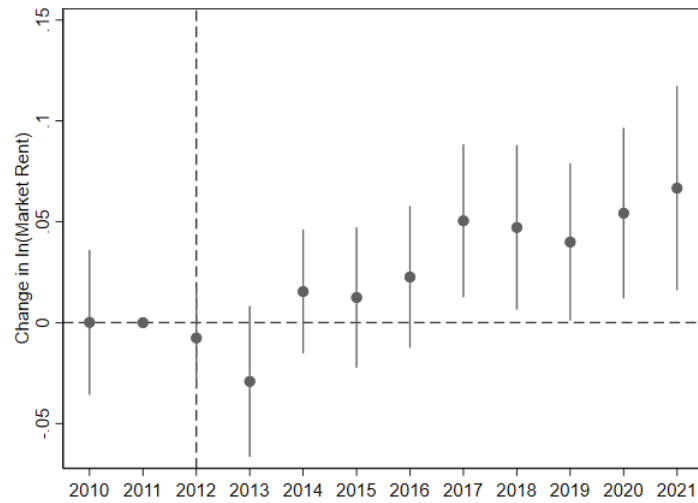
Figure B.2: High Surge Rent Impacts By Building Height

(a) Buildings Above Median Height
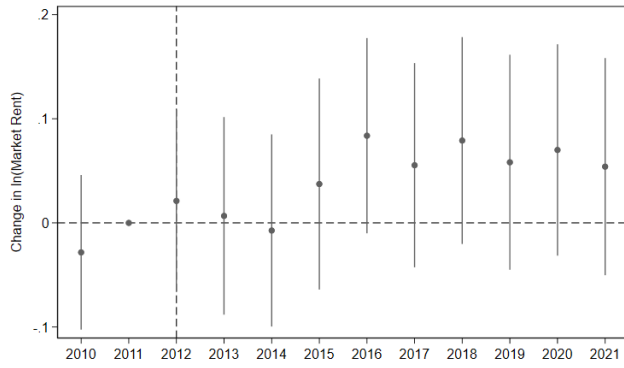
(b) Buildings Below Median Height
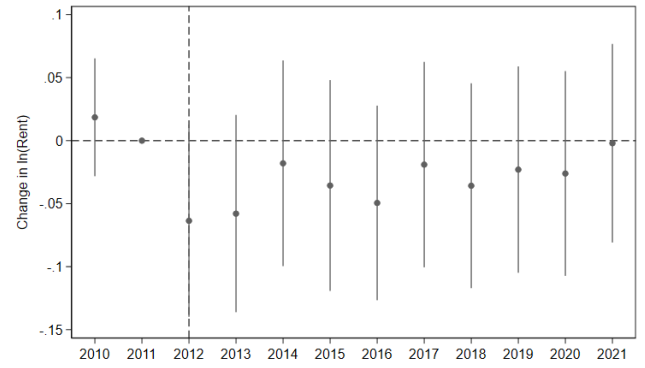
Figure B.3: Differential Rental Impacts for Ground Floor Apartments
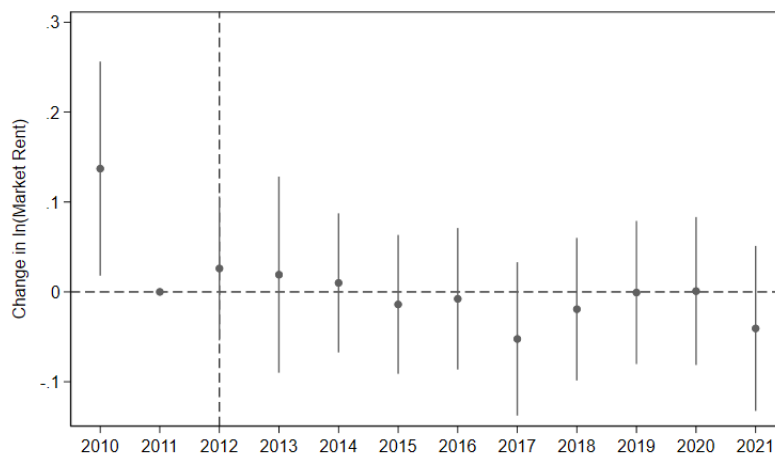
Figure B.4: Differential Asking Rental Impacts for 2013-2015 Job Filings

(a) Buildings that filed for 2013-2015 renovation permit
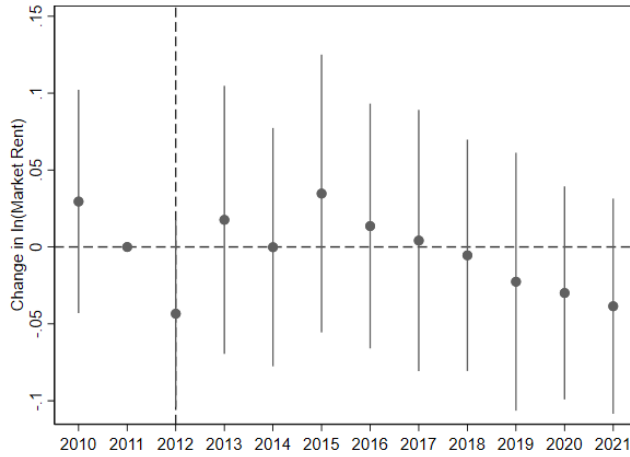
(b) Buildings that did not file for 2013-2015 permit
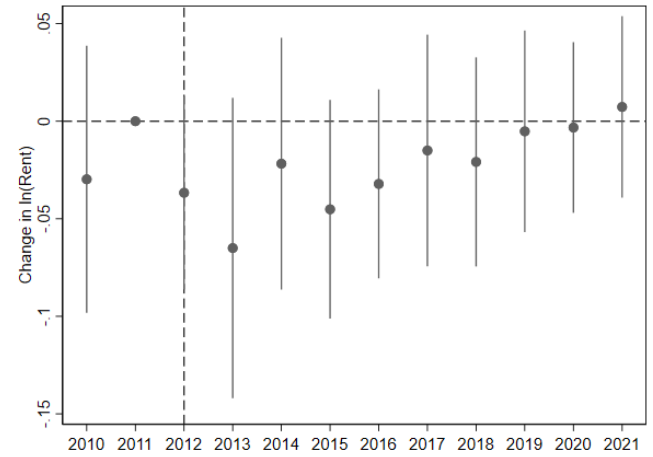
Figure B.5: Impact on the Share of Residential Sales on High Surge Blocks

(a) Share of BBls on block sold
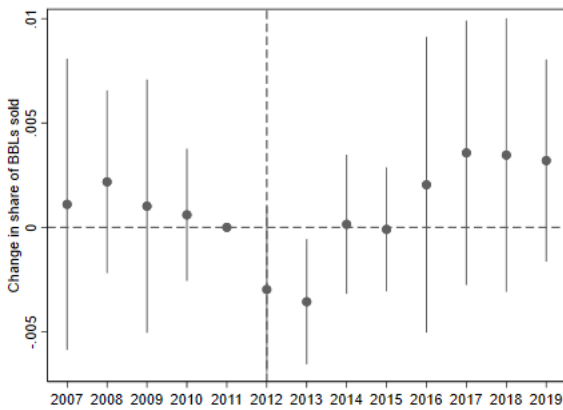
(b) Share of units on block sold
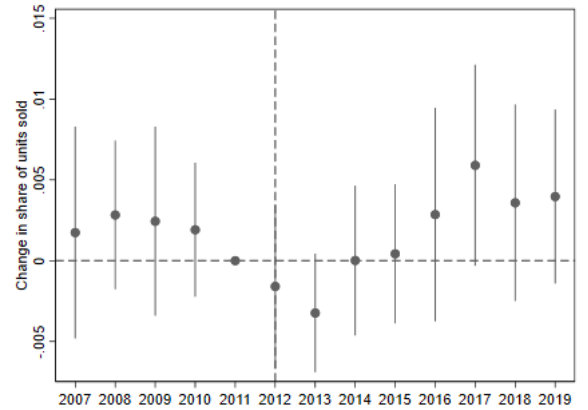
Figure B.6: High Surge Asking Rent Impacts without Properties that sold 2010-2021
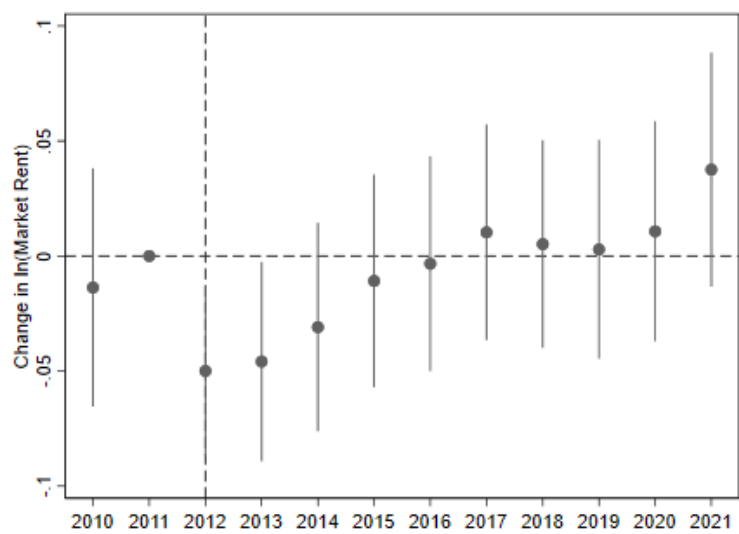
Figure B.7: High Surge Voucher Rent Impacts by Renovation Type

(a) A1 Renovations
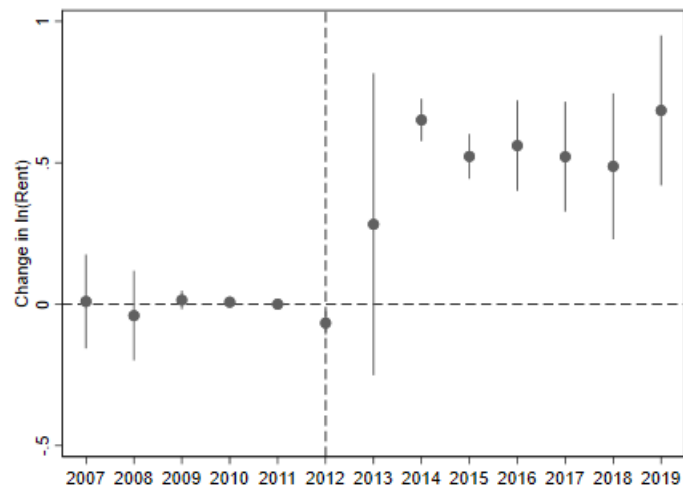
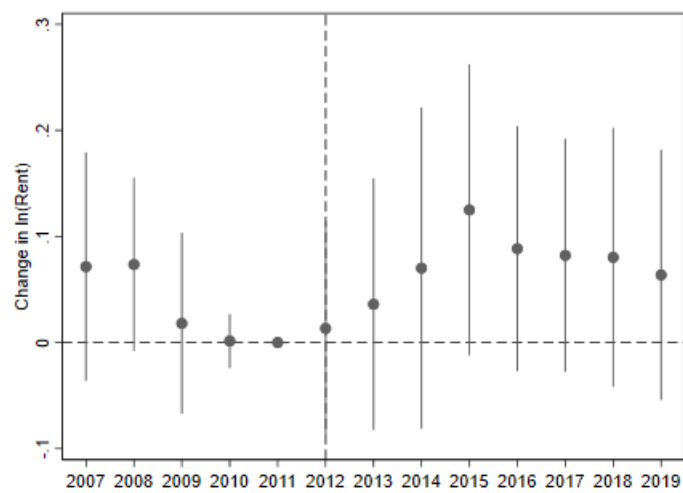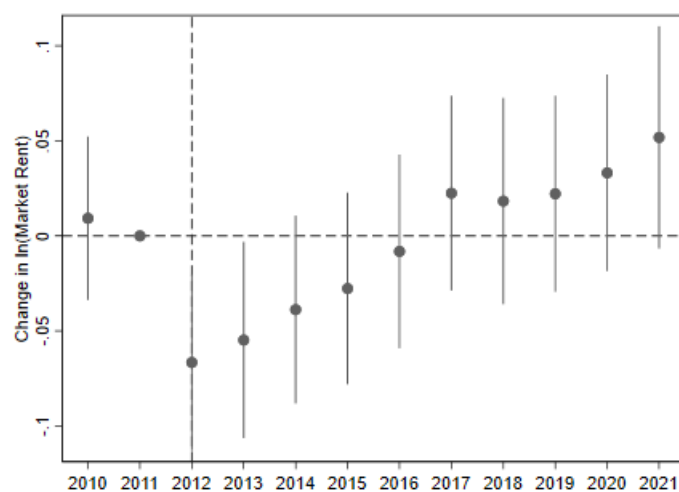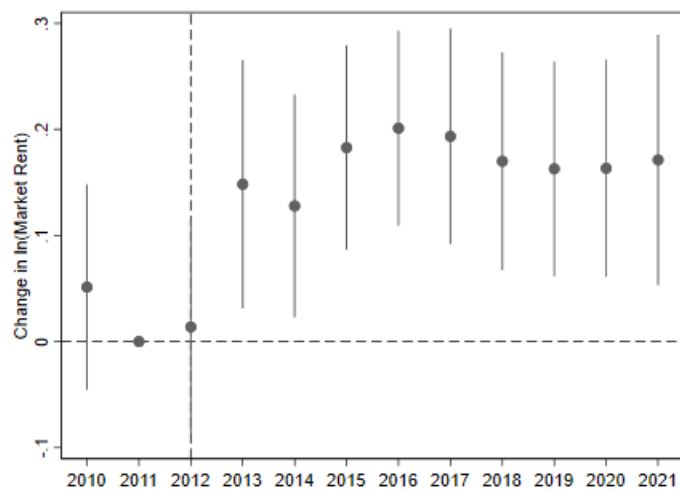(b) A2 Renovations
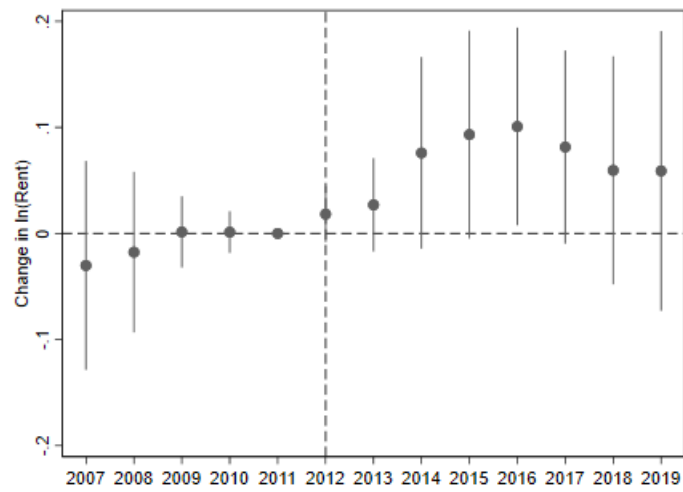
(c) A3 Renovations

Figure B.8: Rental Impacts for High Surge Areas Outside the Flood Zone

(a) All Listings Outside the Flood Zone

(b) Above Median Income Neighborhoods

(c) At or Below Median Income Neighborhoods