Storm Surges, Informational Shocks, and the Price of Urban Real Estate: An Application to the Case of Hurricane Sandy[*]

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Abstract: The impacts of a major hurricane on residential real estate can be devastating. Hurricane Sandy in New York City (NYC) is among the examples of how flooding can unexpectedly extend beyond FEMA flood zones. Such surprises or negative shocks can provide property owners—especially those not flooded—with new information about future flood risks, based on the difference of the property distance from the flood zone and the distance to the actual locations of flooding. We use a difference-in-differences approach to quantify the effects of these shocks on residential property values for non-flooded NYC properties after Sandy. The short-run negative "surprise" effect was lower NYC housing prices by about 6%-7% for each mile (or about 2% per standard deviation) difference between the property distance from the flood zone and the distance to the actual locations of flooding. The corresponding positive "surprise" effect is insignificant. The long-term "surprise" effects of flood risk on housing prices tend to disappear, as residents' memories of the "surprise" fade and they seem to only recall the actual storm surge several years after the hurricane.

Key words: Hurricane Sandy, Storm Surges, New York City, Real Estate Prices
JEL Classification: R3

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1. **Introduction**

Over the past decade, hurricanes in the United States, including 2017 in Houston (Hurricane Harvey) and Florida (Irma), and 2012 in New York City (Hurricane Sandy), are examples of how flooding damage can unexpectedly extend beyond the Federal Emergency Management Agency (FEMA) designated flood zones.[1] Such surprises or shocks can provide property owners—including those that were not flooded—with new information about future flood risks, based on the difference between the distance of their properties from the flood zone and the distance to the actual locations of flooding. We quantify the effects of these shocks on property values for non-flooded properties.

Hurricanes, of course, can impose costly damage. When Harvey struck the Houston, Texas area in late-August 2017, damage assessment was about $125 billion (Mooney, 2018). In early September 2017, Hurricane Irma hit Florida, with waist-deep flooding in downtown Miami (Sun-Sentinel, 2017). The total costs of Irma were estimated to be about $50 billion (National Hurricane Center, 2018).

On a somewhat smaller but nevertheless dramatic scale, on October 29, 2012, Hurricane Sandy made landfall in New York City. It was arguably the largest and most damaging storm to hit the New York metropolitan region. There were 65 deaths in New York, New Jersey and Connecticut related to the storm. Estimates of total losses for New York City alone were about $19 billion, and $33 billion for the entire state.[2]

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[1] For Harvey see: https://www.nytimes.com/interactive/2017/09/01/us/houston-damaged-buildings-in-fema-flood-zones.html?mcubz=1&_r=1.

[2] For New York City see: http://www.nyc.gov/html/sirr/downloads/pdf/final_report/Ch_1_SandyImpacts_FINAL_singles.pdf.

Studies to date have focused on estimating the cost of the damage—how much did the storm destroy in terms of market value or replacement costs (ESA, 2013). However, to our knowledge, relatively less work has explored the implicit costs of storm surges on the value of residential single-family real estate in the city for properties *that were not damaged by the surge*. Understanding how the flooding affected the properties that remained dry is important because it can give clues to how the market perceives the future risks of storm surges that are likely to occur more frequently over time. Which neighborhoods reacted the most and why? This paper investigates real estate price volatility due to the shock from the storm surges, by focusing on changes in single family residential[3] real estate prices for those properties not directly flooded.

Our focus is on the price (or treatment) effects of distance from the surge for non-flooded properties at least 0.03 miles from the surge but no more than 1 mile away from the surge. We also consider how these treatment effects are different for non-flooded properties closer versus further from Sandy storm surge locations as compared vis a vis the insurance flood zone delineations. The flood zone maps are assumed to be how residents form their expectations regarding flood risk. These flood zones are important because they are intimately tied to flood insurance rates.

In 1968, the U.S. Congress created the National Flood Insurance Program (NFIP) to help provide a means for property owners to financially protect themselves. The NFIP offers flood insurance to homeowners, renters, and business owners if their respective town or city participates in the NFIP. Participating communities agree to adopt and enforce ordinances that meet or exceed

[3] Our data set includes buildings with one residential unit, which consists of both single-family homes and other structures with one residential unit (which, in some cases, may include some commercial units in addition to the residential unit). We exclude Manhattan due to less than 0.5% of all single-family residential property sales in New York City located there.

Federal Emergency Management Agency (FEMA) requirements to reduce the risk of flooding (FEMA, 2017b).[4]

FEMA partners with states and communities through the Risk Mapping, Assessment, and Planning (Risk MAP) program to identify flood hazards and assess flood risks. These data are incorporated into flood maps, known as Flood Insurance Rate Maps (FIRMs), which support the NFIP and provide the basis for community floodplain management regulations and flood insurance requirements. Most commonly used for insurance purposes are the 100-year floodplain maps, which are regions designated to have a 1% chance of being inundated each year.

Real estate buyers, who seek a mortgage, are often required to purchase flood insurance if they are within a FEMA-designated floodplain (FEMA, 2017a). The FEMA floodplain maps thus serve as a publicly available assessment of the likelihood of a property being flooded. In addition, for those outside the floodplain, the distance to the plain can presumably be used to provide information about the relative flood safety of the neighborhood. Being 200 feet from a floodplain suggests that a property is potentially at more risk than one 2,000 feet away.

While it is relatively straightforward to estimate the effects of the storm on those properties that were flooded by a major storm, our main goal is to estimate the degree to which residential properties that remained dry were not directly impacted by a storm, conditional on proximity to the storm surge. If the Hurricane represents an informational shock about the likelihood of future damage then, presumably, this effect will be capitalized into property values, above and beyond the capitalization due to proximity that has already occurred due to the pre-existing flood risks, as people reassess the likelihood of future storm shocks and the potential damage they could cause.

[4] Note that as of October 2020, the FIRMS for New York City have not officially changed from what they were before Sandy. Evidently, the process of changing the maps has proven too politically contentious (New York City, 2020).

This paper aims to isolate the changing expectations of the real estate market due to new information, via hedonic regressions, to look at housing price capitalization after the storm surge. Our analysis is motivated by the following. In the short run it is impossible to use distance to the storm surge as a way to disentangle the information that might have been provided by the storm from Sandy damage on property values. Part of the challenge is that damage can be incurred by individual housing units, and there can be overall damage to the neighborhood affecting nearby units. Even focusing on units outside of, but near to, the flood plain will not change this basic problem. We handle this challenge by including two separate measures – one is distance to the storm surge, to control for damage and exposure to damage (although this distance might also capture some effects of information) - and then we add a second control, distance to the storm surge minus distance to the FEMA boundary. We call this second control a "surprise" effect. After controlling for the location of the storm surge, this "error" in the FEMA boundary is new information that might affect the value of houses.

Houses that are outside of the FEMA boundary are not expected to be hit by a storm, conditional on distance from the storm surge. The fact that the FEMA boundares were realized to be imperfect after Hurricane Sandymotivates our inclusion of the "surprise" term. We find that residents update their information based on the inaccuracies in the FEMA boundaries, leaving those residents more vulnerable than they previously anticipated. We find short run evidence that this new information (i.e., the surprise) is important for housing prices, even after controlling for distance to the storm surge for dry properties.

We reach these conclusions for the short-run analysis by selecting a sample of observations outside of the storm surge that is within one mile of the Sandy flood zone but more than 0.03 miles from the flood, and outside the FEMA floodplain, in four boroughs of New York City (excluding

Manhattan). We break up the estimation sample into two subsamples – properties experiencing “negative” shocks (i.e., properties that were closer to the storm surge than the FEMA flood map boundaries), and those with “positive” shocks (i.e., being further from the storm surge than expected based on the FEMA flood zone). The short-run effects are for sales of properties within the period of roughly one year following the storm, opposed to the longer-term effects, such as up to five years after the storm.

We find that, on average, in the short-term only the negative shocks—where the flooding came closer than expected—have a statistically significant treatment effect for the proximity to the storm surge on residential property values. These results are robust to alternative regression specifications. The finding of a statistically significant effect from negative shocks but not from positive shocks is consistent with the literature in behavioral economics, which finds that negative events can often unleash extreme reactions from people (Card and Dahl, 2011).

In the long-term, however, the “surprise” effect seems to disappear, while the proximity to the storm surge is still significant. Residents apparently change their perceptions of the flood risk, over a period of several years following the storm. It is possible that the actual storm surge location was more memorable in the long-term, compared with the storm surge location relative to the FEMA boundaries (which, incidentally, were never updated by the federal government following the storm).

The remainder of this paper proceeds as follows. First, we review the literature on how storm risk information impacts real estate, and more generally, how storms impact real estate, to demonstrate that our approach has not been considered in other storm and real estate studies. Then we present our approach, followed by a discussion of the data we use for our analysis of New York City and information shocks resulting from hurricane Sandy. This sets the stage for the presentation of our empirical results, and some falsification tests. Finally, we offer some concluding remarks.

2. Literature Review

The events in the past few years of Hurricane Harvey in Texas and Irma in Florida demonstrate that the FEMA flood zones have left residential real estate owners an imperfect measure of flooding likelihoods (Fessenden, et al., 2017). This motivates the need to study how information shocks due to unanticipated flood risk information might impact house prices. There is little known research on this specific topic.

There is a growing literature on the specific topic of flood risk information. One recent paper is Yi and Choi (2019), who study the 2008 floods in Des Moines, Iowa. They use a difference-in-differences approach to track properties that sold over time and found that homeowners update their perceptions of flood risks in locations where the flood extended beyond pre-existing flood zones. This Yi and Choi (2020) finding is consistent with our result that in the long run homeowners base their new expectations of flood risk on the locations of the previous storm surge "exposure". Another paper in this literature is Bin and Landry (2013), who find that the effects of unexpected flood risk following a major storm disappear after several years. They examine Pitt County, North Carolina and find a discount of between 5% and 9% following Hurricanes Fran and Floyd. More recent data indicate a higher discount rate, although as noted above, these effects vanish as additional time elapses.

The findings of Bin and Landry (2013) are similar to those of Atreya et al. (2013), who examined a 100-year flood event that occurred in one county in Georgia. Immediately after the flood, house prices fell for properties within the flood plains, but these effects became smaller over time and eventually vanished. A related study is Atreya and Ferreira (2015), who found that prices of flooded properties after this same 100-year flood in Albany, Georgia fell by much more than properties that were in the flood zones but were also dry as a result of the storm.

Other relevant research on flood risk information includes Smith et al. (2006), who focus on damaged properties after Hurricane Katrina in the Miami area. They find that middle income individuals move away from risk. Wealthy individuals, on the other hand, prefer to stay in their homes but purchase insurance. Lower income individuals prefer to move into affordable housing. In a related paper, Carbone et al. (2006) studied two separate counties' responses to risk information from Hurricane Andrew in Florida – one county that was damaged, and another county with no damage. They find that the storm provides significant information to residents of these two counties.

Zhang (2016) considers whether there was any impact on properties locating in the floodplain in Fargo, ND. They use a spatial quantile approach to address this. A key finding is that lower priced houses are affected more adversely by being in the floodplain.

In another recent study, McCoy and Zhao (2018) find that the likelihood of investment in damaged buildings is higher for properties in the flood zones than flooded properties outside the flood zones, and the latter effect is statistically insignificant while the former effect is significant.

Pommeranz and Steininger (2020) estimate various spatial hedonic models for housing prices in Dresden, Germany. In particular, they investigate the impacts of flood zone risk categorization (low risk, moderate risk, high risk, extremely high risk) on housing prices. They estimate both direct and indirect effects. Direct effects are the impacts of a house's flood zone risk on the price, while indirect effects are based on a weighted average of flood zone risks from surrounding properties. That is, the indirect effect aims to test for spillovers of risk from surrounding properties. They find negative indirect effects from surrounding properties (i.e., higher average neighborhood risk leads to lower prices), but no statistically significant direct effects. This suggests that buyers use the average risk of a neighborhood to estimate home values, likely because of the difficulty of ascertaining the specific risk of a particular property. Our paper, unlike theirs, looks at the impact of new information, and thus we aim to see how home buyers update their housing price expectations when they acquire this additional information about the risk of flooding.

More broadly, there are a variety of studies that investigate the impacts of storms or natural disaster on real estate and local economies without specifically focusing on the changes in flood risk. These include studies of specific hurricanes, as well as others on the proximity to the coast. We mention one in particular here because of its focus on Hurricane Sandy in New York City. Specifically, Ortega and Taspinar (2018) examine Sandy and the New York City housing market, and they address the question of whether housing demand shifted towards less exposed areas. They divide the city into six Hurricane Evacuation Zones (HEZ's). They allow for "treatments" of 0 (no damage), 1 (minor damage), and 2 (major damage), and compare prices post-Sandy for the treatment versus control groups. The control group is the property sales outside of the flood zone. Their difference-in-differences model includes a dependent variable of the log of house sales prices, and they include a dummy for post-Sandy sales for being in zones 1 or 2, and neighborhood and time fixed effects. They also estimate a second difference-in-differences model with all three treatment groups, each of which is interacted with a post-Sandy dummy variable. They find evidence that the treatment effects are significant. They also find that for damaged houses, the treatment effects appear to be permanent, with a drop in values between 17% and 22%.[5, 6]

With these studies in mind, our research examines treatment effects of proximity to the storm surge, and also considers both positive and negative surges that do not precisely overlap with the pre-determined flood zones. Given the data limitations in general for sales of flooded properties, we now turn to our methodology to estimate the impacts on dry properties.

3. The Theory of Price Effects

Our aim is to understand how a storm shock can affect those properties that were not damaged by the storm. The point is that for many property owners the storm represented new information on the potential damage due to storm surges. Our main identification strategy is to look at the shock that occurred based on the difference between the storm exposure and the FEMA boundary, conditional on exposure. A priori, it is not straightforward to separate the damage to the overall neighborhood and the damage to individual properties. As a result, our approach includes two controls – one for the "surprise" and another for actual exposure. In the short-run, our variable of

[5] Other more general studies, that do not explicitly focus on risk perceptions, include Bin et al. (2011), who focus on a similar geographic area in North Carolina as Bin and Landry (2013), to estimate an approximate value of lost property due to potential flooding in these areas. For a 20 to 70 year period into the future, they forecast between a $179 million and $576 million loss for properties in four counties near the shore in North Carolina. Atreya and Czajkowski (2019) use a spatial hedonic model to study the price effects of proximity to the coast in Galveston, Texas. They find that with ¼ mile from the coast, properties sell for higher prices than those that are further away. An earlier study in this literature is MacDonald, Murdoch and White (1987), who estimate a hedonic house price function to study Monroe, Louisiana, an area prone to flooding. Given the nonlinear functional form for the dependent variable (i.e., the sales price), it is not straightforward in general to indicate one magnitude and direction for the marginal effects, but these effects depend on the fitted values of each of the sales prices. They provide a few examples of the effects for a small sample of homes, and they find that for these houses a higher flood risk leads to a decrease in sales prices in the range of $2000 to $8000. But none of these studies explicitly consider how changes in expectations of flood risks impact house prices.

[6] Examining the impacts of a hurricane as a natural experiment extends beyond the literature on real estate impacts. Meltzer et al. (2020) investigate the impact of Hurricane Sandy on small businesses vulnerability in New York City by looking at firms and employment before and after the storm. Their regression results show significant post-Sandy job declines, of about 4.5 to 6 per census block, for the retail sector only. But, across all job types, the impacts from Sandy are noisy and largely insignificant.

interest is the treatment effect for proximity to the storm for properties that sold after the storm, conditional on the distance to the closest FEMA boundary. In our longer-term analysis, we find that the key variable is the "exposure" variable in the equation below. Therefore, we aim to estimate a model with two separate treatment effects:

$$lnP_{it} = \theta[surprise \times (post\ storm)]_{it} + \gamma[surprise]_{it} + \alpha[exposure \times (post\ storm)]_{it} + \mu[exposure]_{it} + \varphi[post\ storm]_{it} + \tau + \rho + X_{it}\zeta + \varepsilon_{it} \tag{1}$$

for $i = 1, \dots, N$ non-flooded properties that sold on day t = 2010-01-01, 2010-01-02,…, 2013-12-31; τ are year-quarter fixed effects, ρ are census tract fixed effects, and where X_{it} are control variables (including property characteristics), and ε_{it} is the error term; *(post storm)* is an indicator variable with value 1 if an observation sold after the storm, and 0 otherwise; *exposure* is the distance from the storm surge; the *surprise* is the difference between the storm surge and what was previously expected from the FEMA floodplain maps, *(exposure – (FEMA distance)),* where *exposure* is the distance from property i to the actual storm surge. In the short-run, the treatment effect from the surprise after the storm – our main coefficient of interest - is the coefficient, θ. The exposure treatment effect is the coefficient, α, which is our treatment effect of interest in the long run (since people have time to update their expectations and we anticipate they no longer believe the FEMA flood zone designations after a large "surprise"). Equation (1) is estimated throughout with robust standard errors. In the long run, in the absence of changes in the FEMA flood maps (as was the case in New York City), we would expect residents to use the actual storm surge distance, i.e., *exposure*, as their basis for anticipating future storm risk. We would expect the long-run treatment effect, α, to be positive, as residential properties located a greater distance from the storm surge should be priced higher.

We also allow for a "buffer" of 0.03 mile (or approximately 158 feet, or more than half the length of a football field) between each property and the storm surge location, so that we ensure the immediate neighborhood is not substantially impacted by the flood.[7] In other words, we drop any observation for which the storm surge distance is less than 0.03 mile from that observation. We also only consider properties that are no further than one mile away (or 5,280 feet) from the storm surge, on the dry side of the surge, and also that sold within a period before and after the storm (the date of the storm was October 29, 2012, and for the short-run analysis our sample is for property sales between January 1, 2010 and December 31, 2013). The long-run analysis is for property sales between January 1, 2010 and December 31, 2017.

As a hypothetical example, consider two identical houses, A and B, where each is 900 feet from the closest FEMA floodplain boundary line. For house A, suppose the flood approached within 2000 feet, for a $surprise = 2000 - 900 = 1100$ (so that any value of the surprise greater than zero is "good news" or a positive surprise). In the case of house B, suppose the flood came to within 200 feet of the house, for a $surprise = 200 - 900 = -700$; thus, house B experienced a negative surprise (or "bad news"). In this case, we would expect house B to lose value,, since the storm surge went further past the FEMA boundary for house B. For property B, decreases in the *(exposure – (FEMA distance))* variable imply a larger negative value, or a larger surprise, which represents new negative information. This should lower the value of property B relative to properties that have already capitalized the risk associated with proximity to the current FEMA

[7] Our empirical results are robust to decreasing this buffer to 0.02 miles or 0.01 miles (where 0.01 miles is approximately 52 feet)).

boundary. Alternatively, a larger negative value on this difference means that the storm surge went further past the FEMA boundary, which implies a smaller negative value or a smaller surprise and so should be associated with higher housing values post-Sandy. Simply stated, the more negative the surprise, the lower the housing price; and the greater the positive surprise, the greater the housing price. This would then suggest that in general we would expect $\theta > 0$, for both house A and house B, where θ is the effect of a one-mile (or equivalently, a 5280 foot) surprise on the housing price change. Note that the surprise *(exposure – (FEMA distance))* variable is measured in miles in our tables below. We also mention in the body of the paper the effects of a one standard deviation change in the surprise and exposure variables (with a corresponding Appendix Table A.2).

4. Hurricane Sandy

4.1 The Data

Here we provide some basic information about the data; Appendix A gives more details about the data collection, processing, and sources. **Table 1** provides descriptive statistics for the data set for 2010-2013, which is our main sample for the difference-in-difference regressions. Information about additional control variables is provided in the Appendix.

{Table 1 about here: Desc stats.}

Recall that Hurricane Sandy hit New York City on October 29, 2012. We provide statistics for single-family residential properties[8] that were within one mile (but outside) of the storm surge boundary, but at least 0.03 miles from the storm surge boundary, and sold between January 1, 2010

[8] Once again, our data set includes buildings with one residential unit, which consists of both single-family homes and other structures with one residential unit.

and December 31, 2013 (see **Figure 1**). Here residential properties are any kind of structure that has one residential unit. The largest fraction of single-family residential properties in our sample (41.1%) are in the borough of Queens. The next largest fraction is in Staten Island (29.5%), followed by Brooklyn (19.2%) and the Bronx (10.1%). Less than 0.5% of sales were in Manhattan; because of this relatively small number of residential properties in Manhattan, as well as the different nature of much of the residential single-family real estate in Manhattan, we omit Manhattan and focus our analysis on the other four boroughs of Brooklyn, Bronx, Queens, and Staten Island. There are 13,882 single family residential property sales that satisfy the filters described above. The average residential property in this sample sold for slightly over $288 per square foot, was 76 years old, had two floors and approximately 1,542 square feet.

We utilized GIS shapefiles related to the storm surge of Hurricane Sandy. These files have been generously provided by the Natural Resources Defense Council (NRDC). The maps indicate the location of the storm surge and the location of the FEMA floodplain. The maps show four areas: the area of FEMA floodplain that remained dry, the area in the FEMA floodplain that was hit by the storm surge, the area of the surge that was outside of the FEMA floodplain, and the area that was neither in the floodplain nor the storm surge. Thus, we categorize each property based on it being in one of those four areas. We restrict our analysis to the unaffected ("dry") properties since we are interested in the impacts of an informational shock. Also, many flooded properties could not be easily sold after the storm, so it is not sensible to include the flooded properties in our analysis. As described in Section 3 above, we focus on properties that were at least 0.03 miles from the storm surge and no more than one mile from the dry side of the storm surge, which (for the short-run analysis) sold between January 1, 2010 and the end of 2013.

4.2 Regression Results – "Surprise" Treatment Effect

We hypothesize that the coefficient for the (short-run) "surprise" treatment effect, θ, is positive—the more negative the surprise, the lower the housing price; and the greater the positive surprise, the greater the housing price. **Table 2** presents regression results for the four boroughs (BX, BK, QN, SI) combined. Equation (1) excludes hedonic controls, but the regression includes year-quarter fixed effects and census tract fixed effects. Equation (2) adds additional hedonic controls, including (among others) the log of land area, the log of building's age, the log of building area, and the log of the number of floors in the building; and a constant, year-quarter fixed effects, and census tract fixed-effects. The sample includes single family residential properties that sold between the dates of January 1, 2010 and December 31, 2013. The parameter estimate for θ is statistically insignificant. This insignificance suggests that overall for the four boroughs, with each mile difference between the distance to the storm surge and the distance from the FEMA boundary, sales prices did not change.

{Table 2 about here: Diff-in-diff Regs 2010 to 2013 }

In an effort to dive deeper, next we separately consider the issue of positive versus negative shocks. **Table 3** shows the coefficient estimates from when we divide the sample into two subsamples—those with negative surprises, *Sandy-FEMA<0* (Column (1)), and those with positive surprises, *Sandy-FEMA>0* (Column (2)). **Figure 1** maps all the residential property sales in our sample, where a blue dot is a positive shock, a red dot is a negative shock.

{Figure 1 about here: Map}

The results from **Table 3** column (3) and column (4) suggest that, on average, there was no significant relationship between the treatment effect and housing prices for positive shocks. The treatment effect coefficients for the negative shocks—Columns (1) and (2)—are positive and statistically significant (with value of 0.0609) in the model with hedonics, and 0.0726 (with t-statistic = 1.89) in the model with no hedonics. In terms of standard deviations of the *Sandy-FEMA* variable, these marginal effects are slightly more than 2% per standard deviation, conditional on proximity to the storm (see Column 2 in Appendix Table A.2).

{Table 3 about here : +, - shocks}

The above results imply that in the short run, if a property is further away from Sandy than expected, there is no significant impact on prices. But for properties that are closer to Sandy than expected, the treatment effect coefficient implies that on average, property values would rise. Properties where the storm surge came a mile closer than expected (i.e., from the FEMA flood zones) would have experienced a 6% to 7% reduction in sale prices per square foot by increasing this distance between the storm surge and the FEMA zone, ceteris paribus. In the remainder of this paper, we focus our attention on separate models with separate "negative shocks" and "positive shocks."

4.2.1 Additional Tests

The "surprise" treatment effects for the negative shocks in columns (1) and (2) of Table 4 are positive and statistically significant. In this section of the paper, we perform several additional tests. First, we perform a falsification test based on a "fake" storm before the actual storm date – which is essentially a test of pre-trends. Second, we consider a long-run analysis to examine whether over an extended timeframe after the actual storm, people do not perceive this "surprise" treatment effect any longer, and whether homeowners only remember the actual "exposure".

To confirm that the results are, in fact, picking up a true shock, we performed a falsification test. For the scenario where we found a positive and significant treatment effect overall when we consider all of the negative shocks, we perform the falsification test using a "fake" storm. We assume a "fake" storm date that was before the actual storm. In this exercise, the "fake" storm was on December 31, 2010. The pre-storm sales are assumed to occur between January 1, 2010 and December 30, 2010 and the post-storm sales occurred between January 1, 2011 and October 28, 2012 (recall the actual storm was on October 29, 2012). In this falsification, we avoid sale dates before 2010 so as to minimize picking up any influence the Global Financial Crisis may have had on real estate markets. The results for the falsification test are presented in **Table 4**. We expect the treatment effects for these fake storms to be insignificant. In both cases (for the parameter estimates of θ and α), we find that the "fake" storm treatment effects are statistically insignificant.

{Table 4 about here: "fake Sandy" diff-n-diff}

We also explore a long-run analysis for the actual storm, where the sample period runs from January 1, 2010 through December 31, 2017. The end-date here is nearly 5 years after the storm. If surprises are primarily borne out in the data in the short-run, while homeowners' memories of the surprises fade in the long-run as they only remember the details of the actual surge, we would expect θ to be insignificant but α to be positive and significant. In contrast, we do expect that individuals would remember both the "surprise" and the exposure effects. In fact, in the results in Table 6, we see that the "surprise" effect does not matter to homeowners in this long-run analysis, while the "exposure" effect is statistically significant, and roughly in the same range of the estimates found in **Table 3** for the negative shocks. In this case, the price effects are approximately 4.4% per standard deviation of the *Sandy* (i.e., exposure) variable (see column 3 in Appendix Table A.2).

{Table 5 about here: Long-Run flood risk effects}

5. Conclusion

This paper estimates the effects that a major hurricane has on properties that are not flooded by the storm. Specifically, our difference-in-differences approach examines how prices of non-flooded properties are affected by the distance between the storm surge and the flood zone, following the storm. We consider single family residential properties in 4 boroughs of New York City that sell before and after Hurricane Sandy, on the dry side of the storm, in a band within one mile of the storm surge but at least 0.03 miles (158 feet) from the surge. As part of our analysis, we also separate the sample into those properties that had positive or negative shocks to explore for the possibility that the effects of the surprise are different. The parameter estimate for the short-run negative shock is statistically significant and positive–implying a negative surprise leads to lower prices—but the parameter estimate for the positive surprise is insignificant. After the storm, this short run "surprise" provides new information about future flooding expectations from storm surges. In the long-term, the "exposure" level – rather than the "surprise" effect– affects home prices for those properties with a negative shock. The magnitudes of this long-run "exposure" effect are roughly the same as the short-run "surprise" effect. We conclude that several years after the storm, residents tend to forget about the surprise, and they base their long-term perceptions of flooding risk on their actual exposure from the storm.

Interestingly, our estimate of the effect of a negative shock on property values (about 6% to 7% decrease for a 1-mile shock) is lower than the effects that Ortega and Taspinar (2018) found for flooded properties in New York City after Sandy (17% to 22% discount). With the non-flooded properties from Sandy, even a negative "surprise" still implies a future flood risk probability less than 1. This probability is likely lower than the future flood risk for a property that was actually flooded by Sandy. This might explain why the Ortega and Taspinar (2018) analysis – which focused on flooded properties – found a larger home price discount than we did (with our focus on non-flooded properties).

Given that the average property in our sample sold for approximately $262 per square foot, the impacts of a 1-mile negative shock result in prices that are approximately $18 per square foot lower, on average. Given that the average single-family residence in our sample is slightly under 1,500 square feet, this implies the negative shock effect can lead to a $27,000 drop in sale price of the typical home. With the publicly available FEMA flood plain maps as the best data existing before the storm, the possibility of a property being closer to the flood plain shortly after the storm than previously thought can be a valuable information source for potential home buyers in New York City.

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Tables

Table 1: Descriptive Statistics

Variable	Mean	St. Dev.	Min.	Max.	Nobs.
Sales price ($)	435,000	250,000	23900	3,700,000	13882
Dist. to Sandy (miles)	0.46	0.277	0.03	1	13882
Sandy Dist. - FEMA Dist. (Miles)	-0.082	0.279	-1.088	0.928	13882
dist_fema_miles	0.542	0.355	0	1.915	13882
post-Sandy Dummy	0.326	0.469	0	1	13882
Dist. to shoreline (miles)	1.031	0.735	0.012	3.685	13882
Dist. to Empire State Bldg. (miles)	11.21	3.32	1.998	21.953	13882
# Units	1.02	0.145	1	3	13882
Lot Area (ft^2)	3114.0	2140.4	353	70773	13882
Year Constructed	1943	26.8	1814	2013	13882
Bldg. Area (ft^2)	1542.4	652.3	356	25837	13882
# Floors	2.03	0.517	0	22	13882

Notes: Statistics given for properties with one unit of housing (single-family dwellings) sold between January 1, 2010 and December 31, 2013, within one mile of Sandy flood zone (on dry side), but more than 0.03 miles from the flood and outside the FEMA floodplain in all boroughs excluding Manhattan. The "# units" variable is the total number of units in a building (including both nonresidential and residential units), in which there is only one unit of housing. Information about additional variables used in regressions is given in the Appendix.

Table 2: Difference-In-Difference Regression for Sandy within 1 mile. Dep. Var.: Ln(Price per square foot), 2010-2013

Variable	(1)	(2)
(Dist. Sandy - FEMA (miles)) x Post Sandy	0.00729	-0.00571
	(0.30)	(0.27)
Dist. to Sandy (miles) x Post Sandy	0.0245	0.0316
	(0.97)	(1.40)
Dist. Sandy - FEMA (miles)	0.0968**	0.111***
	(2.27)	(2.97)
Dist. Sandy (miles)	-0.00321	-0.106**
	(0.09)	(2.37)
Post Sandy	0.0112	0.00973
	(0.35)	(0.34)
Dist. to Shore (miles)		0.109***
		(2.93)
Dist. to Empire State Bldg. (miles)		0.0580***
		(3.08)
ln(total units)		-0.563
		(1.10)
ln(land) (ft^2)		0.191***
		(16.29)
ln(age)		-0.0903***
		(12.11)
ln(building area) (ft^2)		-0.645***
		(39.36)
ln(# Floors)		0.0398**
		(2.13)
Constant	5.595***	8.958***
	(248.19)	(14.35)
N	13882	13836
R-sq	0.419	0.54
adj. R-sq	0.378	0.506
AIC	10352.7	7136.1
BIC	10511	7535.4

Notes: t statistics in parentheses. * p<0.10, ** p<0.05, *** p<0.01. Robust standard errors. All regressions contain year-quarter dummies and census tract fixed effects. Results are for properties with one unit of housing (single-family dwellings) sold between January 1, 2010 and December 31, 2013, within one mile of Sandy flood zone (on dry side), but more than 0.03 miles from the flood and outside the FEMA floodplain in all boroughs excluding Manhattan. Equation (1) has no hedonic controls. Equation (2) has additional controls. Not all controls are shown (see Appendix for more information).

Table 3: Diff-In-Diff Regression for Sandy within 1 mile. Dep. Var.: Ln(Price per square foot), 2010-2013, Positive vs. Negative Shocks

Variable	(1)	(2)	(3)	(4)
	Neg. Shock	Neg. Shock	Pos. Shock	Pos. Shock
(Dist. Sandy - FEMA (miles)) x Post Sandy	0.0609*	0.0726*	-0.00815	0.0105
	(1.78)	(1.89)	(0.17)	(0.19)
Dist. to Sandy (miles) x Post Sandy	0.0670**	0.0552*	0.0148	0.0195
	(2.24)	(1.65)	(0.39)	(0.46)
Dist. Sandy - FEMA (miles)	0.131	0.0721	0.0765	0.0138
	(1.51)	(0.81)	(1.37)	(0.21)
Dist. Sandy (miles)	-0.0452	-0.0135	-0.210***	0.00465
	(0.67)	(0.26)	(3.28)	(0.09)
Post Sandy	0.0329	0.0491	-0.0256	-0.05
	(0.84)	(1.12)	(0.62)	(1.04)
Dist. to Shore (miles)	0.0705		0.218***	
	(1.18)		(3.89)	
Dist. to Empire State Bldg. (miles)	0.0227		0.117***	
	(0.76)		(4.05)	
ln(total units)	-0.0148		0.353*	
	(0.19)		(1.96)	
ln(lot area) (ft^2)	0.208***		0.170***	
	(13.21)		(9.10)	
ln(age)	-0.0996***		-0.0795***	
	(11.15)		(6.21)	
ln(building area) (ft^2)	-0.657***		-0.632***	
	(29.97)		(24.70)	
ln(# Floors)	0.0146		0.0494*	
	(0.56)		(1.76)	
Constant	8.631***	5.568***	7.078***	5.642***
	(22.05)	(154.31)	(15.13)	(179.29)
N	8500	8527	5309	5328
R-sq	0.549	0.434	0.535	0.402
adj. R-sq	0.505	0.381	0.5	0.36
AIC	4470.5	6367	2451	3741.9
BIC	4844	6515.1	2773.2	3880.1

Notes: Hedonic characteristics are included but building-level controls not shown in Columns (1) and (3). Columns (2) and (4) exclude hedonic characteristics. t statistics in parentheses. * p<0.10, ** p<0.05, *** p<0.01. Robust standard errors. All regressions contain year-quarter dummies and census tract fixed effects. Results are for properties with one unit of housing (single-family dwellings) sold between January 1, 2010 and December 31, 2013, within one mile of Sandy flood zone (on dry side), but more than 0.03 miles from the flood and outside the FEMA floodplain in all boroughs excluding Manhattan. The “total units” variable is the total number of units in a building (including both nonresidential and residential units), in which there is only one unit of housing.

Table 4: Falsification Diff-n-Diff., Negative Shock. Dep. Var.: Ln(Price per square foot)

Variable	(1)
	Neg. shock
(Dist. Sandy - FEMA (miles)) x Post Sandy	-0.00582
	(0.15)
Dist. to Sandy (miles) x Post Sandy	-0.0331
	(0.88)
Dist. Sandy - FEMA (miles)	0.173
	(1.55)
Dist. Sandy (miles)	-0.0269
	(0.30)
Post Sandy	0.00471
	(0.16)
Dist. to Shore (miles)	0.121*
	(1.65)
Dist. to Empire State Bldg. (miles)	0.00832
	(0.22)
ln(total units)	-0.417***
	(6.63)
ln(land) (ft^2)	0.197***
	(10.29)
ln(age)	-0.113***
	(9.35)
ln(building area) (ft^2)	-0.629***
	(22.45)
ln(# Floors)	-3.6E-05
	0.00
Constant	8.846***
	(18.04)
N	5810
R-sq	0.558
adj. R-sq	0.497
AIC	3059.9
BIC	3359.9

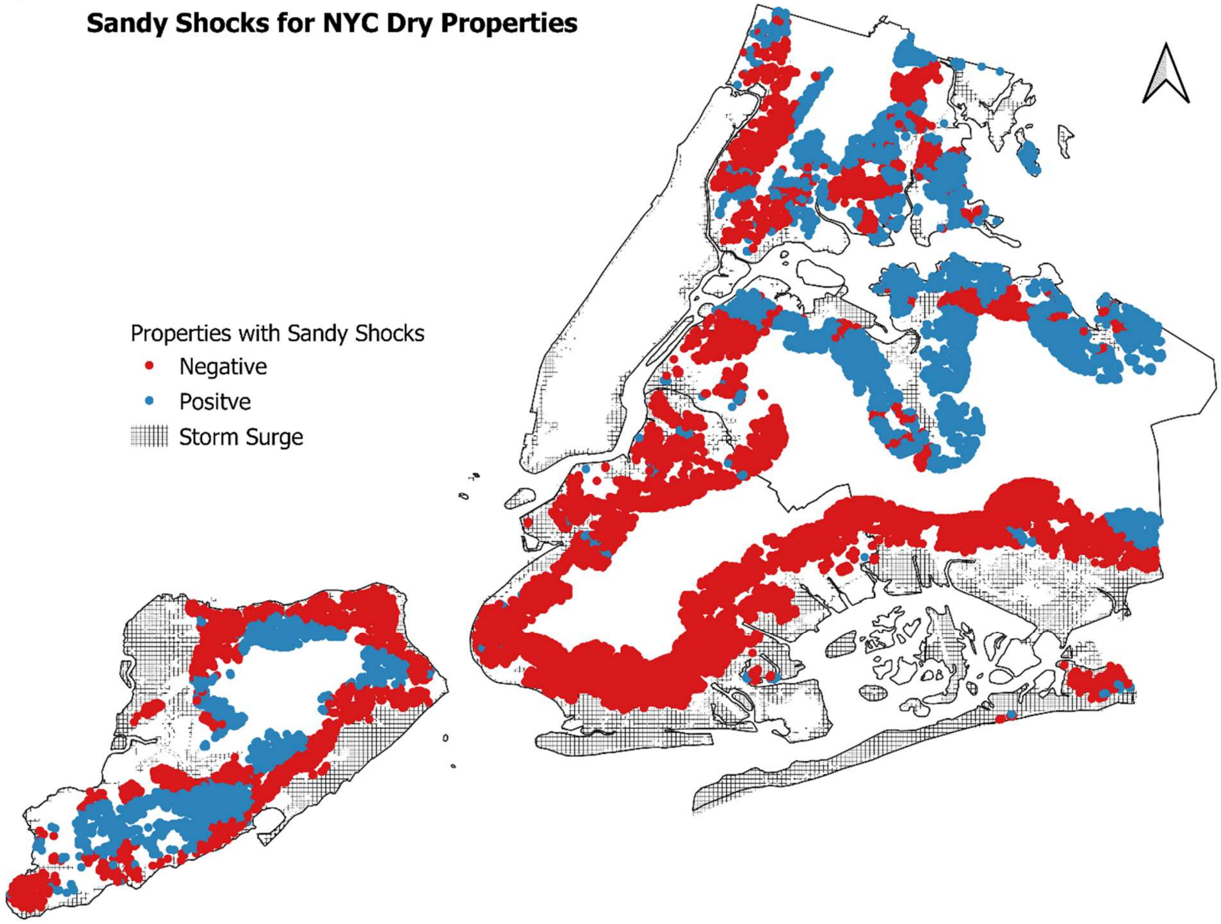
Notes: The actual storm occurred on Oct 29, 2012. In column (1), a treatment effect was created that was for a “fake” storm on December 31, 2010. The sample considered for this falsification test was January 1, 2010 through Oct 28, 2012. The “fake surprise” treatment effect is shown in row 1 of Table 4. This “fake surprise” treatment effect is insignificant. We focus on the negative shock here – and not the positive shock - since the negative shock in Table 4 is statistically significant but the positive shock is insignificant; therefore, we would expect the negative shock to be insignificant in this “fake” storm in Table 4. t statistics in parentheses. * p<0.10, ** p<0.05, *** p<0.01. Robust standard errors. All regressions contain year-quarter dummies and census tract fixed effects. The “total units” variable is the total number of units in a building (including both nonresidential and residential units), in which there is only one unit of housing.

Table 5: Long-Run Diff-In-Diff Regression for Sandy within 1 mile. Dep. Var.: Ln(Price per square foot), 2010-2017, Positive vs. Negative Shocks

Dependent Variable: ln(price per sf)	(1)	(2)	(3)	(4)
	Neg. Shock	Neg. Shock	Pos. Shock	Pos. Shock
Dist. Sandy - FEMA (miles) x Post Sandy	0.0199	-0.00751	-0.00648	-0.00208
	(0.77)	(0.30)	(0.17)	(0.05)
Dist. to Sandy (miles) x Post Sandy	0.0722***	0.0660***	-0.00644	0.0223
	(3.15)	(2.90)	(0.22)	(0.75)
Dist. Sandy - FEMA (miles)	0.0989	0.0549	0.044	0.00209
	(1.54)	(1.00)	(0.95)	(0.04)
Dist. Sandy (miles)	0.00119	-0.0442	-0.119**	-0.00382
	(0.03)	(1.31)	(2.33)	(0.10)
Post Sandy	0.221***	0.182***	0.201***	0.157***
	(11.62)	(9.19)	(8.58)	(6.32)
Dist. to Shore (miles)	0.0315		0.118***	
	(1.21)		(2.92)	
Dist. to Empire State Bldg. (miles)	0.0454**		0.0665***	
	(2.22)		(3.30)	
ln(total units)	-0.307		0.464***	
	(1.13)		(2.95)	
ln(land) (ft^2)	0.196***		0.181***	
	(16.85)		(13.41)	
ln(age)	-0.0878***		-0.0683***	
	(14.32)		(8.14)	
ln(building area) (ft^2)	-0.649***		-0.622***	
	(40.54)		(32.27)	
ln(# Floors)	0.0077		0.0215	
	(0.39)		(0.97)	
Constant	8.972***	5.589***	7.715***	5.666***
	(22.22)	(219.13)	(24.21)	(217.13)
N	13933	20891	8547	13106
R-sq	0.53	0.406	0.537	0.388
adj. R-sq	0.501	0.382	0.514	0.369
AIC	7637.6	16230.4	3854.3	9305.4
BIC	8082.5	16444.9	4242.3	9507.4

Notes: Hedonic characteristics are included but building-level controls not shown in Columns (1) and (3). Columns (2) and (4) exclude hedonic characteristics. t statistics in parentheses. * p<0.10, ** p<0.05, *** p<0.01. Robust standard errors. All regressions contain year-quarter dummies and census tract fixed effects. Results are for properties with one unit of housing (single-family dwellings) sold between January 1, 2010 and December 31, 2017, within one mile of Sandy flood zone (on dry side), but more than 0.03 miles from the flood and outside the FEMA floodplain in all boroughs excluding Manhattan. The "total units" variable is the total number of units in a building (including both nonresidential and residential units), in which there is only one unit of housing.

Figure 1



Note: Properties in Manhattan are omitted due to the limited data on single family properties that sold in that borough (consisting of less than 0.5% of all residential single property sales in New York City). Properties are designated to have negative shocks if their distance to the storm surge is less than their distance to the FEMA flood zone; and properties are designated to have positive shocks if their distance to the storm surge is greater than their distance to the FEMA flood zone. A property is considered to have a positive or a negative shock only if it is at least 0.03 miles away from the actual storm surge, and no more than 1 mile away from the actual storm surge. Dots shown for property sales from 2010 to 2013.

Appendix: The Data

1. Data Sources and Preparation

- *Real Estate Sales*: Source: New York City Department of Finance. Data about individual sales, which includes prices, sales, date, building type at sale, building type at date of download (this allows to check if the building type has changed since the sale), gross square footage, land area of lot, and year built. The sales data contains all transfers of title. We removed all transactions that were less than $10,000 on the assumption that they were not bona fide, open market sales. Further in the regressions we excluded observations that were in the lower first or upper 99^{th} percentile or price per square foot of building area to further eliminate observations that were outliers (both due to possibility of being non-market transaction or were genuine outliners).

- *Additional Building Information*: Source: New York City Department of City Planning (DCP). The DCP annually produces the Primary Land Use Tax Lot Output (PLUTO) file which contains information about each tax lot in the city, including the building type, the number of units, the number of residential units, building area, age, lot size and shape, and other variables about the structure and location (see Table A.1). The PLUTO file also contains census tracts and latitude and longitude coordinates, which we used to find the distance to the Sandy flood zone and the FEMA floodplains.

  The PLUTO data was merged with the sales data by the unique borough-block-lot (BBL) id number. In the data set we retained observations where the building types remained constant within the sales file and with the data in the PLUTO file. Furthermore, we dropped observation where the age, log size, building area were different across files to remove buildings that might have been torn down or substantially changed over time.

- *Sandy Flood Zone and FEMA Floodplain*: GIS shapefiles were generously provided by the National Resources Defense Council (NRDC). They provided us with GIS shape files that indicated the locations in the city of the surge flood, and the locations of FEMA floodplain. We used the same files as shown in Figure 1 of their report on Sandy, at https://www.nrdc.org/sites/default/files/hurricane-sandy-coastal-flooding-report.pdf.

  Using this information, we then created our Sandy-related variables, which include the distance to the flood zone boundary for all properties, the distance to the shoreline, and the distance to the FEMA floodplain boundary. For flooded properties, we ascertained whether the building was in the FEMA floodplain map that was in effect in 2012. We also used the NRDC shape file to ascertain the distance of each property to the closest shoreline.

2. Additional Variables Not Shown in Regression Table

In several specifications, we included additional building and lot controls not shown in the table. These include building type-style dummies (e.g., a dummy variable for cape-code style, one for two-story-detached, etc.), dummies for proximity to other structures, dummies for basement types, and dummies for lot shape. Descriptive statistics are available upon request.

Table A.1: Additional Control Variables Used in Some Specifications.

Building Type	
Type	**Style**
One family dwelling	Cape code
One family dwelling	Two stories, detached
One family dwelling	One story
One family dwelling	Large suburban residence
One family dwelling	City residence
One family dwelling	Attached or semi-detached
One family dwelling	Summer cottage
One family dwelling	Mansion or town house
One family dwelling	Bungalow
Walk up apartment	Cooperative
Residence - multiple use	Primary one family with two stores or offices
Residence - multiple use	Primary one family with one store or office
Residence - multiple use	Single or multiple dwelling with stores or offices
Building Proximity to Other Buildings	
Detached	
Semi-attached	
Attached	
Basement Code	
Above grade full basement	
Below grade full basement	
Above grade partial basement	
Below grade partial basement	
Unknown	
Lot Shape	
Regular shaped	
Irregular shaped	
Unknown	

3. Alternative Regression Results

Table A.2: Regression Coefficients for a Standard Deviation Unit Change

Variable	Table 2, Eq. 1	Table 3, Eq. 1	Table 5, Eq. 1
(Dist. Sandy - FEMA (miles)) x Post Sandy	-0.002	0.022*	0.009
Dist. to Sandy (miles) x Post Sandy	0.018	0.035**	0.044***
Dist. Sandy - FEMA (miles)	0.067***	0.067	0.051
Dist. Sandy (miles)	-0.064**	-0.026	0.001
Post Sandy	0.01	0.033	0.236***
Dist. to Shore (miles)	0.174***	0.103	0.046
Dist. to Empire State Bldg. (miles)	0.419***	0.156	0.320**
ln(total units)	-0.12	-0.003	-0.074
ln(land) (ft^2)	0.220***	0.230***	0.222***
ln(age)	-0.142***	-0.160***	-0.140***
ln(building area) (ft^2)	-0.468***	-0.454***	-0.448***
ln(# Floors)	0.024*	0.008	0.004

Standardized variables coefficient estimates. These coefficients come from a “beta” regression where all the variables are converted to standard deviation units. Note only selected coefficients shown but specifications are same as regressions in the main text.