Hurricane Wilma and Affordable Housing in Southeast Florida

Abstract

In this paper, I analyze the impact of hurricanes on housing affordability by estimating the effect of Hurricane Wilma on the housing market, with a specific lens focused on the affordability of housing transactions. My data includes housing transaction values, neighborhood median incomes, and high resolution wind speed estimates for the three most impacted counties affected by Hurricane Wilma; Broward, Miami-Dade, and Palm Beach. I construct a measure of housing affordability using transaction values with neighborhood median incomes. I use a two-way fixed effects model to empirical demonstrate that increasing exposure to Hurricane Wilma's winds reduces the affordability of a transacted home by 3.59 index points. Additionally, I show that the reductions in the affordability index of a transacted home result in less affordable home sales following Hurricane Wilma. The results described in my paper identify the distribution of disaster aid as a potential mechanism leading to decreases in transaction affordability. My research provides policy relevant information that can facilitate a more equitable disaster response for hurricane impacts.

Key Words: Affordable Housing, Hurricanes, Disaster Impact, Equity

1 Introduction

Three out of every ten Americans are considered housing cost burdened, spending more than 30% of their monthly income on shelter (JCHS, 2022). As environmental threats such as hurricanes, floods, and sea level rise place increasing pressure on coastal housing markets, challenges to current issues of housing affordability are likely to grow. Economic theory postulates that higher housing costs are a result of low housing supply (Glaeser and Gyourko, 2018). Consequently, the issue of under-supply can be exacerbated in coastal communities from hurricane induced shifts to the housing market (Graff Zivin et al., 2023; Vigdor, 2008). Coupling the impact hurricanes have on increased prices in the housing market with more frequent high-intensity hurricanes due to climate change (Kossin et al., 2020), my study investigates how hurricanes may exacerbate issues of housing affordability.

In this paper, I analyze the impact of hurricanes on housing affordability by estimating the effect of Hurricane Wilma on the housing market, with a specific lens focused on the affordability of housing transactions. My data includes housing transaction values and high resolution wind speed estimates for the three most impacted counties affected by Hurricane Wilma; Broward, Miami-Dade, and Palm Beach. I use a two-way fixed effects model to provide empirical evidence on the disproportionate hurricane vulnerabilities for communities located in hurricane hot spots. The results described in my paper identify the distribution of disaster aid as a potential mechanism leading to decreases in transaction affordability. My research provides policy relevant information that can facilitate a more equitable disaster response for hurricane impacts.

I begin by asking, if hurricanes are found to increase housing prices in Florida (Graff Zivin

et al., 2023), what is the effect on the relative affordability of these housing transactions? Hurricanes may drive price increases for expensive homes through a signaling of strong structural integrity. The result for middle and lower income households, already priced out of these homes, would then be negligible. However, if increased transaction costs in lower income neighborhoods are the cause of observed mean price increases, reductions in housing affordability will effect the ability of lower income households to purchase a home.

If housing price increases in lower income neighborhoods are minimal, affordability decreases may not significantly prohibit purchases. For example, housing price increases that lead households to pay 28% of their income towards housing would not result in a cost burdened household. Therefore, I ask how changes in affordability affect the availability of non-cost burdened homes? The general rule of thumb suggests that households paying more than 30% of their income on housing are considered cost burdened. In the tri-county area used for this study, more than 43% of households fit this description. Using 30% of income expended on housing as a cut off for affordability, I estimate how hurricane exposure impacts the count of affordable housing transactions for the median income household.

Finally, I investigate how the current structure of disaster aid contributes to recovery within hurricane impacted locations. I ask how disaster aid programs, specifically the Small Business Administration (SBA) disaster loans, influence changes in housing affordability based on loan accessibility. High sensitivity to borrowing rates and greater take up of low-interest loans (Collier and Ellis, 2022) suggests households view disaster loans as an opportunity to improve the post-disaster value of their homes at cheap borrowing costs (Billings et al., 2022). Thus, I hypothesize that the upgrades to cheaper housing, resulting in a transaction premium, will contribute to reductions in the supply of affordable housing.

Linking the intensity of hurricane exposure to the affordability of housing transactions presents a number of methodological challenges. First, wind speed exposure varies over land based on a parcel's given location within the storm. I address this challenge by capturing the spatial variation in wind exposure using a high resolution hurricane model (Nolan et al., 2021). This model enables the linkage of wind speed estimates at the parcel level. Additionally, the random path and wind profile of hurricanes provide a plausibly exogenous measure of intensity that I use to capture the causal effect of hurricane impacts on the housing market. My use of a high-resolution hurricane intensity measure is similar to the approach used by Billings et al. (2022) in their study of hurricane flooding on household credit.

Second, the literature does not provide a clear definition on how to measure housing affordability. Current approaches in the housing literature include using cost to income ratios and counts of homes available for HUD (U.S. Department of Housing and Urban Development) assisted funding; yet, each of these approaches presents different challenges that introduce important caveats to the study of affordability (Sirmans and Macpherson, 2003; Stone, 2006; Joice, 2014). In addition, experienced hurricane intensity varies throughout small geographic regions (Nolan et al., 2021). To address the definitional ambiguity of housing affordability while capturing hurricane intensity variation, I construct a measure of housing affordability using micro-level housing data on transaction costs combined with median incomes of the transactions' census block (hereafter referred to as a neighborhood).

Finally, the disaster recovery process is complex. This complexity presents challenges in isolating the mechanisms that contribute to post-hurricane housing recovery. Specifically, households have a number of different options to use for disaster recovery including insurance, personal savings, and government aid (Collier and Ellis, 2022). Housing insurance, for

wind damages, is a wide-spread tool for homeowners because of federally backed mortgage requirements. Due to the ubiquity of mortgages in the housing market, I assume the majority of homes have access to insurance. Additionally, personal savings data are not readily available for households within the study sample. I assume that higher income households have more access to private savings, and thus have lower demand for disaster aid (Collier and Ellis, 2022). Together these assumptions imply that homeowners seeking disaster loans are those with damages exceeding insurance payouts and limited access to personal savings. Therefore, disaster aid plays an important role in the recovery of this subset of households. I use the approval rate of SBA loan applications within a zip code to measure how access to disaster loans influences the affordability of transacted homes.

The transaction data I use in this analysis comes from the individual property appraisal office of each affected county. My data set includes over eight hundred thousand transactions from 1999-2011. Transaction values are used in the affordability calculation because the sales price of a home represents the sum of discounted monthly payments (mortgages) for homeowners over a thirty year time period[1]. My housing data is integrated with neighborhood income data from the U.S. Census to construct my measure of housing affordability. My income data measures a neighborhood's median household income at the smallest geographic level available. My constructed affordability index, for each transaction, is attached to an individual parcel. Parcels are then assigned a measure of wind speed. Wind data is measured as the peak wind speed (in miles per hour) at any point in the tri-county area. The high resolution wind data I use provides important variation in experienced hurricane intensity that allows for estimation of marginal impacts on housing affordability.

[1]Most home mortgages are made on the 30-Year time horizon

In line with results from previous research (Graff Zivin et al., 2023), I find statistically significant evidence that increasing wind speed exposure leads to reductions in the affordability of transacted homes. In my analysis, I find that as wind increases by 1 mile per hour the affordability of a housing transaction is reduced by 3.59 affordability index points on average. Consequently, the hurricane induced reductions for housing affordability lead to reductions in the net number of affordable homes transacted. I estimate that for a 1 mile per hour increase in wind speed the probability of a transaction being affordable is reduced by 0.7% from the baseline. Overall, reduced transaction affordability and a lower likelihood of an affordable sale results in 2.76% less affordable home sales for every mile per hour increase in wind speed experienced in the average impacted neighborhood.

Finally, I find that access to disaster loans influences the affordability of transacted homes within hurricane impacted regions. In particular, within the average zip code a 1% increase in the approval rate for an SBA loans is associated with a reduction of 0.92 affordability index points for a post-Wilma housing transaction. The decreasing transaction affordability associated with greater SBA acceptance rates aligns with the increased wealth inequality following disasters observed by Howell and Elliott (2019). My results suggest that households are using disaster aid to upgrade their homes following disaster impacts leading to less affordable housing transactions.

For policy makers, these results suggest that the post-disaster housing market may become burdensome to middle and lower income households. The current disaster aid infrastructure may contribute to the observed outcomes, which can lead to further issues of housing affordability within coastal communities. If the goal of disaster aid is in promoting equity, it may be prudent for policy makers to reassess how they use aid to facilitate recovery.

The following section summarizes the current literature on hurricane effects in both the housing and labor market as well as the role of post-disaster aid as a recovery tool. The rest of the paper is laid out as follows; Section 3 describes the data while Section 4 provides the empirical models used to conduct this analysis. Sections 5 presents and discusses the results of this study. Section 6 concludes with reference to further research opportunities.

2 Hurricanes, Markets, and Disaster Recovery

A robust, yet still growing body of disaster research is focused on analyzing disaster impacts to housing markets and accompanying disruptions in the labor market. Arguably the most mature field of disaster research analyzes the impact of disasters on housing markets, via risk capitalization. The main takeaway from these studies suggests that disaster events lead to households updating their understanding of risk, resulting in housing price decreases within high risk areas (Bin and Polasky, 2004; Hallstrom and Smith, 2005; Carbone et al., 2006; Bin and Landry, 2013; Ortega and Taspinar, 2018; Bakkensen et al., 2019; Gibson and Mullins, 2020; Cohen et al., 2021). Additionally, McCoy and Zhao (2018) observe that hurricane damaged households are more likely to make home improvement investments if they are located within a flood zone. Finally, Smith et al. (2006) show how households at different incomes respond to hurricane impacts and risk differently based on their ability to relocate or insulate from these risks. Overall, these papers demonstrate that hurricanes create a divide in housing prices between high risk and low risk housing locations. My results contribute to this literature by demonstrating that hurricanes decrease the general affordability of all housing within hurricane impacted locations regardless of location within a flood zone.

Hurricane impacts to housing affordability can also affect outcomes within the labor market. Groen et al. (2020) show that wages increase within hurricane affected areas as a result of decreasing labor supply and increasing labor demand. These results are similar to findings from Belasen and Polachek (2009) where wage increases are also observed within hurricane affected counties, while wage decreases are observed in neighboring counties. The observed wage relationship between neighboring counties suggest that households priced out of the hurricane impacted counties migrated to nearby locations and over saturate the labor supply. Deryugina et al.(2018) provides further support of the relationship between housing costs and local wages with results of increased wages correlating with increases in the cost of living in New Orleans following Hurricane Katrina. Overall, this body of literature relating wage impacts to hurricane exposure suggests that impacted regions see an increase in wages due to a reduction in labor supply. My results provide complementary evidence to these findings by demonstrating that reductions in the labor supply of impacted counties may be a consequence of reductions in housing affordability.

Most closely related to my study is a smaller body of literature on the effects of hurricanes to the equilibrium price of housing. Vigdor (2008) argues that the observed housing price increases in New Orleans following Hurricane Katrina are unlikely to return to pre-Katrina levels due to major reductions in the housing stock. These results differ from Graff Zivin et al.(2023) and Murphy and Strobl (2010) where the authors estimate only temporary housing price increases that attenuate four to five years after hurricane exposure. One likely explanation for the different results is due to the intensity of hurricanes studied. Vigdor (2008) studies the impact after Hurricane Katrina, one of the largest hurricanes in US history. Graff Zivin et al.(2023) and Murphy and Strobl (2010) look at hurricanes, varying in

intensity, over a longer time period. My study more closely follows Vigdor (2008) by studying Hurricane Wilma, the twelfth costliest hurricane in US history. The general result from this body of literature suggests hurricanes increase housing prices. My contribution to this literature contextualizes the housing price increases relative to the neighborhood incomes, providing a more robust discussion of hurricane impacts on housing affordability.

Finally, separate from my main analysis but connected to my mechanism of interest, is a growing body of literature on the role of government aid in the post-disaster recovery process. Howell and Elliott (2018) observe growing levels of inequality, particularly between homeowners and renters, correlated with increasing levels of disaster aid. The observed increasing levels of wealth inequality correlated with disaster aid availability, aligns with results I observe between housing affordability and SBA loan access. Additionally, Billings et al. (2022) find poor credit history and the lack of an ability to repay loans as the main reasons households are denied access to SBA loans. This leaves vulnerable households with post disaster credit issues. These additional burdens for lower income households make adjusting to decreases in housing affordability more difficult. My research adds to the disaster aid literature by identifying a channel through which aid may contribute to greater inequality in the post-hurricane landscape.

3 Data

In this paper, I ask how Hurricane Wilma affected the market for affordable housing within impacted counties along Florida's Southeast Coast. I use micro-level housing data along with neighborhood median incomes to construct a measure of housing affordability. Then,

using a high resolution wind speed output from the H*WIND model for Hurricane Wilma, I assign a measure of hurricane exposure to each house (Powell et al., 1998; Nolan et al., 2021). The section below describes the data in detail.

3.1 Housing Transactions

The tri-county area in Southeast Florida, made up of Palm Beach, Broward, and Miami-Dade County, has the second highest rate of cost burdened households in the country [2] with 43.5% of households paying more than 30% of their income on housing. The composition of these cost burdened households includes both owners and renters; however, the percent of cost cost burdened households slightly decreases when only including homeowners (32%).

The housing transaction data is obtained from the county appraiser's office[3] in each county. The data set used in the main analysis specification is a repeated cross-section of residential housing transactions (single family and condo) for Palm Beach, Broward, and Miami-Dade County. Information on the date, price, and qualification code for up to three of the most recent transactions (for each parcel) are recorded. Sales occurring between January 1, 1999 and December 31, 2011 are included in the analysis. Prices are then standardized to 2005 values using the St. Louis Federal Reserve's Consumer Price Index (CPI) for housing of all urban consumers within the tri-county area defining my study. The qualification codes characterize the type of transactions and can be dichotomized into qualified or disqualified sales.

The data set contains housing specific characteristics for each parcel, including the year of

[2]Out of the 933 largest metropolitan areas

[3]The data was purchased from a geospatial data company called Mapwise https://www.mapwise.com. This company compiles all of the county appraiser data throughout the state of Florida and connects the parcel appraisal data with spatial identification of each parcel.

Table 1: Summary Statistics for Study Sample

	Broward				MiamiDade				PalmBeach			
	Pre-		Post-		Pre-		Post-		Pre-		Post-	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Transaction Value '000s ($)	211.407	220.876	208.394	263.823	249.727	344.391	327.181	472.425	260.532	473.814	297.124	652.335
Affordability Index	220	331	315	441	169	184	170	279	244	135	314	266
Total Square Feet	1370	1389	1211	1446	1664	998	1652	1074	2749	1536	3112	1881
Age of Home	24	14	27	16	26	18	26	24	24	16	26	18
Distance to Coast (m)	2372	2811	2277	2694	3085	3810	2630	3540	4446	5377	4837	5536
Elevation (m)	2.53	0.96	2.54	1.01	2.18	0.95	2.18	0.95	4.62	1.29	4.63	1.33
Housing Count												
Total	236897		168528		228683		136994		63298		42274	
Condo	97226		82200		127819		87362		0		0	
Single Family	139671		86328		100864		49632		63298		42274	

Notes: Summary statistics describing the price as well as household characteristics for pre-event and post-event housing transactions of households in Broward, Miami-Dade, and Palm Beach County. Additionally, the count of transactions within each county are provided and split into condo or single family residential distinctions.

build and the total square footage of each home. Additionally, spatial characteristics defined from the centroid of the parcel such as distance to the coast and elevation are amended to the housing transaction data set. The spatial attributes of each parcel enables the assignment of a particular neighborhood to each parcel. The neighborhood designation for each parcel is used to construct the affordability index, described in the follow section 3.2.

Table 1 provides summary statistics of the housing and spatial variables broken down by the pre- or post-event periods for each county. In all three counties the average affordability index increased between the pre- and post- Wilma periods. Miami-Dade experienced the smallest increase in housing affordability, while Broward County experienced the largest with with a 95 point increase for the average transaction's affordability index. Of the three study areas, Broward is the only county to experience a decrease in the average transaction price. Throughout the sample the count of transactions is lower in the post-Wilma period. All other control variables are consistent between the pre- and post- event periods.

3.2 Affordability Index

The next step of my data set up requires the construction of a housing affordability index. I construct an affordability index based on a similar process used by the National Association of Realtors[4] (NAR) and the Federal Reserve Bank of Atlanta[5]. The process is described as follows:

$$M_{it} = P_{it} \cdot 0.8 \cdot \frac{\frac{r_t}{12}}{1 - (\frac{1}{1+\frac{r_t}{12}})^{360}} \tag{1}$$

$$Q_{it} = M_{it} \cdot \frac{10}{3} \cdot 12 \tag{2}$$

$$\text{Affordability Index}_{it} = \frac{I_{bt}}{Q_{it}} \cdot 100 \tag{3}$$

Equation 1 calculates the principal and interest payments for a given transaction assuming a 20% down-payment with a fixed 30-year effective mortgage rate. M_{it} represents the 30-year discounted monthly costs of a housing transaction. The subscript i represents an individual housing transaction while t represents the year of sale. The effective mortgage rate is represented by variable r for a given year t. Equation 2 describes the qualifying income needed for a bank supplied home loan. Multiplying by $\frac{10}{3}$ in equation 3 restricts the qualifying income to be no greater than 30% of the household's income. The M_{it} and Q_{it} values are used to construct the affordability index in equation 3.

[4]https://www.nar.realtor/research-and-statistics/housing-statistics/housing-affordability-index/methodology

[5]https://www.atlantafed.org/center-for-housing-and-policy/data-and-tools/home-ownership-affordability-monitor

The affordability index (A_{it}) is calculated with the neighborhood's (b) median income (I_{bt}) obtained from the US Census and is adjusted for inflation based on the year of sale t. This income value I_{bt}, is compared to the qualifying income of the household transaction Q_{it} and multiplied by 100 to produce the affordability index. Transactions with indices below 100 are considered unaffordable for the median income household within block b, while indices over 100 are considered affordable.

The neighborhood median income is obtained from the 2000 US Census, and it is standardized to the year of sale for each housing transaction using the St. Louis Federal Reserves Urban Consumer Price Index (CPI). I use median incomes from the pre-hurricane period to capture how post-event transaction prices relate to the pre-event incomes of households within that particular neighborhood.

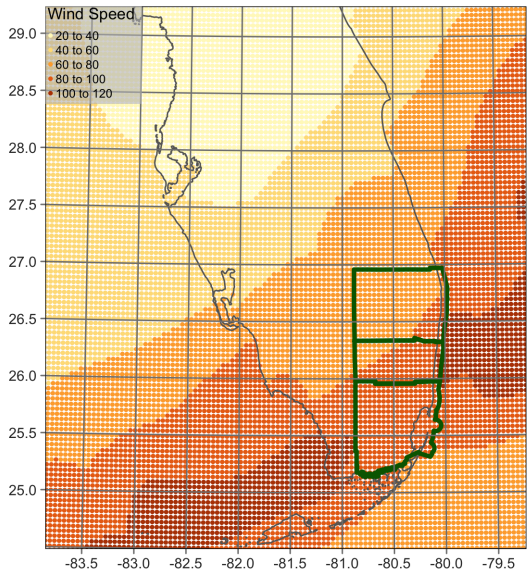
An important caveat of this analysis is the proxy of household incomes, where neighborhood medians are treated as individual household incomes. Individual household incomes accompanying each of the transactions would provide a more complete picture of changes in the cost burden of hurricane effected households.

3.3 Hurricane Wilma

Hurricane Wilma was the strongest hurricane to hit the United States during the highly active 2005 hurricane season. Wilma made landfall in southwest Florida near Marco Island on October 25^{th}, 2005. Wilma then crossed the Florida peninsula in 4.5 hours, severely impacting the coastal counties on the east coast of Florida before spilling into the Atlantic Ocean. Based on statistics from the Property Claims Services of the Insurance Services

Office, Wilma created $10.3 billion dollars in insured damages and an estimated $21.007 billion in total property damages (Pasch et al., 2014).

Figure 1: Wilma Map



Map of Florida with Hurricane Wilma windswath. The counties used in this study are outlined by green lines in the southeastern portion of the state.

I use wind swaths created by Nolan et al. (2021) to study the effect of Wilma's high intensity winds on the market for affordable housing throughout Southeast Florida. Wind swaths are defined as peak wind speeds experienced at any given location over the span of a hurricane event. Figure 1 provides Wilma's wind swath across Florida suggesting that the highest wind speeds experienced over land were located in the southern portion of Florida. Palm Beach, Broward, and Miami-Dade counties were selected for this study due to the high level of wind speeds experienced as well as the completeness of the available housing data.

The wind files contain maximum 1-minute average winds at points spaced 1-km apart over Florida. These data points are the proxies for household exposure. I create a smooth

surface of maximum wind speed intensity through interpolation to assign each parcel a level of exposure.

Table 2: Summary Table of Wind Speed Exposure in the Study Counties

County	Mean Wind Speed	SD Wind Speed	Max Wind Speed	Min Wind Speed
MiamiDade	94.42	1.91	97.79	87.02
Broward	92.46	2.23	97.96	83.95
PalmBeach	79.64	7.81	96.01	62.88

Notes: This table provides the average wind speed experienced in each of the study counties along with the standard deviation of the experienced wind speeds. The maximum and minimum wind speeds experienced in each county are also provided to show the range of experienced wind speed.

Table 2 provides descriptive statistics for experienced wind speeds throughout each of these counties. Miami-Dade County experienced the highest average wind speeds, while Palm Beach had the lowest on average. Additionally, Palm Beach had the highest variation in wind speed experienced throughout the entire county with maximum wind speeds similar to those experienced in Broward and Miami-Dade. Yet, the lowest experienced wind speed in Palm Beach was more than 20 miles per hour slower than minimum speeds experienced in the other two counties.

4 Methods

My goal in this study is to estimate Hurricane Wilma's effect on the affordability of housing within Southeast Florida's coastal communities. This is done in three steps. First, I analyze how changes in exposure to high intensity wind speed affect the affordability index of transacted homes. Second, I estimate how changes in the affordability index influence the likelihood of an affordable transaction. Finally, I estimate the effect of mean wind exposure within a neighborhood on the count of affordable home sales. The causal interpretation

of these estimates relies on the exogeneity in exposure resulting from the randomness in Wilma's path and strength.

4.1 Affordability Index Model

First, I ask whether Hurricane Wilma reduced the affordability of housing transactions within the Broward, Miami-Dade, and Palm Beach Counties. Equation 4 estimates the effect of high intensity hurricane winds on housing affordability:

$$Y_{ibd} = \delta(WindSpeed_i * Post_d) + \alpha' Post_d + \beta_1' AgeHouse_{it} + \boldsymbol{\beta_2'} \mathbf{X}_i + \gamma_b + \gamma_q + \gamma_c + \epsilon_{ibd} \quad (4)$$

The dependent variable Y_{ibd} is a measure of the affordability index for a transacted parcel i within neighborhood b occurring on day d. The variable of interest, δ, measures the marginal effect of hurricane winds on the transaction affordability of exposed household i. In model 4 the unit of observation is an individual transaction i on a date d. However, as explained in MacKinnon et al. (2022) the unit of inference is interpreted based on within-neighborhood variation due to the decision to cluster standard errors at the neighborhood level.

The vector X_i represents the set of control variables observed at the household level, which do not vary over time. These household specific variables include elevation of the house (in meters), total square footage of the house, distance to the coast (in meters), and whether the home is a condo or single family residential unit. $AgeHouse_{it}$ is a household characteristics that varies over time t based both on the year of a transaction and the year the house was built. The physical attributes including elevation and distance to the coast

provide controls for the varying levels of climate risk each household faces with respect to hurricane impacts. On average, homes that are closer to the coast and located in lower elevated areas have higher risks of suffering impacts from hurricane events.

Time and place fixed effects are included to capture unobserved, common trends that may influence housing affordability. γ_b is a neighborhood level fixed effect controlling for amenities within each neighborhood such as proximity to parks and other recreation sites. I assume that these neighborhood amenities do not change over time within this study period. Additionally, homes in close proximity typically have similar building characteristics (Ortega and Taspinar, 2018), so these neighborhood fixed effects also control for potential biases introduced by housing characteristics not available in the transactions data set. γ_q is a quarter-year fixed effect that controls for seasonality of transactions in the housing market. Finally, γ_c is a county fixed effect controlling for different affordability trends between the three counties.

The standard errors are clustered at the neighborhood level to control for possible spillover effects of housing transactions within the same census blocks. The inclusion of both neighborhood fixed effects and neighborhood error clustering accounts for spatial correlation exhibited by housing transactions (Shr and Zipp, 2019). As suggested by MacKinnon et al. (2022), I report the key distribution statistics for the number of units at the given clustering level. In the Wilma data set there are $2,410$ neighborhoods with the number of properties within each neighborhood ranging from 1 to $4,228$. The average number of properties within a neighborhood is 270 and the median number of units is 132.

4.1.1 Repeat Sales

The widespread damages from a major hurricane may influence the type of housing transacted in the post event period (Graff Zivin et al., 2023). Therefore, I expand on the previous analysis and implement a sample adjustment to include only repeat housing transactions with the intention of averting possible shifts in the type and quality of transacted homes. Parcels are included if they have at least one transaction prior to 2005 and at least one transaction post 2005. In the case where parcels have multiple transactions in either the pre or post period, the transaction closest to the event year (2005) is used. For example, if a parcel has a transaction in 2002 and 2004, the transaction value in 2004 is used as the pre-event data point.

4.2 Affordable Home Sales

The next step of the analysis asks how reductions in affordability can lead to decreasing **counts** of affordable housing transactions through two research questions. First, how does exposure to Hurricane Wilma's winds affect the likelihood of a transaction being affordable? Then, how does exposure to Wilma's winds reduce the count of affordable home sales within an impacted neighborhood? Both of these questions use an affordability index value of 100 as the cutoff between affordable and non-affordable home sales.

The first question is approached by estimating a logit function where the probability of an affordable transaction is defined by:

$$Pr(y_{id} = 1) = \frac{e^{y^*_{ibd}}}{1 + e^{y^*_{ibd}}} \tag{5}$$

such that

$$y_{ibd} = \begin{cases} 0 & \text{if } y^*_{ibd} \leq 0 \\ \\ 1 & \text{if } y^*_{ibd} > 1 \end{cases} \tag{6}$$

where

$$y^*_{ibd} = \delta(WindSpeed_i * Post_d) + \alpha' Post_d + \beta'_1 AgeHouse + \boldsymbol{\beta'_2}\mathbf{X}_i + \gamma_b + \gamma_q + \gamma_c \tag{7}$$

This model uses the same unit of observation as model 4 and calculates the influence of experienced wind speed on the likelihood of transaction i being affordable. In model 7, the δ variable measures wind speeds effect on the probability of an affordable transaction. Similar to model 4 the standard errors are clustered at the neighborhood level.

Then building on this approach I ask whether average wind speed affects the number of affordable home sales within an impacted neighborhood? For this analysis, I model the count of affordable home sales within a neighborhood using the Poisson model in equation 8 (Hausman et al., 1982).

$$Pr(Y_{bt} = y_{bt}|x_{bt}) = \frac{e^{-\lambda_{bt}}\lambda_{bt}^{y_{bt}}}{y_{bt}!} \tag{8}$$

In model 8 the dependent variable, y_{bt}, can take on the values $\{0, 1, 2, ...\}$ representing the aggregate count of affordable home transactions within neighborhood b during year t. The distinction of an affordable sale is made based on the affordability index of the

transaction as described in section 3.2. Neighborhoods without a housing transaction in a given year are treated the same as neighborhoods without any affordable transactions. Model 8 uses neighborhoods (b) as the unit of observation creating a balanced panel at the year-neighborhood (bt) level.

$$ln(\lambda_{bt}) = \boldsymbol{\gamma} + \delta(WindSpeed_b * Post_t) + \alpha' Post_t + \boldsymbol{\beta}' \mathbf{X}_{bt} \tag{9}$$

Equation 9 is the link function for the Poisson model (8). The link function (9) assumes λ is a deterministic function of the control variables $\mathbf{X}_{bt}$, the vector of fixed effects $\boldsymbol{\gamma}$, and the wind speed impact interaction term estimated by δ. The estimand of interest, δ, captures the impact of wind speed on the number of affordable home sales within the impacted neighborhood for a given year. I aggregate wind speeds for a particular neighborhood by averaging each homes experienced wind speed within the neighborhood.

Importantly, equation 9 does not include an error term implying that the variation captured by model 8 is provided in the randomness in y_{bt}. In this link function the vector $\mathbf{X}$ includes census block averages for elevation, housing age, distance to the coast, and the square footage of a house. The fixed effects used in model 8 represented by $\boldsymbol{\gamma}$ are at the neighborhood and quarter-year level. Similar to model 4 the standard errors in the Poisson model are clustered at the neighborhood level.

5 Results

In this section I report results in two parts. First, I present the causal relationship between experienced wind speed and the affordability index. Then, I present results describing im-

pacts to the count of affordable home sales. Together these results show how reductions in affordability of the average home transaction effect the availability of affordable housing in the post-Wilma housing market.

5.1 Changes in the Affordability Index

Table 3: Full Sample OLS Estimates

	Affordability Index					
	Specifation 1	Specification 2	Specfication 3	Specification 4	Specification 5	Specification 6
Post Event	361.71***	350.92***	386.17***	386.19***	386.03***	386.34***
	(33.23)	(32.95)	(29.21)	(29.22)	(29.23)	(29.55)
Post*WindSpeed	−3.26***	−3.21***	−3.59***	−3.59***	−3.58***	−3.59***
	(0.36)	(0.36)	(0.32)	(0.32)	(0.32)	(0.32)
Num.Obs.	876 674	876 674	876 674	876 674	876 674	876 674
R2	0.101	0.104	0.140	0.140	0.140	0.151
House Age		X	X	X	X	X
Total Square Feet			X	X	X	X
Elevation				X	X	X
Distance to Coast					X	X
FE County	X	X	X	X	X	X
FE Block Group	X	X	X	X	X	
FE Sale Year-Quarter	X	X	X	X	X	
FE Block Group by Sale Year-Quarter						X
Std Error Clusters	Block Group	Block Group	Block Group	Block Group	Block Group	Block Group

+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

Notes: This table presents OLS regression results for the impact of Hurricane Wilma on affordable housing in Broward, Miami-Dade, and Palm Beach Counties. The different model specifications are presented to demonstrate the stability of the estimate of interest regardless of model specification.

I report the results for the ordinary least squares estimates of the δ and α parameters from model 4 in table 3. The different specifications represent the sequential addition of control variables as displayed in the bottom half of table 3. In column 5 I provide estimates for the full model (4) specification. My estimates for δ are located in the second row of Table 3, representing the interaction term between variables *Post* and $WindSpeed$. In column 5, my estimated impact of Wilma on the affordability index suggests that a 1 unit increase in wind speed leads to an average reduction of approximately 3.59 points on the affordability index of a transacted home. The negative estimate is largest for the fully specified model,

but is consistently negative with all other model specifications. These results align with the findings from Graff Zivin et al. (2023) of increased transaction prices resulting from hurricane exposure.

Next, I present estimates for α in the first row of table 3 labeled *Post*. These estimates represent the general trend in housing affordability between the pre- and post-Wilma time periods. My estimates of α suggest a significant increase in the average affordability of transacted homes in the post-Wilma period. The post-Wilma period (2006-2011) coincides with the housing market crash of 2008 and 2009, which provides support for my findings of increased housing affordability during this time period.

Table 4: Repeat Sales OLS Estimates

	Affordability Index			
	Specification 1	Specification 2	Specification 3	Specification 4
Post Event	1034.49***	1178.09***	1030.08***	1023.52***
	(48.32)	(49.12)	(48.24)	(62.57)
Post*WindSpeed	**−11.52*** **	**−12.08*** **	**−11.51*** **	**−11.37*** **
	(0.53)	(0.53)	(0.53)	(0.69)
Num.Obs.	148 484	148 484	148 484	148 484
R2	0.624	0.049	0.624	0.937
Age of House	X	X	X	X
FE County	X	X	X	X
FE Parcel	X		X	
FE Sale Year-Quarter		X	X	
FE Parcel by Sale Year-Quarter				X
Std Error Clusters	Block Group	Block Group	Block Group	Block Group

+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

Notes: Repeat Sales OLS Regression Results for different model specifications.

I present the results of the repeat sales analysis in table 4. I estimate even larger marginal impacts of Wilma's wind speed on the affordability of transacted homes. For a 1 mile per hour increase in experienced wind speed, an average (repeat) transaction is reduced by 11.51 units on the affordability index. My repeat sales analysis addresses issues discussed in section 4.1.1 relating to potential changes in the stock of transacted homes between the

pre- and post-hurricane time periods. My estimates obtained in table 4 alleviate potential biases introduced by the omission of unobserved housing specific variables through the use of parcel fixed effects.

Through both tables 3 and 4, I provide evidence that housing becomes less affordable as exposure to Hurricane Wilma's wind speed increases. However, if reductions in affordability predominately occur in high income neighborhoods, locations where housing is already unaffordable, the overall impact on housing accessibility should be negligible. In the following section I further investigate the types of homes where housing affordability decreases.

5.2 Loss of Affordable Transactions

My results in this section are estimated using the affordability threshold discussed in section 4.2 to demonstrate that reductions in the housing affordability index lead to decreases in the probability of an affordable transaction and less affordable home sales overall.

In Table 5, I present the results of the logit model (5) which describes the effect of wind speed on the probability of an affordable housing transaction. My estimate of δ, provided as the estimand of the interaction between the variables $Post$ and $WindSpeed$ in column 2, is averaged over all observations to provide a single value of the effect. My average marginal effect demonstrates that as exposure to wind speed increases by 1 mile per hour, the probability of an affordable transaction is reduced by 0.7%. My result provides supporting evidence that decreases in affordability are affecting the sale of affordable homes.

Finally, in table 6, I show the results of increasing wind exposure on the number of affordable home sales within an exposed neighborhood. My estimates from the Poisson

Table 5: Logit Model Results for Probability of Affordable Home Sale

	Affordability Index		
	Logit 1	Logit 2	LP Model
Post*WindSpeed	−0.0388	−0.0729	−0.0055
	(0.0042)	(0.0064)	(0.0004)
Post Event	3.1333	6.1241	0.4329
	(0.3738)	(0.5802)	(0.0352)
Num.Obs.	1 030 449	857 898	876 674
Avg Marginal Effect	**-0.0057**	**-0.0071**	
Avg Marginal Effect SD	**(0.0005)**	**(0.0007)**	
House Age		X	X
Total Square Feet		X	X
Elevation		X	X
Distance to Coast		X	X
FE Block Group	X	X	X
FE Sale Year-Quarter	X	X	X
Std Error Clusters	Block Group	Block Group	Block Group

Notes: GLM (Logit) results for the probability of an affordable housing sale with respect to experienced wind intensity from Wilma.

model suggest every mile per hour increase in wind speed leads to 2.76% less affordable home sales for the average neighborhood.

Overall, marginal increases in wind speed exposure from Hurricane Wilma leads to fewer affordable home sales in the Southeast Florida housing market. My evidence implies that average reductions in the affordability index of a transacted home has implications on the **count** of affordable housing transactions.

5.3 Mechanisms

In the previous section I provide results describing the effect Hurricane Wilma had on the market for affordable housing. In summary, my results indicate that increasing levels of wind speed exposure induce reductions in the affordability of transacted homes as well as reductions in the count of affordable home sales. In this section I explore potential mechanisms triggered by Hurricane Wilma that contribute to the previous results.

Table 6: Poisson Model Results for Affordable Housing Counts

	Poisson 1	Poisson 2
Post*WindSpeed	−0.018	−0.021
	(0.002)	(0.002)
Num.Obs.	29 395	29 395
Neighborhood Average		
House Age		X
Total Square Feet		X
Elevation		X
Distance to Coast		X
FE Block Group	X	X
FE Sale Year	X	X
Standard Error Clusters	Block Group	Block Group

Notes: GLM (Poisson) results for the change in count of affordable home sales with respect to experienced wind intensity from Wilma. The unit of observation is at the neighborhood level.

5.3.1 Disaster Aid

High levels of loss incurred from major hurricanes like Wilma generate flows of disaster aid on the order of hundreds of millions to billions of dollars. Thus, understanding how the distribution of disaster aid shapes the post-disaster housing market is important in promoting equitable recovery outcomes. My results in this section investigate the question; how do acceptance rates for Small Business Administration (SBA) loans[6] (a form of disaster aid) impact housing affordability for post-Wilma transacted homes. I analyze the relationship between housing affordability and the approval rate of SBA loans using the following model:

[6]The SBA provides low-interest loans for homeowners, renters, and businesses following disaster declarations. The SBA data is integrated with the transaction and wind speed data via the spatial association of SBA loan acceptance rates and county zip codes.

$$Y_{ibd} = \zeta(ApprovalRate_z * Post_d) + \delta(log(WindSpeed)_i * Post_d) + \alpha' Post_d +$$

$$\beta_1' AgeHouse_{iy} + \boldsymbol{\beta_2'} \mathbf{X}_i + \gamma_b + \gamma_q + \epsilon_{id} \quad (10)$$

Similar to model 4, Y_{ibd} represents the affordability index of a transaction from parcel i in neighborhood b on date d. In equation 10 the estimand of interest is ζ, which represents the relationship between the approval rate of SBA loans within zip code (z) and the affordability index of a transacted home within the same zip code (z).

Table 7: SBA Disaster Aid and Housing Affordability

	Affordability Index	
	Model 1	Model 2
SBA Approval Rate Post Wilma	−0.848	−0.919
	(0.214)	(0.193)
Post*WindSpeed	−3.295	−3.611
	(0.365)	(0.321)
Post Event	407.884	434.177
	(33.889)	(30.454)
Num.Obs.	875 168	875 168
R2	0.102	0.140
Elevation		X
Age House		X
Distance to Coast		X
Total Square Feet		X
FE Block Group	X	X
FE Sale Year-Quarter	X	X
Std Error Clusters	Block Group	Block Group

Notes: This table provides estimates on the relationship between SBA Approval rates and the affordability of transacted homes in the post-Wilma housing market.

In table 7 I present the results of model 10. My estimate for ζ in table 7 suggests that as SBA approval rates within a home's zip code increase by 1%, the average affordability of a transacted home is reduced by 0.92 index points.

The decreasing levels of affordability associated with increasing disaster loan approval rates suggest that households may be using these low cost loans to fix-up and improve the

quality of their damaged homes and sell them for a premium in the years following Wilma. Gallagher and Hartley (2017) provide similar evidence in the wake of Hurricane Katrina where households use insurance payouts to pay down mortgages and sell their homes.

6 Discussion & Conclusion

In this paper, I estimate the effect of hurricane Wilma's winds on the transaction affordability of housing within Southeast Florida's housing market. My results suggest that exposure to high intensity wind speeds has important ramifications on the affordability of housing transactions. First, my estimates suggest that increasing exposure to wind speed leads to reductions in the affordability index of the average home transaction. These results alone do not suggest that changes in housing affordability have important consequences for the accessibility of affordable housing. However, I also show that the reductions in housing affordability result in a lower probability that the average transaction will be affordable. Overall, the reductions in affordability of a housing transaction lead to lower counts of affordable transactions within the impacted housing market.

My main contribution with this paper provides context to the estimated increase in housing prices resulting from hurricane exposure. While previous literature defines a causal relationship between wind exposure and housing prices (Graff Zivin et al., 2023), this paper demonstrates that the estimated price increases have an effect on housing affordability for median income households. These results have important implications for policy makers throughout Florida. In particular, the tri-county area observed in this study already struggles with housing affordability. Therefore, tying housing and disaster policy together can increase

the resilience of vulnerable communities in Southeast Florida.

Additionally, my results demonstrate that the current system of disaster recovery may contribute to the issues of affordability observed in the post-Wilma landscape. These results align with previous studies on the influence of disaster aid and equity (Howell and Elliott, 2019; Billings et al., 2022). Due to the observed effects of hurricanes on housing affordability, post disaster government responses will need to focus on providing more access to affordable housing.

I conclude with several limitations and potential avenues for future work. First, this study does not include data on individual household incomes. Inclusion of household incomes for the selling and purchasing parties of a transaction would provide an important lens into the gentrifying effects of hurricanes. Additionally, this study does not capture changes in housing tenure decisions due to rising prices. Sheldon and Zhan (2019) find increasing rental rates for households moving into hurricane impacted areas. If homeowners within impacted regions sell their homes and become renters, rental prices are likely to increase. Future work can compliment this study through an analysis of hurricane effects on rental prices. Finally, this study focuses on one specific hurricane. This presents issues of external validity. Including a larger set of hurricanes would help to develop a general relationship between hurricanes and housing affordability.

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