Can Disasters Bolster Housing Demand? A Difference-in-Differences Analysis of Post-Hurricane Housing Dynamics in Puerto Rico

Erik Johnston

California Polytechnic State University, San Luis Obispo

9 June 2025

Natural disasters, like hurricanes, can cause large and lasting disruptions to housing markets. Such events act to limit housing stock, while simultaneously displacing residents, driving housing demand up, and, in theory, triggering a rise in housing costs. Storm impacts vary from area to area and home to home depending on a variety of economic conditions and hedonic attributes, making it difficult to identify the portion of housing price increase that can be uniquely attributed to storm impacts. Applying a difference-in-difference model to Puerto Rico Community Survey data accessed through IPUMS, this research aims to disentangle housing price increases caused by storm impacts rather than idiosyncratic economic factors in the San Juan Metropolitan Area of Puerto Rico.

II. Introduction:

The Commonwealth of Puerto Rico is a self-governing island territory of the U.S. located in the Caribbean Sea. Puerto Rico sits in an area infamous for its frequent and intense hurricane activity, dubbed "Hurricane Alley." Hurricanes are characterized by 74 mile per hour or greater maximum sustained winds and are rated in five categories, with category five indicating the strongest storm rating possible. Over the past ten years, Puerto Rico has experienced three hurricanes, two of which have been category four or five, causing severe damage to the island's housing stock and infrastructure. These latter two were Hurricane Irma (category five) and

Hurricane Maria (category four), which struck Puerto Rico on September 6, 2017, and September 20, 2017, respectively.

With storm damage acting to limit housing stock and increase demand in the wake of a hurricane, canonical theory suggests that housing markets should observe an increase in price, assuming downward-sloping demand and inelastic supply. However, the literature finds that, empirically, housing markets generally observe a moderate decrease in price in the short run (Bin and Landry, 2013; Hallstrom and Smith, 2005; Hennighausen and Suter, 2020). Some literature emphasizes the distinction between the conditions under which people make decisions about housing, allowing for considerations of expectations. In areas where there is a history of natural disasters, shocks, that would otherwise act as exogenous market forces, become an endogenous variable that consumers factor into their housing decisions because expectations in that area have adapted over time. In these areas, housing markets see no effects or moderate decreases in price as a result of natural disasters.

Standard economic theory predicts that supply constraints, given inelastic demand, should raise prices. This is in contrast, however, to the empirical pattern of price decline or stagnation due to expectation revision that the literature (Bin and Landry, 2013; Petkov 2022) outlines. Puerto Rico makes a notable divergence from the established empirical trend with a moderate observed increase in home value in the wake of Hurricanes Irma and Maria, motivating this research. In its current form, observed housing price dynamics in the San Juan Metropolitan Area cannot be explained by the expectation framework current literature puts forward. Given the island's history with tropical cyclones, it is a reasonable assumption that expectations account for storm impact, yet Puerto Rico still sees increasing prices in the short run, further motivating this work.

This study seeks to quantify the proportion of housing price increases can be casually attributed to the storm impacts of Hurricanes Irma and Maria. This hypothesis is formally tested by constructing a difference-in-difference model. The model will contain a binary indicator for data collected before or after the cyclones, and a binary indicator to represent data as belonging to the treatment group (Puerto Rico) or the control group, (Miami). The interaction of these binary indicators will determine the proportion of price increases that Hurricanes Irma and Maria caused. The model is fit with data from the San Juan-Carolina-Caguas Metropolitan Area, which will be referred to as the San Juan Metropolitan Area (SJMA) throughout this work, collected by the Puerto Rico Community Survey, accessed through IPUMS.

There is a rich and diverse body of literature surrounding the effects of natural disasters, specifically hurricanes, increasingly fueled by climate change, on urban real estate markets. Much of this work tends to emphasize empirical findings utilizing quasi-experimental designs to derive insights. Among natural disasters, floods, as a consequence of storms or hurricanes, present the greatest risk to housing markets as the most prevalent form of natural disaster, with frequency expected to increase in in the face of climate change. Much work in the area focuses on estimating the effects flood impact and perceived flood risk, often relying on insurance data, on housing markets. The research tends to be concentrated in mainland USA, whereas this research seeks to develop inference for the island territory of Puerto Rico.

Recently, Santiago-Bartolomei et al. (2022), studied the storm impacts of Hurricane Maria in the San Juan area of Puerto Rico, shedding light on housing market dynamics in the area of study. The study quantifies storm impact by calculating a “pending need” variable, the difference in disaster aid claimed and the amount awarded by FEMA. They find that pending need is negatively correlated with housing sales, but positively correlated with median home

price, suggesting that in post-storm conditions exchange of housing stock is hindered and these exchanges carry an inflated transaction price. This finding conflicts with other past studies that associate hurricane or flooding risk with negative housing prices, at least in the short run (Bin and Landry, 2013; Hallstrom and Smith, 2005; Hennighausen and Suter, 2020). This potentially suggests some unique attribute of the Puerto Rican economy is disrupting the well-evidenced trend that exists in other areas. One factor to consider is 2012 tax incentives introduced to revitalize the Puerto Rican economy. In the year following the introduction of these tax benefits, the Federal Housing Finance Agency house price index tracked an increase of nearly 4% according to a July 2019 comprehensive housing market analysis of Puerto Rico published by the U.S. Department of Housing and Urban Development.

While this work is useful in establishing an understanding of the post-storm shifts that occur in the SJMA housing market, namely supply-constraint driven price increases, the model utilized here cannot conclude causation because it does not include a baseline for comparison, weakening the analysis by ignoring pre-existing trends. This is where I seek to fill gaps in current existing research.

Petkov (2022) resolves the pre-existing trends issue by utilizing a difference-in-difference approach. Petkov (2022) uses insurance deductible information to construct expectation structures which explain the mechanisms driving housing market changes. Perceptions significantly influence storm impacts on housing market dynamics. Where hurricanes present "new news," there is an observed price increase with unchanged quantity demanded after their occurrence, suggesting supply-side constraints drive up prices. Conversely, in areas where hurricanes are expected, prices remain relatively stable after a hurricane. The work of Yi and Choi (2020) confirms the latter finding by analyzing housing and flood plain data from Des

Moines, IA. Areas in designated flood zones that had actually previously experienced flooding saw no price change, however for units that were not located in flood zones, but experienced flooding, saw persistent price declines.

Both observations conflict with observed outcomes in Puerto Rico after Hurricane Maria, where there is a consistent history of flooding, yet prices have seen persistent increases since 2017. This confirms the idea that there may be other economic forces at work on housing prices, revealing a potential limitation of this research.

The primary challenge with difference-in-difference estimation is finding a suitable control that exhibits parallel trends in the outcome variable. Due to the diverse, nuanced nature of urban patterns, housing markets tend to be unique which makes it difficult to find an acceptable control when using housing price as a dependent variable. In Boustan et al. (2020) the researchers employ a fixed-effects panel regression to analyze the effect of natural disasters of a set of economic outcome variables. The fixed-effects approach potentially presents a more suitable approach for comparing housing markets because it uses each unit as its own control over time, directly controlling for within-unit variation.

Some studies marry the two strategies such as in Ellen, I. G. (2024), which studies storm impacts of Hurricane Sandy in New York City. Samples are differentiated by high surge ($\geq$ 2 ft. flooding) and low surge (< 2ft. flooding), and incorporates fixed effects for building characteristics, census tract, seasonality, and borough. This paper, as well as others, suggest storm-driven flooding impact on housing price can be quite heterogeneic depending on neighborhood amenities. For example, Cohen et al. (2021), also studies New York City and finds that properties with better subway access and higher incomes were more affected. This suggests study of unit-level variation may be important in analysis, though this can pose significant

challenges in practice depending how frequently and thoroughly data is collected at the property level.

III. Data & Methodology

The model upon which this analysis is based is a price dynamics model rooted in the simpler theories of supply and demand. After a storm, there are two primary short-run housing market outcomes, (i) the reduction in housing stock that, holding all other factors constant, would drive housing prices up, and (ii) damage to residential properties that would make housing less desirable, or, altogether unlivable, reducing demand, and ultimately housing price. The model this work utilizes seeks to reconcile these two conflicting forces and identify which dominates empirically in SJMA. In answering this question, this work determines whether observed price increases can be causally attributed to Hurricanes Irma and Maria themselves, or if they are more so associated with the unique economic and geographic context of the island. Such economic and geographic factors include its status as an island, acting to restrict mobility after the occurrence of a natural disaster, and tax structure which provides strong incentives to move to the island for wealthy individuals.

The fixed effects estimation approach, while capable of yielding causality, proved challenging in the context of this work due to the cross-sectional nature of the data which lacked many unit-level observations that would be necessary to robustly estimate storm impacts. Though, fixed effects are implemented to a lesser extent in the model specification by incorporating year fixed effects as shown in Equation 1 below. The difference-in-difference framework may be used to casually attribute outcomes in a variable of interest to the occurrence of a specific event in time, making it a natural choice in the context of this research and the preferred framework for evaluating the research question at hand. Consider the analysis of Card

and Kruger (1993) [1] as an example of how a difference-in-difference framework may be employed. To illustrate more concretely, consider an analysis of rent control policy on housing supply. Analyzing rent-controlled in comparison to uncontrolled apartments across two periods, before and after the policy was implemented allows one to isolate the effect of the rent-control policy. In the case where the two groups of housing do not have significant differences in amount of supply, one could conclude that the rent-control policy did not influence housing supply. Conversely, if the two groups had significantly different outcomes in supply after the policy was implemented, the difference in the outcomes could be attributed in the policy, granted a sufficient set of control variables.

The primary assumption in a difference-in-difference is the comparison of a counterfactual, meaning that in the absence of a storm, or treatment, units in the treatment group would have followed the same, or parallel, pattern in the outcome variable as the control group. It is imperative to the validity of estimation that the chosen counterfactual holds parallel trends in the outcome variable prior to the occurrence of the treatment event. This analysis will essentially test for parallel trends in home value between the SJMA and the chosen counterfactual, Miami. If the parallel trends do not hold after the occurrence of a storm, this will yield information that storm impacts significantly impact the price of a home in a positive or negative way. Additionally, it is required that the control group was not impacted by the treatment. In context, this means the metropolitan area used as a control must not have been impacted by Hurricanes Irma and Maria. This will formally be tested using the following regression.

---

[1] Two groups, fast-food restaurants in New Jersey (where minimum wage increased) and fast-food restaurants in Pennsylvania (where minimum wage did not change), and two time periods were considered, before the wage increase and after the wage increase. By looking at employment in New Jersey after wage increases in comparison to Pennsylvania where there was no wage increase, the researchers were able to isolate the effect of the wage increase policy on employment New Jersey, challenging theoretical beliefs[1]

$$\log(H_{it}) = \beta_0 + \beta_1 \text{Treatment}_i + \beta_2 \text{Post}_t + \beta_3 (\text{Treatment}_i \times \text{Post}_t) + \beta_4 X + \varepsilon_{it} \quad (1)$$

This regression equation is appropriate and fitting because it aptly links an outcome in a response variable the occurrence of an event at a specific point in. It is anticipated that the sign on both binary indicator variables will be positive. As mentioned, treatment indicates that the household experienced Hurricanes Irma and Maria, and post-disaster indicates that the household exists in a post-storm world, both forces act to constrain the existing stock of houses and any ongoing development projects in an area. These expectations align with theoretical predictions and observed price outcomes in the SJMA.

For this analysis, cross-sectional data from the Puerto Rican Community Survey (PRCS), accessed through IPUMS is utilized. The set of data used includes variables for home value represented by H_{it}, a binary indicator of pre or post September 2017 represented by Post_t, a binary indicator for control or treatment represented by Treatment_i. A term is included for the interaction of the two indicator variables to capture the causal impact of Hurricanes Irma and Maria on home value. Additionally, a set of control variables is incorporated in the model, including household income (HHINCOME), housing unit size measured by room (ROOMS), and employment status (EMPSTAT), represented by the variable X in Equation 1 above for years spanning 2005-2023. Incorporating household income captures the effect of purchasing power and demand-side influences on housing prices. Housing unit size is a relevant control in that it captures the impact of intrinsic property value differences. Incorporating unemployment status reflects the stability of the local economy which is relevant to housing demand and investment. The outcome variable, home value, has been adjusted to reflect 2023 dollars. Further this variable has been logged, which is a standard practice for home price data to assist in addressing skewness that is often present in home price data.

For the purposes of analysis, Hurricanes Irma and Maria are treated as a singular extended event due to the temporal proximity with which the events occurred. Observations in 2017 were coded to zero, meaning they are included in the pre-treatment group. This is because PRCS data is collected monthly, but is only reported on an annual basis, meaning the data utilized in this study largely reflects economic conditions before the hurricanes struck the island. Further, it should be noted that home value is assumed to accurately represents the price at which housing units are sold in the local housing markets. This is assumption is made because the ACS and PRCS do not track sales data. In fact, sales data for the SJMA seems to be collected primarily through private institutions and are not reported publicly by reliable sources.

Table 1

Summary Statistics of Quantitative Variables

Variable	Mean	Median	SD	Min	Max	N
VALUEH	349632.48	200000	538430.3	100	6199000	670107
HHINCOME	98830.75	65000	116660.5	-12300	2368000	670107
ROOMS	5.92	6	2.0	1	16	670107

Miami was chosen as the counterfactual to the SJMA for a variety of reasons. The first of these reasons is that is shares geographic features like coastline which serve to bolster tourism economies in both areas. Further, both Miami and Puerto offer strong tax incentives for individuals and businesses. Under Act 60 there is a 100% exemption from Puerto Rico income taxes on interest and dividend income earned by bona fide residents, similarly in Florida there is no individual income tax. Act 60 also allows businesses that qualify as export services or manufacturing to pay a reduced corporate tax rate of 2–4% and allows for certain businesses to

enjoy 100% municipal tax exemption for their first five years. Florida's corporate income tax rate sits at only 5.5% compared to the 6.5% average across all states, and businesses are not subject to state capital gains tax or inventory tax. Finally, Miami was minimally impacted by Hurricane Irma, allowing me to isolate the effect of the hurricane on the SJMA in analysis.

Table 2

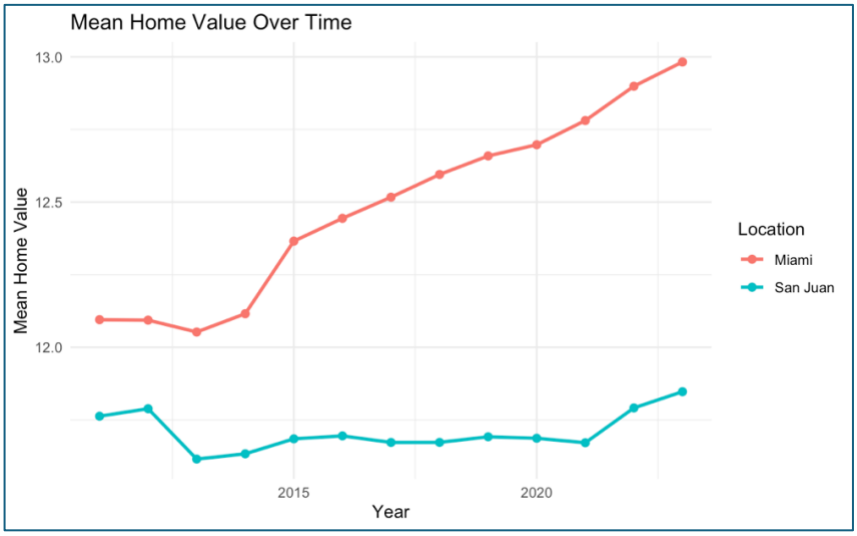
Balance Check of Quantitative Variables

Variable	Miami	San Juan
VALUEH	430628.04	169920.32
HHINCOME	120822.39	50035.91
ROOMS	6.14	5.42
EMPSTAT	0.62	0.46

Finally, for the purpose of the analysis, Miami is considered to satisfy the parallel trends assumption and be an acceptable counterfactual for San Juan by the logic previously mentioned. Statistically this assumption does not hold, however this will not be accounted for in the analysis.

Table 3

Visual Check of Parallel Trends Check



IV. Results:

In order to test the research hypothesis, the previously specified difference-in-difference model is coded as an ordinary least squares regression with binary indicators for control or treatment groups and pre or post-treatment. Household weights provided by IPUMS are applied to ensure representative estimates of household level characteristics for the population. This is particularly important because the SJMA is being compared to a sample from the mainland United States. Using weights ensures comparability. The model was run both with and without fixed effects for the year variable. Incorporating, fixed effects for years allows for the model to control for shocks or trends, like economics conditions or policy changes, in a given year that impact all units in the sample regardless of treatment. It should be noted that the regression which incorporates fixed effects for years requires that the binary post and treatment variables themselves are omitted due to the fact that post variable holds perfect multicollinearity with the year fixed effects.

Table 4

Difference-in-Difference without Year Fixed Effects Regression Results

Coefficients	Estimate	Standard Error	T-value	Significance Score
Intercept	11.470	0.00391	2934.07	<0.00001
Treatment	-0.2785	0.00316	-88.11	<0.00001
Post	0.3009	0.00247	121.86	<0.00001
Post x Treatment	-0.4244	0.00465	-91.36	<0.00001
HHINCOME	0.00000259	0.00000001	252.07	<0.00001

**The lm() function silently drops ROOMS and EMPSTAT likely for multicollinearity or lack of variation reasons*

Table 5

Difference-in-Difference with Year Fixed Effects Regression Results

Coefficients	Estimate	Standard Error	T-value	Significance Score
Post x Treatment	-0.68946800	0.031227688	-22.078740	0.028814
HHINCOME	0.00000267	0.000000468	5.696365	0.110632
ROOMS	0.12487834	0.012479289	10.006848	0.063408
EMPSTAT	0.03803003	0.041617011	0.913810	0.528651

In both iterations of the model the output indicates that the interaction term is, in fact, significant in explaining variations in housing price. In the model not containing fixed effects The interaction term between treatment and post-period in the model not containing fixed effects (-0.4244) implies that homes in the SJMA, depreciated by 34.55% ($e^{-0.4244}$) more than those in Miami, after accounting for underlying time trends and baseline differences between household income, property size, and employment status. This effect is economically meaningful, indicated that Hurricanes Irma and Maria had causal effects on home price in the SJMA. The interaction term between treatment and post-period in the model containing fixed effects (-0.689468) implies that homes in the SJMA, depreciated by 49.81% ($e^{-0.689468}$) more than those in Miami, after accounting for underlying time trends, baseline differences between household income, property size, and employment status, and yearly shocks that impacted all units regardless of treatment. In both forms of the model, the effect is economically meaningful, indicating that Hurricanes Irma and Maria had causal effects on home price in the SJMA.

This conclusion does not align with expectations and theoretical predictions and substantiates empirical findings that prescribe ideas about the behavior of home prices in the short run following a natural disaster like a hurricane.

V. Conclusion:

This study sought to disentangle the causal impact of Hurricanes Irma and Maria on housing prices in Puerto Rico's San Juan Metropolitan Area (SJMA). The classical theories of supply and demand suggest that in the face of supply-side constraints prices should increase. Natural disasters are empirically shown to have the opposite effect, however, on the price of homes as consumers of housing adjust expectations around the likelihood of a similar event in the future impacting their housing condition. Puerto Rico has been an exception to this pattern however, seeing large increases in home values in the seven years following Hurricanes Irma and Maria. For that reason, this work sought to investigate the causal impact of the storms on housing prices in the San Juan Metropolitan Area. Based on produced results, it is shown that Hurricanes Irma and Maria caused a decrease between 34.55% and 49.81% in home prices on average when compared to the control group of Miami, Florida. This finding suggests that there are other idiosyncratic features of the local economy in the San Juan Metropolitan Area that are strong enough to outpace the depreciation in home price that is induced by storm impacts in the area, creating a potential avenue for future research.

However, there are multiple limitations that my research faces that impact the robustness of my conclusions, presenting opportunity for further development of my work. The first, and most significant of these limitations is that Miami did not satisfy the parallel trends assumption. This is significant in that failure to meet this assumption leads to spurious conclusions. Finding a suitable control group for an area that is as geographically and economically unique as the

capitol area of Puerto Rico proved difficult. In the future this work may be bolstered by implementing synthetic control methods to generate a suitable counterfactual for the SJMA. Additionally, the data utilized occur over a series from 2011-2023. Although the American and Puerto Rican Community Surveys provide index factors to adjust for price changes over time these indexes are not localized to the areas of interest. This posed challenging as there was no publicly accessible consumer price index unique to the metropolitan areas of Miami or San Juan. If local price indexes were accessible, they may be used to strengthen the accuracy of findings.

References

Bin, Okmyung, and Craig E. Landry. “Changes in implicit flood risk premiums: Empirical evidence from the housing market.” *Journal of Environmental Economics and Management*, vol. 65, no. 3, May 2013, pp. 361–376.

Boustan, Leah Platt, et al. *The Effect of Natural Disasters on Economic Activity in US Counties: A Century of Data*. *Journal of Urban Economics*, vol. 118, 2020, p. 103257. Elsevier.

Cohen, Jeffrey P., et al. *Storm Surges, Informational Shocks, and the Price of Urban Real Estate: An Application to the Case of Hurricane Sandy*. *Regional Science and Urban Economics*, vol. 90, 2021, p. 103694. Elsevier.

Ellen, Ingrid Gould, and Rachel Meltzer. “Heterogeneity in the recovery of local real estate markets after extreme events: The case of hurricane sandy.” *Real Estate Economics*, vol. 52, no. 3, 24 Mar. 2024, pp. 714–752.

Hallstrom, Daniel G., and V. Kerry Smith. “Market responses to Hurricanes.” *Journal of Environmental Economics and Management*, vol. 50, no. 3, Nov. 2005, pp. 541–561.

Hennighausen, Hannah and Jordan F. Suter. "Flood Risk Perception in the Housing Market and the Impact of a Major Flood Event." *Land Economics*, vol. 96 no. 3, 2020, p. 366-383. *Project MUSE*.

National Oceanic and Atmospheric Administration. *What Is a Hurricane?* NOAA Ocean Service, n.d. Accessed 16 Mar. 2025.

Petkov, Ivan. *Weather Shocks, Population, and Housing Prices: The Role of Expectation Revisions*. *Economics of Disasters and Climate Change*, vol. 6, 2022, pp. 495–540. Springer.

Santiago-Bartolomei, Raúl, et al. *Tracking Neighborhood Change in Geographies of Opportunity for Post-Disaster Legacy Cities: A Case Study of San Juan, Puerto Rico*. Lincoln Institute of Land Policy, Working Paper WP22RS1, Jan. 2022.

U.S. Department of Housing and Urban Development, Office of Policy Development and Research. *Comprehensive Housing Market Analysis: Puerto Rico*. 1 July 2019.

Yi, Donggyu, and Hyundo Choi. “Housing market response to new flood risk information and the impact on poor tenant.” *The Journal of Real Estate Finance and Economics*, vol. 61, no. 1, 4 June 2019, pp. 55–79.