Vulnerability of Renters and Low-Income Households to Storm Damage:

Evidence from Hurricane Maria in Puerto Rico

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Hurricane Maria, one of the most devastating hurricanes in Puerto Rican history, made landfall in September of 2017 with sustained winds of 160mph and extensive flooding resulting in close to 3000 fatalities (1, 2). According to the Centers for Disease Control and Prevention (2017), deaths and injuries in such natural disasters are often attributable to housing damage, especially by collapsed housing structure and flying debris. In the case of Puerto Rico, Hurricane Maria damaged more than 300,000 homes, almost a third of the total housing stock (3).

In this context, the present study seeks to identify the characteristics of those surviving households most affected by this damage. Existing literature suggests that housing damage from natural disasters is more prevalent in areas with higher proportions of renter households and/or low-income households. But studies to date have for the most part addressed these questions at the community level [including studies at the census tract level (4), zip code level (5), neighborhood level (6, 7) and planning district level (7)]. In addition, previous studies have for the most part looked only at overall damage prevalence, and not degrees of damage severity. For example, Chakraborty (8) focused on the areal extent of Hurricane Harvey-induced flooding across Census tracts in Houston, Texas. But for the case of Hurricane Maria, data collected by the Federal Emergency Management Agency (FEMA) in Puerto Rico (3, 9) has made it possible to identify both housing characteristics and levels of damage severity suffered by individual households.

Using this data, our primary objectives are three-fold. First, we seek to determine the vulnerability of individual renter households versus homeowners with respect to damage severity. Second, we analyze the vulnerability of lower- versus higher-income households with respect to damage severity. Finally, we look for possible relations between these two sets of results. More specifically, given the finding by U.S. Department of Housing and Development (3) that the incomes of renter households in Puerto Rico tend to be lower than for homeowners, together with the historical persistence of income inequalities in Puerto Rico (10), we seek to determine whether such income inequalities have contributed to a higher vulnerability of renter households with respect to damage severity.

METHODS

Study population and data collection

This study is based on the *Individual Assistance Housing Registrants* file for major disasters published by FEMA (8), which includes both housing and household characteristics for 740,000 individual homes inspected by FEMA. Of these homes, the 306,126 units found to be directly damaged by Hurricane Maria constitute our basic study population.

Specification and Measurement of Variables

Outcome variable. Our primary outcome variable for this study is *severity of home damage*. This ordinal variable is defined by FEMA (3, 11) to consist of three levels of damage severity: "Minor damage" (designated as "Moderate damage" in certain FEMA documents), "Major damage", and "Destroyed". More specifically, *minor damage* involves a real property FEMA verified Loss of less than $17,000; *major damage* involves a real property FEMA verified Loss of at least $17,000; and *destroyed* involves damage that is "not economically feasible to repair". (Damage maps based on this data are provided in Figure 1 & supplementary Figure C.)

Covariates. Our selection of relevant covariates includes both housing attributes and household attributes. The housing attribute of most interest for our purposes is *Residential Type*, designated by FEMA as a nominal variable with six categories: "Apartment", "House/Duplex" (here referred to as "House"), "Townhouse", "Condo", "Mobile Home", "Trailer", or "Boat". Our interest in this variable is motivated by existing literature relating residential types to household characteristics (12, 13, 14). In particular, renters and households with comparatively lower income (hereafter lower-income households) tend to live in certain housing types – most notably in apartments (12) as confirmed for our data in Supplementary Table C. Our second housing attribute relates to the type of damage (rather than severity of damage) inflicted by Hurricane Maria, and is of interest for our purposes because of its possible relation to damage severity. This nominal *Damage Type* variable is classified to be either "Flood Damage" or "Wind Damage". Here it should be noted that FEMA only asked residents whether or not the damage was caused by flooding. But since wind damage together with flood damage were by far the most common types of damage from Hurricane Maria (15, 16), we have chosen to employ this dichotomous interpretation.

Turning next to household attributes, our two most important attributes (as mentioned in the introduction) are household income and housing tenure. *Household Income* is a continuous variable indicating the annual income level prior to the disaster, as reported by household. *Housing Tenure* is also a dichotomous variable with values "1" = *renter* and "0" = *homeowner*. In addition to these primary attributes, we include a dichotomous variable, *Large-Size Household*, with value "1" if the reported size of the household is greater than 3 (rounded from the average size, 2.98, based on census data for Puerto Rico in 2000). Our primary interest in household size is its well-known positive relation to household income [as for example in the household size-income tabulations for Puerto Rico (18)].

Statistical Analyses

We first use two-way cross tabulations (with Pearson chi-square tests) and one-way ANOVA (with F-Statistic) to compare relevant household characteristics to the severity of their home damage, as presented in Table 1. These results are further articulated in Table 2 and Supplementary Table A and Table 2, where *generalized ordered logistic regressions* are employed to estimate the risk of relative damage levels incurred by these household groups. A typical model is illustrated below, where Y_i denotes an *ordinal* damage variable for household, $i = 1,..,n$, with outcomes, $j = 1,2,3$ = ("minor", "major", "destroyed"), and where variables $(x_{1i}, x_{2i},..,x_{ki})$ represent the relevant characteristics of household, i .

$$(1) \qquad P(Y_i > j) = \frac{\exp(a_j + x_{1i} b_{1j} + x_{2i} b_{2j} + \cdots + x_{ki} b_{kj})}{1 + \exp(a_j + x_{1i} b_{1j} + x_{2i} b_{2j} + \cdots + x_{ki} b_{kj})} \ , \ i = 1,..,n, \ j = 1,2$$

In particular, $P(Y_i > 1)$ denotes the probability of a *major-or-destroyed* outcome, and $P(Y_i > 2)$ denotes the probability of a *destroyed* outcome. (These observed outcomes are mapped in Figure 1 and supplementary Figure C.)

Within this general modeling framework, we consider both *simple* regressions allowing the effects of each covariate to be analyzed separately (as in supplementary Table A) and *multiple* regressions including all covariates (as in Table 2). Here we first test the *main* effects of both housing tenure and income, and then allow for a possible *interaction* effect between them. All analyses were carried out using the STATA 15 software package, where in particular, the *gologit2* model was employed for all regressions.

Finally, the only noteworthy missing data in our sample is with respect to reported income levels of households, where 12% of values are missing. Here we adopted the list-wise deletion method, which reduced our study sample from 306,126 to 267,989 for the regression analyses in Table 2 and Supplementary Table A. But to check for possible bias, multiple-imputation procedures using the full sample were also applied to these regressions (as discussed at the end of the next section).

RESULTS

Among the 306,126 homes in Puerto Rico that were damaged by Hurricane Maria, we see from Table 1 that more than 13,000 suffered major-or-destroyed damage. Among these homes, our major finding is that renters suffered substantially more damage than homeowners. Even though renters constituted less than 8% of the primary residents experiencing structural damage, nearly two thirds (66%) of the 8,802 homes suffering major damage were renter occupied. Moreover, the percent of renter-occupied homes destroyed was four times that of owner-occupied homes (4.8% versus 1.2%). These figures are almost as dramatic for mean incomes of households across damage levels. In particular, the mean income of households suffering destroyed outcomes ($14,013) is less than half that for minor damage outcomes ($30,933).

Our logistic regression results in Table 2 together with supplementary Table A add further detail to these findings. First, the ordered logistic regressions in supplementary Table A help to clarify the relative risks of both major-or-destroyed outcomes and destroyed outcomes among these household groups. With respect to renters versus homeowners, there is a significantly greater risk of major-or-destroyed outcomes for renters [Odds ratio (OR) = 17.53, 95% Confidence Interval (CI): 16.85, 18.23] and to a somewhat lesser extent, a greater risk of destroyed outcomes for renters (OR = 4.10, 95% CI: 3.82, 4.41). The results for household income also show that lower-income households are at significantly greater risk of damage. In particular, lower-income households are at greater risk of destroyed damage [*b* (beta coefficient) = -1.64e-06, 95% CI: -2.29e-06, -9.86e-07] compared to major-or-destroyed damage (*b* = -9.44e-07, 95% CI: -1.28e-06, -6.07e-07). Additional results in supplementary Table A are compared with those of Table 2 below.

Our main results in Table 2 involve simultaneous analyses of both housing tenure and income effects, while controlling for the additional effects of residential type, family size, and damage type. Turning first to the *Main Effects* (ME) model in Table 2, we see that renters continue to be at significantly greater risk of damage than homeowners. More specifically, even when the effects of income levels are controlled for (along with all other effects), renters continue to be at

greater risk than homeowners both with respect to major-or-destroyed outcomes (OR = 19.76, 95% CI: 18.95, 20.61) and destroyed outcomes (OR = 5.00, 95% CI: 4.64, 5.39). Similarly, the qualitative results in supplementary Table A with respect to household income continue to hold when the effects of housing tenure (and other variables) are controlled for, i.e., lower-income households continue to be at greater risk both with respect to major-or-destroyed outcomes (b = -3.61e-07, 95% CI: -5.64e-07, -1.57e-07) and destroyed outcomes (b = -1.33e-06, 95% CI: -2.03e-06, -6.24e-07). Turning to other control variables, it is of interest to observe that for residential housing types there is a dramatic reversal in sign for relative damage risks of apartments versus houses. In particular houses are now at significantly greater damage risk than apartments, both with respect to major-or-destroyed outcomes (OR = 1.62, 95% CI: 1.50, 1.76) and destroyed outcomes (OR = 1.61, 95% CI: 1.38, 1.88). Here the key difference from supplementary Table A is that the effects of housing tenure are now being controlled for. As shown in supplementary Tables B and D renters are far more likely to occupy apartments than are homeowners, so that much of the damage risk for apartments is now being captured by their renter occupants. Similar results can be seen for both damage type and family size. With respect to damage type for example, the simple regressions in supplementary Table A show that the risk of major-or-destroyed outcomes is higher for flood damage than wind damage (OR = 1.12, 95% CI: 1.04, 1.20). But when the effects of housing tenure are controlled for, as in Table 2, it is seen that such risks are reversed (OR = 0.71, 95% CI: 0.66, 0.76). This is again partly explained by the result in supplementary Table D which shows that renters are far more likely to suffer flood damage than wind damage (OR = 2.19, 95% CI: 2.09, 2.29). Thus, much of the risk of major-or-destroyed outcomes associated flood damage is again being captured by those renters suffering flood damage.

In our final *Interaction Effects* (IE) model, we include an interaction term to analyze the possible influence of household incomes on relative damage risks between renters and homeowners. Here we find that for both major-or-destroyed and destroyed outcomes the differences in risks between renters and homeowners are substantially greater for lower-income households (b = -6.47e-06, 95% CI: -0.000012, -8.97e-07). Here it should also be noted that a likelihood ratio test between the nested models, ME and IE, shows that the presence of this interaction terms does indeed yield a significantly better fit [chi2(2) = 9.57, $p < 0.01$].

These relations can also be seen graphically in terms of marginal-risk analysis with respect to the IE model. In particular, the marginal risks of destroyed outcomes for both renters and owners at selected income percentile levels are shown in Figure 2 (where for example the marginal risk for renters at the 95th percentile income, say x_{95}, is just above 0.04, and obtained as the mean predicted risk over all individual sample profiles evaluated at tenure = "renter" and income = x_{95}). In a manner similar to the interaction results in Table 2, the differences in income effects between renters and owners are quite dramatic. In particular, as seen from the confidence intervals in this figure, these differences are substantially greater at low income levels. The average marginal risks for renters and owners are also reported in supplementary Table H. Here it is seen that while renters are on average *less* likely to suffer minor-damage outcomes than homeowners, they are six times *more* likely to suffer destroyed outcomes.

Finally, it must be emphasized that while the results in Table 2 and supplementary Table A are based on the list-wise deleted subsample of those 267,989 households reporting income, all these results continue to hold (in a qualitative sense) for multiple-imputation analyses of the full sample of 306,126 households. These full-sample results, based on m = 20 imputations of income, are reported

in supplementary Table E. The similarity between these findings is further supported by the missing-data analysis in Table 1, which shows that while our large sample sizes yield statistically significant differences between damage levels for missing and non-missing income subpopulations, the percentage profiles of damage levels for these subpopulations are actually quite similar (as shown in supplementary Figure A). Qualitative similarities between the housing-tenure profiles of these subpopulations can also be seen in supplementary Figure B.

DISCUSSION

Our findings at the individual household level are consistent with the community-level findings of others with respect to greater damage risk of both renters versus homeowners and lower- versus higher-income households. Our results not only add further detail in terms of individual household comparisons, but also in terms the relative degree of damage severity. For example, Logan (7) found that neighborhoods in New Orleans with higher percentages of renters tended to suffer higher frequencies of home damage from Hurricane Katrina. Similarly, Kamel (5) found that zip code areas in New Orleans with higher percentages of low-income households also suffered greater housing damage (in dollar terms). In addition. Chakraborty (8) found at the census tract level that the aerial extent of Harvey-induced flooding was associated with socioeconomically deprived residents. But whether income or housing tenure are related to more severe damage at the individual household level cannot be determined by such aggregate analyses.

It should be noted however that there do exist previous studies at the individual level that have analyzed relations between hurricane damage and household characteristics. With respect to the effects of housing damage on individuals, several studies have focused on the mental-health impacts of such damage (21, 22). Closer to the present paper are studies of individual household characteristics associated with degrees of housing damage (23, 24). But these studies have for the most part focused on racial differences rather than renters versus homeowners, and have employed income only as a control variable in studying such differences.

Finally, we turn to the key finding of our Interaction Effects model that the relative risk of destroyed outcomes between renters and homeowners is significantly influenced by household income levels. The main reason for this appears to be the interrelation between housing tenure, household income and vulnerability to wind damage. First, the more detailed regression of income quantiles on housing tenure in supplementary Table G shows that there is a general downward shift in the distribution of renter incomes relative to homeowner incomes (with respect to those incomes reported by households). Second, as reported for example by Eaton (25), there is also a general tendency for low-income housing to be more vulnerable to hurricane-force wind damage. Third, our FEMA data shows that almost 99% of all homes destroyed were attributable to wind damage rather than flood damage (Table 1). Taken together, these findings suggest that low-income renters were particularly vulnerable to destroyed outcomes. This is further supported by the fact that while renters generally suffered relatively more flood damage than homeowners (supplementary Table D), this situation is reversed for destroyed outcomes, where renters were four times more likely to suffer wind damage than were homeowners (5.50% versus 1.28%, as shown in supplementary Table F).

It should also be noted that our present study is not without limitations. Perhaps most important for our present purposes is the dollar-based threshold between “major damage” and “minor damage” used by FEMA to define their measure of damage severity. This $17,000 threshold necessarily involves a different level of relative damage severity for say a $30,000

home versus a $300,000 home. Thus, when attempting to relate damage severity to household incomes, it is desirable to employ measures of damage more directly related to home value. Finally, the decision of what constitutes "not economically feasible to repair" may involve more subtle types of observer bias related to perceived financial resources of households and their ability to repair-- which might inflate the percent of low-income households with destroyed outcomes.

In addition, it should be noted that certain groups of hurricane victims may in fact be under-represented in the present set of FEMA IA registered households. Of particular concern are low-income renters not meeting the requirement of FEMA's housing assistance program that applicants have "stable housing" accommodations prior to disasters (26) [In this regard, it has been estimated that as much as 50% of all housing construction prior to Maria was substandard and in violation of existing codes (27)]. More generally, low-income households tend to be less comfortable in "negotiating with disaster recovery bureaucracies" (28), and may often encounter more obstacles (lack of transportation or child care) in doing so (29). Thus there are reasons to speculate that lower-income renters suffering destroyed outcomes from Hurricane Maria may be under-represented in our study.

But in spite of such limitations, this study represents (to our knowledge) the first effort to identify the characteristics of individual households suffering most from Hurricane Maria. These findings not only provide more detailed confirmations of the more aggregate results mentioned above, but are also consistent in spirit with a number of policy efforts currently underway to provide safer storm-resistant housing for low-income households in Puerto Rico [including expansions of both local land-grant programs (27) and the Low-Income Housing Tax Credit program for Puerto Rico (30)]. So we believe that our findings may serve to provide additional substantive support for these efforts.

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Table 1. Two-Way Analyses of Home Characteristics and Prevalence of Home Damage at Different Severities

Variables		Damage Level				Statistical Tests
		Minor	Major	Destroyed	Total	
		292,754 95.63%	8,802 2.88%	4,572 1.49%	306,126 100%	
Residential Type	Apartment	7,561 87.26%	915 10.56%	189 2.18%	8,665 100%	Chi2(12) 2.6e+03***
	House/Duplex	274,369 95.82%	7,714 2.69%	4,241 1.48%	286,324 100%	
	Townhouse	6,754 97.40%	126 1.82%	54 0.78%	6,934 100%	
	Condo	3,488 99.2%	24 0.68%	4 0.11%	3,516 100%	
	Mobile Home	333 85.38%	12 3.08%	45 11.54%	390 100%	
	Trailer	221 84.67% 0.08%	6 2.30% 0.07%	34 13.03% 0.74%	261 100% 0.09%	
	Boat	26 72.22% 0.01%	5 13.89% 0.06%	5 13.89% 0.11%	36 100% 0.01%	
	Subtotal	292,752 95.63%	8,802 2.88%	4,572 1.49%	306,126 100%	
Household Size larger than average	No	175,938 95.68%	4,924 2.68%	3,020 1.64%	183,882 100.00%	Chi2(2) 130.89***
	Yes	116,814 95.56%	3,878 3.17%	1,552 1.27%	122,244 100.00%	
	Subtotal	292,754 95.63%	8,802 2.88%	4,572 1.49%	306,126 100%	
Damage Source	Flood Damage	20,950 95.21%	1,005 4.57%	50 0.23%	22,005 100%	Chi2(2) 491.03***
	Wind Damage	271,802 95.66%	7,797 2.74%	4,522 1.59%	284,121 100%	
	Subtotal	292,754 92.84%	8,802 88.58%	4,572 98.91%	306,126 92.81%	
Housing Tenure	Renter-occupied	17,187 71.14%	5,808 24.04%	1,166 4.83%	24,161 100%	Chi2(2) 4.4e+04***
	Owner-occupied	275,565 97.73%	2,994 1.06%	3,406 1.21%	281,965 100%	
	Subtotal	292,752 95.63%	8,802 2.88%	4,572 1.49%	306,126 100%	
Income (US Dollars)	Mean	30,933.18	20,537	14,013.15	30,370.92	F (2, 267988) 11.36***
	SE	586.66	1,568.69	2,532.58	563.80	
	Count	256,075	7,808	4,108	267,991	
Missing Income Data	No	256,073 95.55%	7,808 2.91%	4,108 1.53%	267,989 100%	Chi2(2) 34.67***
	Yes	36,679 96.18%	994 2.61%	464 1.22%	38,137 100%	
	Subtotal	292,752 95.63%	8,802 2.88%	4,572 1.49%	306,126 100%	

Abbreviation: SE = Standard error
*** p<0.01, ** p<0.05, * p<0.1.
Chi2(k) = Chi-square with k degrees of freedom.

F(k1, k2) = F Statistic with k1 (between groups) and k2 (within groups) degrees of freedom.
First row has *frequencies*; second row has *row percentages*.

Table 2. Estimating Home Damage Severities by Home Characteristics using Generalized Ordered Logistic Regressions (N=267,989)

Variables	Main Effect Model				Interaction Effect Model			
	Major Damage or Destroyed compared with Minor Damage		Destroyed compared with Minor or Major Damage		Major Damage or Destroyed compared with Minor Damage		Destroyed compared with Minor or Major Damage	
	b	OR	*b*	OR	*b*	OR/ROR	*b*	OR/ROR
Residential type								
Apartment^								
House	0.48*** (0.41, 0.56)	1.62*** (1.50, 1.76)	0.48*** (0.32, 0.63)	1.61*** (1.38, 1.88)	0.48*** (0.41, 0.56)	1.62*** (1.50, 1.76)	0.47*** (0.31, 0.62)	1.60*** (1.37, 1.87)
Townhouse	-0.04 (-0.22, 0.15)	0.96 (0.80, 1.16)	-0.09 (-0.40, 0.22)	0.92 (0.67, 1.25)	-0.04 (-0.22, 0.15)	0.96 (0.80, 1.16)	-0.09 (-0.40, 0.22)	0.92 (0.67, 1.25)
Condo	-1.38*** (-1.78, -0.97)	0.25*** (0.17, 0.38)	-1.65*** (-2.58, -0.72)	0.19*** (0.08, 0.48)	-1.38*** (-1.78, -0.97)	0.25*** (0.17, 0.38)	-1.65*** (-2.57, -0.72)	0.19*** (0.08, 0.48)
Mobile Home	2.05*** (1.72, 2.39)	7.81*** (5.60, 10.89)	2.47*** (2.10, 2.85)	11.85*** (8.16, 17.22)	2.05*** (1.72, 2.39)	7.80*** (5.60, 10.89)	2.46*** (2.09, 2.84)	11.75*** (8.09, 17.07)
Travel Trailer	1.57*** (1.12, 2.03)	4.83*** (3.07, 7.58)	2.29*** (1.81, 2.77)	9.86*** (6.10, 15.94)	1.57*** (1.12, 2.03)	4.83*** (3.07, 7.58)	2.28*** (1.80, 2.76)	9.74*** (6.03, 15.72)
Boat	3.28*** (2.45, 4.10)	26.46*** (11.59, 60.39)	2.92*** (1.85, 3.99)	18.57*** (6.36, 54.20)	3.28*** (2.45, 4.10)	26.46*** (11.59, 60.39)	2.92*** (1.84, 3.99)	18.45*** (6.32, 53.85)
Larger Household								
No^	-0.12*** (-0.16, -0.08)	0.89*** (0.85, 0.93)	-0.33*** (-0.39, -0.27)	0.72*** (0.68, 0.77)	-0.12*** (-0.16, -0.08)	0.89*** (0.85, 0.93)	-0.33*** (-0.39, -0.27)	0.72*** (0.68, 0.77)
Yes								
Damage source								
Wind ^	-0.35*** (-0.42, -0.27)	0.71*** (0.66, 0.76)	-1.97*** (-2.27, -1.68)	0.14*** (0.10, 0.19)	-0.35*** (-0.42, -0.27)	0.71*** (0.66, 0.76)	-1.97*** (-2.26, -1.67)	0.14*** (0.10, 0.19)
Flood								
Tenure								
Owner^	2.98*** (2.94, 3.03)	19.76*** (18.95, 20.61)	1.61*** (1.53, 1.68)	5.00*** (4.64, 5.39)	2.98*** (2.94, 3.02)	19.68*** (18.85, 20.54)	1.68*** (1.58, 1.77)	5.35*** (4.87, 5.87)
Renter								
Income	-3.61e-07*** (-5.64e-07, -1.57e-07)	0.9999996*** (0.9999994, 0.9999998)	-1.33e-06*** (-2.03e-06, -6.24e-07)	0.9999987*** (0.999998, 0.9999994)	-4.46e-07*** (-7.28e-07, -1.64e-07)	0.9999996*** (0.9999993, 0.9999998)	-1.17e-06 *** (-1.84e-06, -5.09e-07)	0.9999988*** (0.9999982, 0.9999995)
Interaction Tenure # income					2.34e-07 (-1.88e-07, 6.56e-07)	1.00 (0.9999998 1.000001)	-6.47e-06** (-0.000012, -8.97e-07)	0.9999935** (0.999988, 0.9999991)

Abbreviations: *b* = beta coefficient; OR = odds ratio; ROR = Ratio of odds ratios for the interaction term.
95% Confidence Intervals in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
^denotes a reference category.

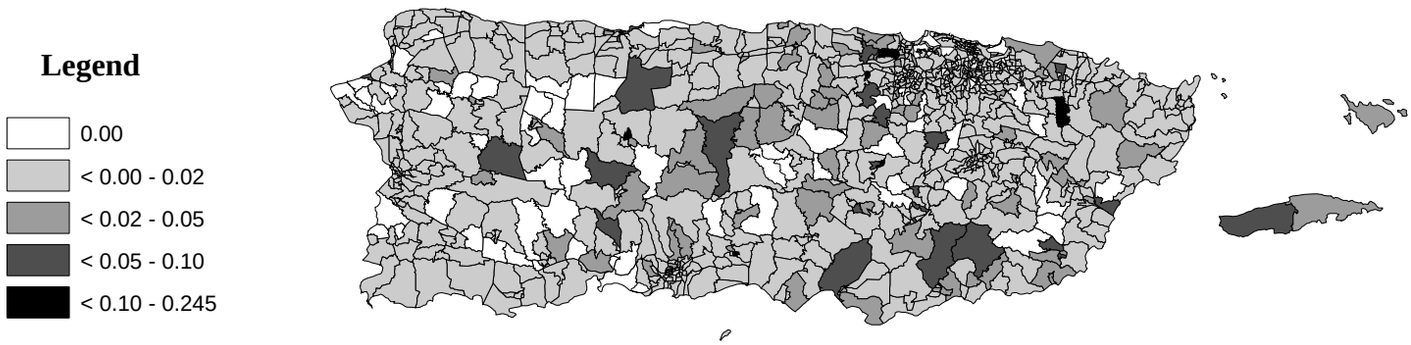

Figure 1.[i] Fraction of Occupied Dwellings in Each Census Tract with "Major-or-Destroyed" Outcomes

[I] Prevalence of "Major-or- Destroyed" outcomes for Figure 1

Five prevalence categories	Freq.	Percent
0.00	105	11.78
< 0.00 - 0.02	657	73.74
< 0.02 - 0.05	95	10.66
< 0.05 - 0.10	26	2.92
< 0.10 - 0.245	8	0.90

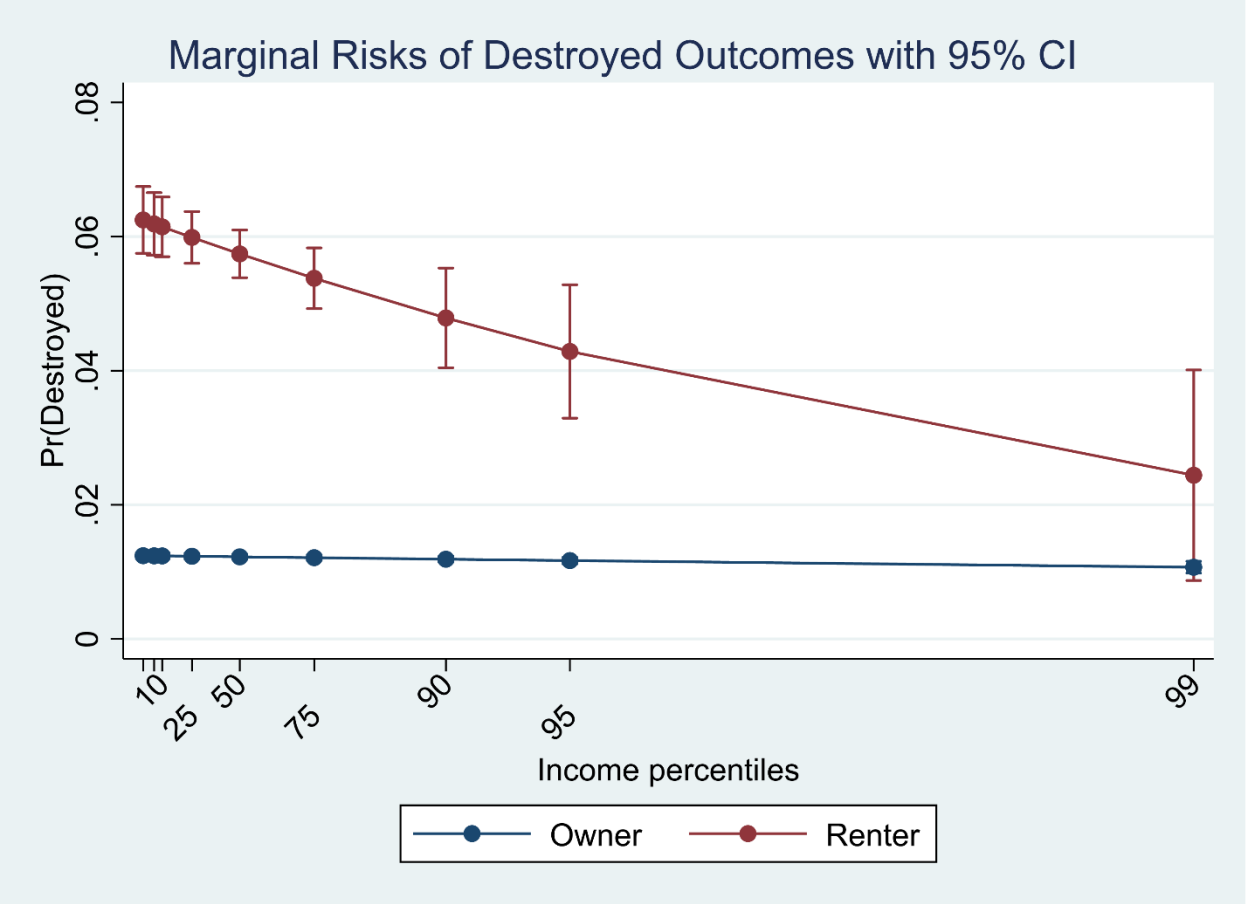

Figure 2. Marginal Risks of Destroyed Outcomes for Renters and Owners with 95% Confidence Intervals (CI)

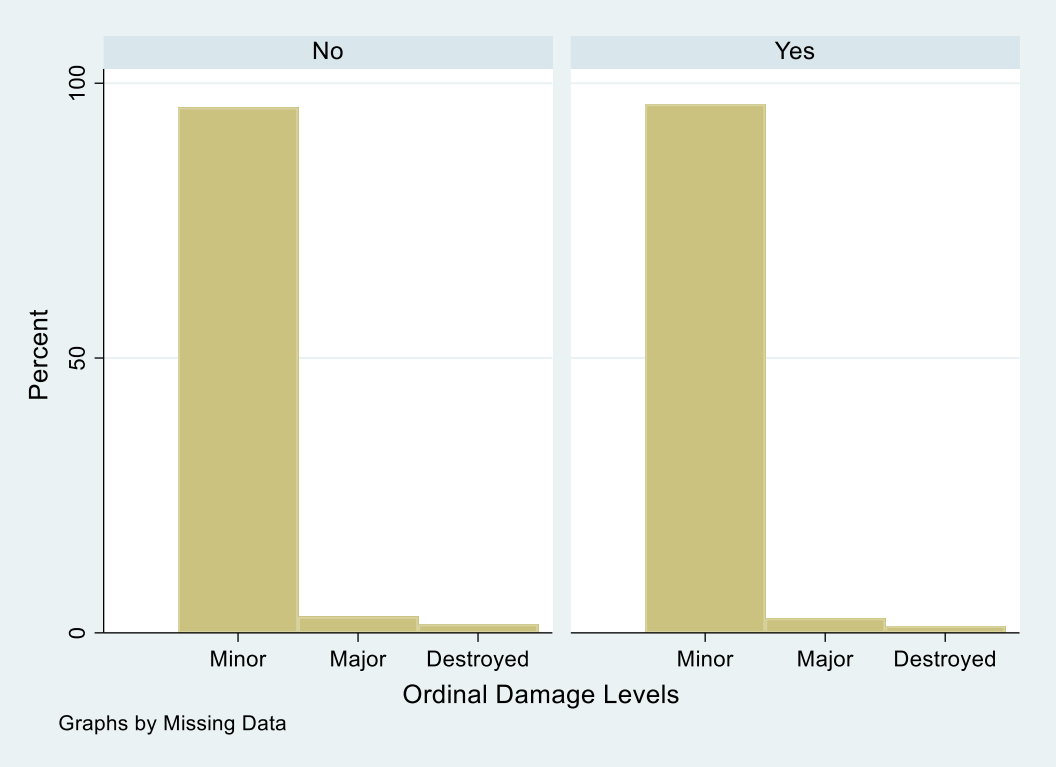

Figure A. Damage-Levels Percentages for Missing and Non-Missing Income Households

Figure B. Owner and Renter Percentages for Missing and Non-Missing Income Households

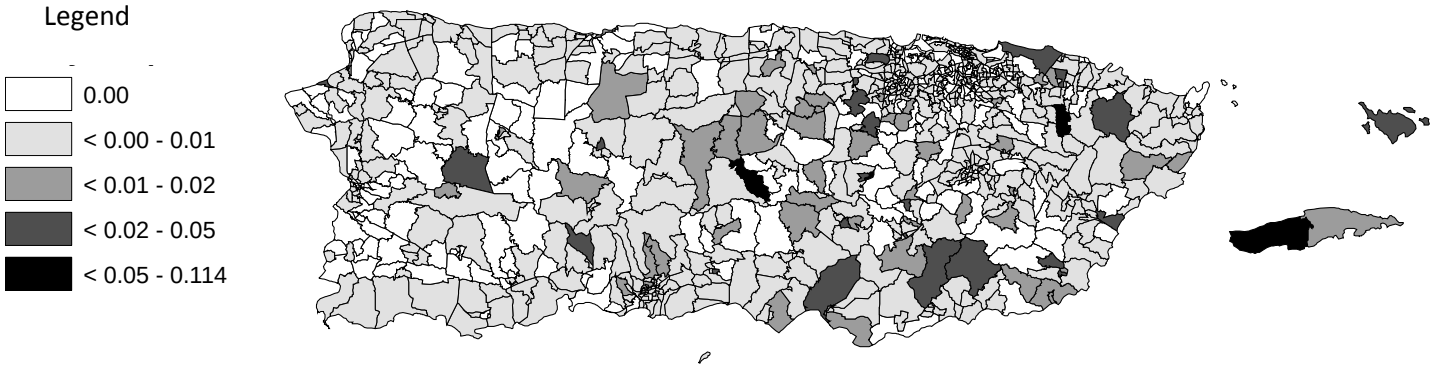

Figure C. Fraction of Occupied Dwellings in Each Census Tract with "Destroyed" Outcomes

Table A. Estimating Severities of Home Damage by Univariate Generalized Ordered Logistic Regressions (N=267,989)

	Major Damage or Destroyed compared with Minor Damage		Destroyed compared with Minor or Major Damage	
Variables	*b*	OR	*b*	OR
Residential type				
Apartment ^				
House	-1.22***	0.30***	-0.40***	0.67***
	(-1.29, -1.15)	(0.28, 0.32)	(-0.55, -0.24)	(0.57, 0.79)
Townhouse	-1.67***	0.19***	-1.02***	0.36***
	(-1.84, -1.49)	(0.16, 0.22)	(-1.35, -0.69)	(0.26, 0.50)
Condo	-2.76***	0.06***	-2.76***	0.06***
	(-3.16, -2.36)	(0.04, 0.09)	(-3.16, -2.36)	(0.04, 0.09)
Mobile Home	0.16	1.18	1.73***	5.65***
	(-0.14, 0.47)	(0.87, 1.60)	(1.36, 2.10)	(3.91, 8.16)
Travel Trailer	0.11	1.12	1.73***	5.66***
	(-0.28, 0.50)	(0.75, 1.65)	(1.28, 2.19)	(3.60, 8.90)
Boat	0.98**	2.67**	1.98***	7.27***
	(0.16, 1.80)	(1.17, 6.07)	(0.91, 3.05)	(2.49, 21.19)
Large Household				
No^				
Yes	0.07***	1.07***	-0.22***	0.80***
	(0.03, 0.11)	(1.03, 1.11)	(-0.29, -0.16)	(0.75, 0.85)
Damage source				
Wind ^				
Flood	0.11***	1.12***	-1.97***	0.14***
	(0.04, 0.18)	(1.04, 1.20)	(-2.27, -1.68)	(0.10, 0.19)
Tenure				
Owner^				
Renter	2.86***	17.53***	1.41***	4.10***
	(2.82, 2.90)	(16.85, 18.23)	(1.34, 1.48)	(3.82, 4.41)
Income				
	-9.44e-07***	0.9999991***	-1.64e-06***	0.9999984***
	(-1.28e-06,	(0.9999987,	(-2.29e-06,	(0.9999977,
	6.07e-07)	0.9999994)	-9.86e-07)	0.999999)

Abbreviations: *b* = beta coefficient; OR = odds ratio.
95% Confidence Intervals in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
^denotes a reference category.

Table B. Cross-tabulation of Residential type and Housing Tenure

Residential Type	Housing Tenure			Pearson
	Owner	Renter	Total	Chi2(6)
Apartment	3,913	4,752	8,665	2.7e+04***
	45.16%	54.84%	100%	
House	267,737	18,587	286,324	
	93.51%	6.49%	100%	
Townhouse	6,466	468	6,934	
	93.25%	6.75%	100%	
Condo	3,227	289	3,516	
	91.78%	8.22%	100%	
Mobile Home	360	30	390	
	92.31%	7.69%	100%	
Travel Trailer	226	35	261	
	86.59%	13.41%	100%	
Boat	36	0	36	
	100%	0%	100%	
Subtotal	281,965	24,161	306,126	
	92.11%	7.89	100%	

First row has *frequencies* and second row has *row percentages*.
Chi2(k) = Chi-square with k degrees of freedom.
*** p<0.01, ** p<0.05, * p<0.1

Table C. Simple Linear Regression of (Log) Income on Residential type (N=267,991)

Variables	*b*
Residential type Apartment ^	
House	0.20*** (0.16 - 0.24)
Townhouse	0.48*** (0.42 - 0.54)
Condo	1.08*** (1.01 - 1.16)
Mobile Home	0.23** (0.04 - 0.42)
Travel Trailer	0.24** (0.01 - 0.48)
Boat	0.76** (0.12 - 1.40)

Abbreviation: *b* = beta coefficient.
95% Confidence Intervals in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table D. Multiple Logistic Regression of Tenure (Renter = 1) on Home Characteristics (N= 267,961)

Variables	OR
Residential Type	
Apartment^	
House	0.05***
	(0.05, 0.06)
Townhouse	0.06***
	(0.05, 0.06)
Condo	0.08***
	(0.07, 0.0-9)
Mobile Home	0.07***
	(0.05, 0.10)
Travel Trailer	0.14***
	(0.10, 0.21)
Boat	Perfect Prediction
Large household	
No^	1.54***
Yes	(1.49, 1.58)
Damage source	
Wind^	2.19***
Flood	(2.09, 2.29)
Income	
	0.999998***
	(0.9999983,
	0.999999)

Abbreviations: OR = odds ratio.
95% Confidence Intervals in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
^ denotes the reference group.
28 observations were dropped due to perfect prediction by housing type “Boat”.

Table E. Multiple Imputation results (m=20) for Main Effects and Interaction Effects models (N=306,126)

	Main Effect Model		Interaction Effect Model	
	Major Damage or Destroyed compared with Minor Damage	Destroyed compared with Minor or Major Damage	Major Damage or Destroyed compared with Minor Damage	Destroyed compared with Minor or Major Damage
VARIABLES	OR	OR	OR/ORO	OR/ORO
Residential type				
Apartment^				
House	1.62***	1.63***	1.62***	1.62***
	(1.51, 1.74)	(1.41, 1.88)	(1.51, 1.74)	(1.40, 1.87)
Townhouse	0.92	0.89	0.92	0.89
	(0.78, 1.09)	(0.67, 1.19)	(0.78, 1.09)	(0.67, 1.18)
Condo	0.22***	0.15***	0.22***	0.15***
	(0.15, 0.33)	(0.06, 0.37)	(0.15, 0.33)	(0.06, 0.37)
Mobile Home	7.71***	12.16***	7.71***	12.07***
	(5.63, 10.56)	(8.57, 17.24)	(5.63, 10.55)	(8.51, 17.12)
Travel Trailer	5.53***	11.83***	5.53***	11.69***
	(3.72, 8.22)	(7.76, 18.03)	(3.72, 8.21)	(7.68, 17.79)
Boat	26.11***	18.87***	26.14***	18.77***
	(12.52, 54.44)	(7.24, 49.20)	(12.53, 54.52)	(7.20, 48.93)
Larger Household				
No^	0.87***	0.70***	0.87***	0.70***
Yes	(0.84, 0.91)	(0.66, 0.74)	(0.84, 0.91)	(0.66, 0.74)
Damage source				
Wind ^	0.69***	0.14***	0.69***	0.14***
Flood	(0.65, 0.74)	(0.10, 0.18)	(0.65, 0.74)	(0.11, 0.18)
Tenure				
Owner^	19.76***	5.05***	19.66***	5.36***
Renter	(18.99, 20.56)	(4.71, 5.42)	(18.88, 20.48)	(4.91, 5.85)
Income	0.9999996***	0.9999984***	0.9999995***	0.999999***
	(0.9999993,	(0.9999977,	(0.9999991,	(0.999998,
	0.9999998)	0.9999992)	0.9999998)	0.999999)
Interaction			1.00	0.999995**
Tenure # income			(0.9999998	(0.9999895,
			1.000001)	0.9999996)

Abbreviations: OR = odds ratio; ORO = ratio of odds ratio for the interaction term.
95% Confidence Intervals in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
^denotes a reference category.

Table F. Cross-tabulation of Housing Tenure and Wind-Damage Severity

Housing Tenure	Damage Levels				Pearson
	Minor Damage	Major Damage	Destroyed	Total	Chi2(2)
Owner	257,048	2,827	3,373	263,248	
	97.64%	1.07%	1.28%	100%	
Renter	14,754	4,970	1,149	20,873	4.4e+04***
	70.68%	23.81%	5.50%	100%	
Total	271,802	7,797	4,522	284,121	
	95.66%	2.74%	1.59%	100%	

First row has *frequencies* and second row has *row percentages.*
Chi2(k) = Chi-square with k degrees of freedom.
*** p<0.01, ** p<0.05, * p<0.1

Table G. Simultaneous-quantile Regression for the 10th, 25th, 50th, 75th, and 90th quantiles of Household Income with bootstrap standard errors (N= 267,989)

	Housing Tenure^	*b*	95% CI
10th Percentile	Renter	-840.00***	-865.76, 814.24
	Constant	2400.00***	2400.00, 2400.00
25th Percentile	Renter	-2220.00***	-2287.69, -2152.31
	Constant	6000.00***	6000.00, 6000.00
50th Percentile	Renter	-3381.00***	-3641.87, -3120.13
	Constant	12000.00***	12000.00, 12000.00
75th Percentile	Renter	-6544.00***	-6659.99, -6428.01
	Constant	21624.00***	21523.60, 21724.40
90th Percentile	Renter	-13300.00***	-13677.05, -12922.95
	Constant	38300.00***	37979.010, 38620.99

Abbreviations: CI = Confidence Interval; b = beta coefficient.
^Reference group is Homeowner.
*** p<0.01, ** p<0.05, * p<0.1

Table H. Average Marginal Risks of damage between renters and owners.

	Minor Damage	Major Damage	Destroyed
Renter	0.68	0.26	0.06
Owner	0.98	0.01	0.01
Contrast	-.30***	0.25***	0.05***
[Renter vs Owner]	(-0.30, -0.28)	(0.24, 0.25)	(0.04, 0.05)

95% Confidence intervals in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
Average Marginal Risk of each damage level for Renter (Owner) is defined as the mean predicted risk of this damage level over all individual sample profiles evaluated at "Renter" ("Owner).