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Natural Disaster Expectations and Household Adaptation[†]

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As climate change increases the frequency and severity of natural disasters, households' adaptation decisions shape both the distribution of losses and the effectiveness of government policy (Carleton et al. 2024). Yet we know relatively little about how households perceive the risks they face and how their perceptions map into adaptation behavior. Unobserved beliefs make it difficult to distinguish limited adaptation driven by low risk perceptions from that driven by constraints or frictions. This paper asks how subjective beliefs about future disaster risk translate into concrete adaptation choices and whether experiencing a major disaster meaningfully accelerates adaptation.

I study these questions using survey data from Puerto Rico collected after Hurricane Maria, one of the most destructive natural disasters in US history. The survey elicits households' subjective expectations about future hurricane risk and measures a range of self-reported adaptation behaviors and plans. To organize the analysis, I develop a stylized model in which households can adapt through (i) precautionary saving, (ii) in-place adaptation through home improvements and insurance, and (iii) relocation. Housing tenure plays a central role because, relative to renters, homeowners face larger potential losses but also have access to a richer set of adaptation technologies. The model delivers testable predictions about how perceived risk should shift each margin, which I evaluate using the elicited beliefs and behavioral responses in the survey.

Empirically, I find that perceived disaster risk is extremely high, with over 85 percent of respondents expecting at least one Maria-level disaster over the next ten years. However, expectations about disaster frequency have limited predictive power for most adaptation behaviors. Experienced damage from Maria is a better predictor along some margins, likely because it better captures individual expected losses. Insurance take-up is strikingly unresponsive to both beliefs and experienced property damage. The findings broadly align with the model's emphasis on tenure and exposure. However, overall adaptation remains modest relative to perceived risk, and the relationship between beliefs and many adaptation margins is weak, suggesting that constraints and frictions rather than low perceived risk may meaningfully limit private adaptation.

This paper is closely related to Aron-Dine (2025), which studies households' ex post responses to Hurricane Maria assuming limited new household adaptation. This analysis here provides new evidence on how disaster expectations shape adaptation decisions in the immediate aftermath of a major event, with findings broadly consistent with the assumptions of Aron-Dine (2025). Despite pervasive pessimism about future hurricane risk, Maria did not catalyze widespread new protective investment or relocation. The broader implication is that risk salience alone is unlikely to generate rapid private adaptation. Identifying the frictions behind the belief-action wedge is therefore central for policy design.

I. Model of Natural Disaster Expectations and Adaptation Decisions

There are two periods. At $t = 0$, households are either renters ($j = \mathcal{R}$) or homeowners ($j = \mathcal{O}$). At $t = 1$, a large natural disaster may occur. Household i assigns subjective probability π_i to a disaster. If a household remains in place, a disaster reduces consumption by $\ell_j^i(k, \iota)$. For renters, I treat $\ell_{\mathcal{R}}^i$ as exogenous, capturing postdisaster conditions such as damaged infrastructure, disrupted

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utilities, weaker labor markets, and higher housing costs.[1] For homeowners, losses are larger absent protective investments because housing damage can generate substantial financial distress even with ex post government transfers. Homeowners can mitigate losses through two $t = 0$ choices: (i) investment in adaptation capital k at unit price 1 (as in Fried 2021) and (ii) insurance coverage $\iota \in [0,1]$ purchased at premium p per unit. I assume that $\ell^i_{\mathcal{O}}(k,\iota)$ is decreasing in both arguments and that, absent protection, homeowners are more exposed than renters ($\ell^i_{\mathcal{O}}(0,0) > \ell^i_{\mathcal{R}}$).

At $t = 0$, households choose whether to move or stay. Each household has cash on hand a_0. Moving yields a tenure-specific value $\bar{V}_j(a_0)$ and requires paying a cost m_j. If the household stays, it chooses savings $a_1 \in [0, a_0]$, which earn gross return R. Households have increasing, concave per-period utility $u(c)$ and discount factor β. If the household stays, period-0 consumption is

$$c_0 = a_0 - a_1 - \mathbf{1}_{j=\mathcal{O}}(k + p\iota) \tag{1}$$

and period-1 resources are $w_1 = Ra_1$. Consumption at $t = 1$ is w_1 in the case of no disaster or $w_1 - \ell^i_j(k,\iota)$ in the case of a disaster. The expected utility from staying is

$$V^i_j(a_0) = \max_{a_1,k,\iota}\Big\{u(c_0) + \beta\Big[\pi^i u\big(w_1 - \ell^i_j(k,\iota)\big) + \big(1-\pi^i\big)u(w_1)\Big]\Big\}, \tag{2}$$

where k and ι are chosen only by homeowners. A household moves if $\bar{V}_j(a_0 - m_j) \geq V^i_j(a_0)$.

A. *Model Predictions*

PREDICTION 1: *Precautionary saving increases with perceived disaster risk and expected losses. For an interior solution, the household Euler equation is*

$$u'(c_0) = \beta R\Big[\pi^i u'\big(w_1 - \ell^i_j(k,\iota)\big) + \big(1-\pi^i\big)u'(w_1)\Big]. \tag{3}$$

Holding k and ι fixed, higher π^i or larger perceived conditional losses ℓ^i_j raise the expected marginal value of resources in period 1, shifting choices toward higher a_1 (lower c_0). Renters have no protection margin in the model beyond savings. Homeowners can respond by saving, investing, or insuring, but because $\ell^i_{\mathcal{O}}(0,0) > \ell^i_{\mathcal{R}}$, they have a stronger underlying incentive to protect themselves against disasters.

PREDICTION 2: *Migration increases with perceived risk and expected losses. Higher π^i or ℓ^i_j lowers the value of staying $V^i_j(a_0)$ while leaving the move option $\bar{V}_j(a_0 - m_j)$ unchanged, implying a cutoff rule in expected losses. Because $\ell^i_{\mathcal{O}}(0,0) > \ell^i_{\mathcal{R}}$, homeowners have stronger incentives to relocate, all else equal.*

PREDICTION 3: *Conditional on staying, homeowners increase protection and insurance when perceived risk is higher. The first-order condition for insurance takes the form*

$$pu'(c_0) = \beta\pi^i u'\big(w_1 - \ell^i_{\mathcal{O}}(k,\iota)\big)\cdot\big(-\partial_\iota \ell^i_{\mathcal{O}}(k,\iota)\big), \tag{4}$$

with an analogous condition for k (setting $p = 1$). An extra unit of insurance reduces disaster losses by $-\partial_\iota \ell^i_{\mathcal{O}}(k,\iota) > 0$, which raises disaster-state consumption. Higher π^i increases the expected return to protection, raising optimal k and ι.

[1] This reduced-form approach follows evidence on postdisaster impacts in Aron-Dine (2025).

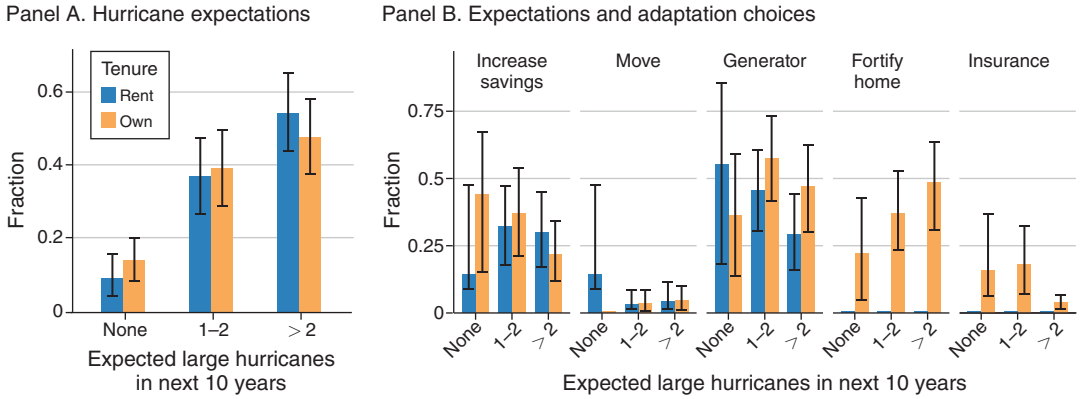

FIGURE 1. NATURAL DISASTER EXPECTATIONS AND ADAPTATION CHOICES BY HOUSING TENURE

Notes: Panel A plots the distribution of household expectations about the number of hurricanes over the next ten years that would cause damage in Puerto Rico at least as severe as Hurricane Maria. The height of each bar represents the fraction of respondents with the indicated expectation. Blue bars show the distribution for renters; orange bars show homeowners. Panel B shows the fraction of households, by expected number of hurricanes, who report having taken or planning to take specific adaptation actions: increasing savings, moving somewhere else in the United States ("Move"), buying a generator ("Generator"), making home improvements to reduce future losses ("Fortify home"), and purchasing hurricane/wind/flood insurance ("Insurance"). The black error bars show the 95 percent confidence intervals computed from 1,000 bootstrap samples.

II. Survey Evidence on Natural Disaster Expectations and Adaptation Decisions

I test the model predictions using data from a survey of Puerto Rican households conducted in June 2023, roughly six years after Hurricane Maria.[2] Hurricane Maria was one of the deadliest and most destructive natural disasters in US history, causing nearly 3,000 deaths and widespread damage to housing and infrastructure on the island. Given the salience of the hurricane's effects, this context is well suited for measuring household expectations and adaptation choices.

A. *Taking the Model to the Data*

The model highlights that adaptation decisions are governed by expected disaster losses, which combine beliefs about the likelihood of a disaster (π^i) and losses conditional on a disaster (ℓ^i_j). Several survey questions map directly to these model objects. I elicit π^i by asking for the expected number of Maria-scale hurricanes over the next ten years. I also ask whether respondents have taken or plan to take forward-looking actions: increasing savings, relocating, making home improvements, purchasing insurance coverage, and buying generators. To proxy for perceived vulnerability ℓ^i_j, I use self-reported housing damage from Hurricane Maria, following the literature on experience effects in belief formation (see Giuliano and Spilimbergo 2025 for a recent review).

I find that households in Puerto Rico are strikingly pessimistic about future hurricane risk. Figure 1, panel A plots the distribution of expectations for renters and homeowners. Nearly all households expect at least one Maria-level hurricane over the next ten years, despite Maria being the largest hurricane in nearly a century. The only other major hurricane to strike the island in recent decades was Hurricane George in 1998, which was substantially smaller in terms of fatalities and measured economic damages.

[2] The survey was administered by TGM Research, with 546 respondents who are broadly representative of the Puerto Rican. I apply survey weights throughout to better align with the income and age distribution in Puerto Rico. See Aron-Dine (2025) for additional details. I further restrict the sample to respondents who reported living in Puerto Rico in August 2017 prior to Hurricane Maria.

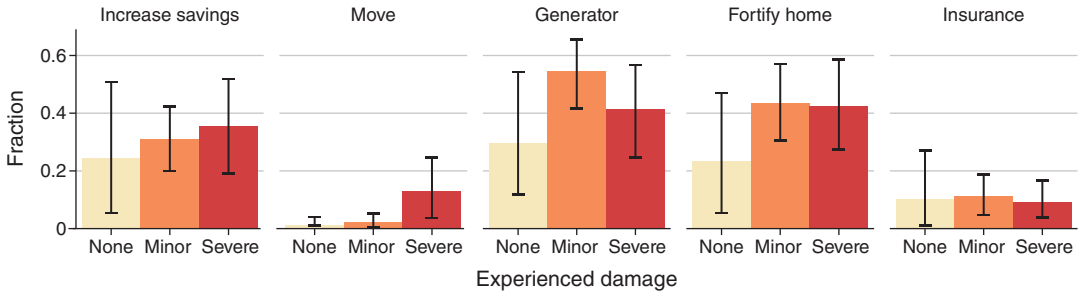

Figure 2. Homeowner Adaptation Choices by Past Experienced Disaster Damage

Notes: This figure shows the fraction of owner households, by the severity of property damage experienced from Hurricane Maria, who report having taken or planning to take specific adaptation actions: increasing savings, moving somewhere else in the United States ("Move"), buying a generator ("Generator"), making home improvements to reduce future losses ("Fortify home"), and purchasing hurricane/wind/flood insurance ("Insurance"). Black error bars represent 95 percent confidence intervals computed from 1,000 bootstrap samples. Damage categories are defined as follows. "Severe": complete failure of one or more major structural components; "Minor": damage to roof or walls, or damage to mechanical components, cosmetic damage, or damage to property features; "None": no reported damage.

Figure 1, panel B relates these beliefs to reported adaptation choices. Beliefs are strongly related to some homeowner actions such as home improvements increase, yet they are weak predictors of many other margins. In particular, I find no statistically significant relationship between expected hurricane risk and precautionary saving. Plans to migrate are relatively rare overall and uncorrelated with expectations. Insurance take-up remains strikingly low and does not vary meaningfully with expected hurricane risk. Generator purchases are the most significant reported adaptation margin, with 47 percent of households saying they have purchased or plan to purchase one—likely reflecting the salience of monthslong power outages and an unreliable electrical grid following Hurricane Maria—yet such purchases are uncorrelated with expected risk.

Households may differ in perceived vulnerability ℓ_j^i even if they report similar beliefs about disaster frequency π^i. If households learn from personal experience, then those who suffered more severe damage during Maria should adapt more aggressively. Figure 2 shows that homeowners who experienced more severe property damage from Hurricane Maria are more likely to report taking adaptation actions. Among homeowners who experienced severe property damage, 35 percent report increasing savings, versus 24 percent among those with no damage; 13 percent plan to relocate, versus 1 percent; 43 percent made or plan to make home improvements, versus 23 percent; and 41 percent purchase or plan to purchase generators, versus 30 percent. Insurance take-up, however, remains strikingly low and does not vary with past damage. Overall, these patterns suggest that experienced losses may better capture perceived vulnerability than stated beliefs about future disaster frequency.

B. *Toward Reconciling Model Predictions and Observed Behavior*

The empirical patterns highlights three puzzles. First, given the widespread pessimism about future hurricane risk in Puerto Rico, why don't more households report adaptation actions? Second, why do so few households consider migrating away from Puerto Rico, especially those who are most pessimistic about the future in Puerto Rico? Third, why is demand for insurance so low?

Several mechanisms could rationalize limited adaptation despite pessimistic expectations. Beliefs may not have changed much after Hurricane Maria; if households were already well informed about hurricane risk, they may have already been taking their optimal level of precautionary actions and therefore report little new adaptation. Even if beliefs shifted, lumpy investments such as home fortification or moving may be infeasible under tight liquidity or credit constraints. Behavioral frictions such as present bias, inattention, or uncertainty about the effectiveness of different adaptation actions

could further delay costly adjustment. In addition, stated survey beliefs may overstate the risk perceptions that actually guide households' decisions.

Plans to leave are rare even among households who think it is very risky to remain in Puerto Rico. This is partially driven by selection. The survey excludes households who left Puerto Rico after Maria, and remaining households may have higher attachment to people or place, higher moving costs, and so forth. Households may perceive limited benefits from moving since the most common destination, Florida, is also exposed to hurricanes. After Maria, households likely update beliefs for all locations. Finally, migration may involve coordination failures if households are willing to move only if friends and family relocate.

Finally, households report adaptation along some margins, yet as in Wagner (2022), demand for disaster insurance is strikingly low. While expected government assistance may crowd out insurance demand, as in Kousky, Michel-Kerjan, and Raschky (2018), households' active adaptation on other margins suggests insurance-specific barriers rather than moral hazard. Insurance may be unattractive, because policies can be both expensive and poorly matched to households' postdisaster needs. Many policies include coverage gaps and high deductibles, expose households to insurer solvency and claims-payment risk, and rely on payout rules that delay liquidity or restrict how funds can be used.

III. Conclusion

This paper studies how households' beliefs about future disaster risk translate into adaptation choices, using a stylized model and survey evidence from Puerto Rico after Hurricane Maria. I find that households are very pessimistic, yet their adaptation responses are limited and often disconnected from stated beliefs. Much more work is needed to understand how households form expectations not only about the risks they face but also about the efficacy of various adaptation mechanisms and how these beliefs relate to the frictions that may constrain responses. Effective adaptation policy requires understanding not only how households form beliefs but also what may prevent them from acting on those beliefs.

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