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Economics of Disaster Risk, Social Vulnerability, and Mental Health Resilience

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We investigate the relationship between exposure to Hurricanes Katrina and/or Rita and mental health resilience by vulnerability status, with particular focus on the mental health outcomes of single mothers versus the general public. We advance a measurable notion of mental health resilience to disaster events. We also calculate the economic costs of poor mental health days added by natural disaster exposure. Negative binomial analyses show that hurricane exposure increases the expected count of poor mental health days for all persons by 18.7% (95% confidence interval [CI], 7.44–31.14%), and by 71.88% (95% CI, 39.48–211.82%) for single females with children. Monthly time-series show that single mothers have lower event resilience, experiencing higher added mental stress. Results also show that the count of poor mental health days is sensitive to hurricane intensity, increasing by a factor of 1.06 (95% CI, 1.02–1.10) for every billion (U.S.$) dollars of damage added for all exposed persons, and by a factor of 1.08 (95% CI, 1.03–1.14) for single mothers. We estimate that single mothers, as a group, suffered over $130 million in productivity loss from added postdisaster stress and disability. Results illustrate the measurability of mental health resilience as a two-dimensional concept of resistance capacity and recovery time. Overall, we show that natural disasters regressively tax disadvantaged population strata.

KEY WORDS: Mental health resilience; natural disaster risk; single mothers; social vulnerability

1. DISASTERS AND RESILIENCE

Natural disasters vary by scale, scope, duration, and levels of loss, with some events causing localized damage, and others causing catastrophic damage across municipalities.[1] What these events share in common is that they are collectively experienced, acute in their onset, and time delimited.[2] Where they diverge in is their individual-level mental health effects. In a meta-analytic study of disaster mental health literature,[3] Norris and Elrod[4] present results on psychosocial outcomes for 225 distinct samples and 132 distinct disaster events. In studies examined, 41% show severe to very severe mental health effects among affected population groups. Norris *et al.*[3,4] also note a variety of demographic and social covariates that condition the likelihood of developing serious or lasting psychological problems in the wake of a disaster. Specifically, individual-level risk factors include prior mental and physical disorders, lower socioeconomic status, membership in an

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ethnic/racial minority group, persons with low social support, the presence of children in the home, and female gender. Of all demographic groups, single females with children are perhaps the most likely to experience posttraumatic stress and an array of other postevent stressors.[49]

The concept of *resilience* helps explain individual variations in response to risk.[5–10] Broadly conceived as the capacity to adapt successfully to stressful situations and traumatic shocks, resilience is believed to contribute to individuals' and communities' ability to maintain their well-being in the face of sudden environmental change.[8] At the level of the individual, resilience is understood as a set of *personal* capacities.[11,5–8] Psychologically resilient individuals are said to be adaptable persons,[7,12] who are better able to frame stress-inducing situations in positive terms and return quickly to positive functioning despite challenging circumstances.[13–16] Resilient communities are those that possess "networked adaptive capacities" that quickly and effectively link adaptive capacities (e.g., communication, social support, economic resources) to postevent functioning and the adaptation of constituent members.[7,17–21] The main focus of our analysis is on psychological resilience.

Despite general enthusiasm about the notion of resilience, researchers have critiqued the term as fuzzy and difficult to measure, weakening efforts to compare resilience across places and studies.[8,22–25] In an effort to provide greater conceptual clarity, Norris *et al.*[8] recommend separating psychological and social resilience from *resistance*. Resistance refers to the capacity to limit displacement from equilibrium following a traumatic event. Resilience, by contrast, points to the ability to return to an equilibrium state—the more rapid the return to preevent functioning, the greater the resilience.[8]

In this article, we build on the analytic framework forwarded by Norris and colleagues [7,8] and define resilience as the ability to maintain mental health equilibrium in the presence of external shocks. We depart somewhat from this framework, however, as we find it useful to view resilience (as the term is understood in ecological sciences) as comprised of two interrelated dimensions, each of which can be estimated. The first dimension addresses the concept of *resistance,* what we refer to as *resistance capacity,* and reflects the degree to which subjects resist or mitigate initial stresses as reflected in the degree of departure from normal functioning following a traumatic event. The second dimension, *recovery time*, refers to the duration of time taken before return to equilibrium after an external shock. Highly resilient subjects deviate less from initial equilibrium and are able to return more quickly to their original baseline. Less resilient subjects deviate more from initial equilibrium and return less quickly to their original baseline.

Our investigation of mental health resilience by vulnerability status is organized as follows. First, we review the literature on the relationship between social vulnerability, disasters, and mental health. With previous literature summarized, we then explain our research design and analytic tests. Third, we present descriptive, regression, and difference-in-difference analyses. Fourth, we consider the economic and social psychiatric implications of our research findings.

2. RESILIENCE AND HURRICANES KATRINA AND RITA

The 2005 Atlantic hurricane season shattered records that have stood for decades—most named storms (28), most hurricanes (15), and most category 5 storms (4).[26] Two of the storms that reached category 5 intensity—Katrina and Rita—hit the United States within a four-week period. Hurricane Katrina first made landfall over the southern tip of Florida on August 25. The storm weakened as it passed over land, but once it returned to the warm waters of the Gulf, it grew rapidly in size and strength. By the time Katrina made its second landfall on August 29, its rotating winds extended nearly 200 miles from the eye of the storm. Katrina laid waste to 90,000 square miles of land along the Gulf Coast, devastating communities in Florida, Alabama, Mississippi, and Louisiana, and leading to a catastrophic failure of the levee system surrounding the city of New Orleans. Katrina caused approximately $90 billion in property damage, destroyed more than 300,000 homes and 150,000 businesses, displaced 1.5 million people, and claimed over 1,800 lives.[27] People of the Gulf Coast were still reeling from Katrina when Hurricane Rita made landfall on September 23. Rita, which affected coastal communities from eastern Texas to Florida, caused over $10 billion in damages, resulted in the forced evacuation of over 2 million people, and led to at least 62 fatalities.[28]

The devastation caused by Hurricanes Katrina and Rita exacerbated preexisting socioeconomic disparities in the southern United States. The rural as well as the three metropolitan areas most affected by the storms—New Orleans, Biloxi-Gulf Port-Pascagoula, and Beaumont-Port Arthur—were

known to have lower educational attainment, median household incomes, rates of health insurance coverage, and higher poverty rates than national averages.[29,30] Preexisting socioeconomic disparities within the region shaped numerous outcomes including evacuation behavior[31] and the probability of survival,[32] property damage experienced,[35] and job losses.[31,34–36] The gendered impacts of Katrina and Rita have received far less scholarly attention.[37] Nevertheless, women in disaster-affected areas were more likely to be living in poverty, raising children on their own, and working in low-paying jobs than their male counterparts in the region and women living elsewhere in the United States.[29,38]

The question of whether disaster events influence mental health outcomes has been studied extensively over the past three decades.[4] Although scholars diverge in their assessments of overall effects of disaster on mental health[3,39] the general consensus is that disaster stressors operate differently on population subgroups, disproportionately harming socially vulnerable or disadvantaged populations. That is, patterns of psychological distress in human populations following a disaster event are conditioned by preexisting social status. We hypothesize that resilience will manifest in distinctive ways for more vulnerable populations. *Resistance capacity* will be conditioned by vulnerability status, with disadvantaged persons less able to absorb/or process catastrophic changes than the larger population. *Recovery time* will be conditioned by vulnerability status, with disadvantaged persons taking longer to return to prefunctioning states.

In this study, we investigate the relationship between vulnerability status and mental health resilience by comparing the resistance capacity and recovery time of exposed single mothers following Hurricanes Katrina and Rita relative to less vulnerable populations (i.e., nonexposed single mothers, exposed others, and the general population). With the onset of a hurricane event (or analogous exogenous shock) we expect to observe a spike in the number of poor mental health days and longer duration before return to preevent functioning. The amplitude of the deviation from the normal state of affairs defines the dimension of *resistance capacity*. The time units required for the population health variable to return to a historically normal state of behavior defines the *recovery time* dimension.

In the following section we detail elements of research design that aim to test whether single mothers with children experience natural disasters differently, and whether their mental health experiences approximate the two-dimensional conceptual model of mental health resilience. In addition, we estimate the economic costs of disaster-related mental stress by calculating expected declines in productivity and wages resulting from the addition of poor mental health days. Economic loss estimates are then subdivided by vulnerability status, adding analytic and conceptual detail to the notion of mental health resilience.

3. RESEARCH DESIGN

Individual exposure to Hurricane Katrina and/or Rita was determined by information on the temporal and spatial coordinates of each hurricane event, the date a respondent was interviewed by the CDC, and the respondent's place of county residence, as reported in the CDC's Behavioral Risk Factor Surveillance System (BRFSS) database. Our estimates of individual exposure assume that the county of residence is where a person lived through the event or postevent period. Although BRFSS data do not permit the identification of individuals who suffered directly from events in terms of significant property loss or worse, Hurricanes Katrina and Rita were sufficiently destructive of routine life in exposed counties that one can safely assume generalized impact on the resident population with measurable psychosomatic outcomes.

To investigate the relationship between individual exposure to Hurricanes Katrina and/or Rita and poor mental health days by vulnerability status, we conduct a series of tests. First, we calculate monthly time-series showing the average number of poor mental health days reported by persons residing in affected versus unaffected areas. Insofar as poor mental health days are related to hurricane exposure, we should observe spikes in the mean number of poor mental health days corresponding with the timing of hurricane events in affected but not unaffected areas. And, inasmuch as mental health resilience is conditioned by vulnerability status, we ought to observe noticeably higher spikes in the mean number of poor mental days for hurricane-exposed single mothers as compared to exposed others, as well as longer periods of recovery to predisaster mental health states.

Second, a negative binomial regression procedure with a difference-in-differences (DD) estimator is used to analyze change in the expected count in poor mental health days for unit changes in predictors. Specifically, we examine mental health

outcomes for persons in hurricane affected and unaffected locales and by vulnerability status, adjusting for known risk factors of mental health status. All persons with known residence before, during, and after Hurricanes Katrina and/or Rita are analyzed.[6]

Third, we analyze the count of poor mental health days reported by respondents residing along the path of Hurricane Katrina from southern Florida to Ohio, and the path of Hurricane Rita from Louisiana to Ohio. We estimate the intensity of the destructive path of each hurricane with property damage and crop loss data from the Spatial Hazard Losses and Events Database for the United States (SHELDUS). Insofar as poor mental health is statistically related to hurricane exposure, the number of poor mental health days ought to correlate with hurricane intensity, dissipating predictably as Hurricanes Rita and Katrina went from category 2 and 3 storms, respectively (upon landfall), to tropical depressions in Ohio. Also, inasmuch as mental resilience is conditioned by social vulnerability status, we ought to observe greater sensitivity to hurricane damage outcomes for single mothers as compared to other exposed populations. In the next section we briefly describe analytic procedures.

3.1. Analytic Procedures and Logic

We use a negative binomial regression procedure (with robust standard errors clustered by county) to analyze the expected count of poor mental health days as a function of hurricane exposure, while adjusting for known correlates of mental health. In a negative binomial regression, the probability of a count conditional on covariates, with dispersion is:

$$P_r(y_i|x_i) = \frac{\Gamma(y_i + \alpha^{-1})}{y!\Gamma(\alpha^{-1})}\left(\frac{\alpha^{-1}}{\alpha^{-1} + \mu_\iota}\right)^{\alpha-1}\left(\frac{\mu_\iota}{\alpha^{-1} + \mu_\iota}\right)^{\alpha-1},$$

where Γ is the gamma function and α represents the degree of overdispersion. The negative binomial procedure assumes overdispersion is gamma distributed across means. The variance of the response variable defined as:

$$\mathrm{Var}(y_i|x_i) = \mu_\iota\left(1 + \frac{\mu_\iota}{\alpha^{-1}}\right) = \mu_\iota(1 + \alpha\mu_\iota).$$

Our analyses logically exploit each hurricane event as a *natural experiment* where mental health outcomes of individuals are examined across pre- and postexposure time periods and exposed and unexposed areas. A regression-based DD procedure is used to isolate the independent mental health impacts Katrina and/or Rita had on affected persons. The logic of DD analysis is straightforward. Let $t = 0$ denote the preexposure period, $t = 1$ denote the postexposure period, and y_{it} denote the mental health condition for person i in period t. A regression-based estimator is modeled as:

$$y_\downarrow it = \beta_\downarrow 0 + \beta_{\downarrow 1} x_\downarrow i + \beta_\downarrow 2\pi_\downarrow t + \beta_\downarrow 3 x_\downarrow i\pi_\downarrow t + (_\downarrow it,$$

where x_i is a dummy variable assuming a value of 1 if an individual resides in an exposed area and 0 if the individual respondent resides in an nonexposed area, and π_t is a dummy variable taking a value of 1 if an individual is surveyed in the postexposure period and 0 if the respondent was interviewed in the preexposure period. The DD estimator is β_3 (the coefficient of interaction between x_i and π_t). Our DD estimator assumes a value of 1 only for individuals in exposed areas and interviewed in the postexposure period. DD parameter estimates are statistically adjusted by the physical health, social support, income, education, and single mother status of each respondent. Given our theoretical interest in the relationship between vulnerability status and mental health resilience, separate DD analyses are performed for single mothers. Next, we discuss measurement of response and predictor variables.

3.2. Variable Operations

Mental health condition is measured as the reported count of poor mental health days experienced by a respondent in the previous 30 days. Data on mental health days are from the CDC's BRFSS, 2005–2006. Specifically, respondents are asked: "Now thinking about your mental health, which includes stress, depression, and problems with emotions, for how many days during the past 30 days was your mental health not good?" The average person (with known residence, and over our study period) experiences 3.37 ($SD = 7.62$) poor mental health days for every 30 days lived, whereas single

[6]Persons residing in other parts of the country affected by another catastrophic natural hazard event during the study period of 2005–2006 were removed from the analysis to limit confounding effects. Examples of counties removed include Columbia County, WI, which suffered $502.3 million in hail and tornado damage in June 2006, and Washington, UT, which suffered a flood event in January 2005, that caused $300 million in property damage. The removal of cases from areas exposed to a catastrophic event other than Hurricanes Katrina and/or Rita reduced the number of valid observations from 606,660 to 528,389, constituting a 12.9% reduction in the number of observations.

mothers suffer 5.95 ($SD = 9.63$) poor mental health days for every 30 days lived. Variable operations and descriptive statistics for all parameters are presented in Table I.

Two variables are used to measure hurricane exposure, our *DD estimator* and *exposure intensity*. Recall, for our DD estimator, a respondent receives a score of 1 if he/she resides in a hurricane-exposed area and was interviewed in the postexposure period, and a score of 0 if not. We define an exposed area as suffering at least $10 million (U.S. dollars) in property damage and crop loss as inventoried by the Spatial Hazard Events and Losses Database for the United States (SHELDUS). *Exposure intensity* is measured as the total crop loss and property damage (in $U.S.) suffered by a county, divided by $1 billion. Dollar damage estimates are from SHELDUS. All counties inventoried by SHELDUS as experiencing some damage caused by either Hurricane Katrina and/or Rita are included in exposure intensity analyses.

To adequately estimate the relationship of hurricane exposure and mental health resilience by social vulnerability status we control for a series of known risk factors.[4] From the BRFSS, we obtained information on each respondent's self-reported *household income*, level of *education*, *physical health* status, amount of *social support* received, and *single mother* status. Respondents with incomplete information on study covariates were list-wise deleted from regression analyses. *Household income* is measured as annual household income from all sources, where 1 = less than $10,000; 2 = $10,000–14,999; 3 = $15,000–19,999; 4 = $20,000–24,999; 5 = $25,000–34,999; 6 = $35,000–49,999; 7 = $50,000–74,999; 8 = $75,000 or more. *Educational attainment* is estimated as the highest grade or year of school completed, where 1 = never attended school; 2 = grades 1–8; 3 = grades 9–11; 4 = grade 12 or GED; 5 = college 1–3 years; 6 = college 4 years or more. *Physical health* is measured as the self-reported number of days during the past month where physical health (i.e., injury, illness) was not good (ranging from 0 to 30). *Social support* is measured as a binary variable, where 1 = a respondent always receives the social and emotional support needed, and 0 = if not. Single mother is also a binary variable, with a respondent coded as 1 if she is a single female with a child present in her household, and 0 if not. As with the previous literature we expect social support to mitigate negative mental health outcomes.

4. RESULTS

Table II reports descriptive and mean comparison statistics of poor mental health outcomes by time period, exposed versus unexposed areas, and vulnerability status (i.e., single mothers vs. general population). In the prehurricane period in exposed counties we find statistically significant differences between single mothers and others on the average number of poor mental health days experienced per 30 days lived (4.8 vs. 3.3, $t = -4.65$). The ratio of poor mental health days lived for single mothers versus others was 1.47 to 1 in the prehurricane period. Single mothers (as compared to the general population) had higher numbers of poor mental health days in both exposed and unexposed counties prior to the onset of Hurricanes Katrina and Rita.

In the posthurricane period, the poor mental health days ratio of hurricane-exposed single mothers versus hurricane-exposed others increased to 1.77 to 1. Both demographic groups (hurricane-exposed single mothers and exposed others) experienced statistically significant increases in the mean number of poor mental days in the posthurricane-exposure period. For hurricane-exposed single mothers we observe a 31.88% increase in poor mental health days (4.83–6.36 days, $t = -3.26$, $p = <0.01$), and for hurricane-exposed others we observe a significant (but more modest) increase of 9.67% across pre- and postexposure time periods (3.28–3.60, $t = -2.488$, $p = < 0.01$).

Coupled with results showing no significant change in mental health outcomes for single mothers *and* others in unexposed areas across time periods, these descriptive and mean comparison results provide an empirical description of the first dimension of mental health resilience—*resistance capacity*. Our results show that shock *resistance capacity* is conditioned by vulnerability status, with persons who are generaly considered socially disadvantaged (namely, single mothers) less able to psychologically absorb and/or process catastrophic changes to routine life.

To estimate the second dimension of mental health resilience, *recovery time*, we graph poor mental health days by time, area, and vulnerability status. Fig. 2 shows the behavior of four median spline curves in two dimensions—the mean number of poor mental health days on the *y*-axis, and time (moving at the monthly time step) on the *x*-axis.

Consistent with contingency statistics reported in Table II, Fig. 1 shows that hurricane-exposed single mothers have manifestly lower *resistance capacity*

Table I. Operations and Descriptive Statistics for Predictors and Response Variables

Variable Label	Variable Definition	All Population	Single Mothers	Exposed Single Mothers	Exposed General Population	Unexposed Single Mothers	Unexposed General Population
		Mean (Std. Dev)	Mean (Std. Dev)	Mean (Std. Dev)	Mean (Std. Dev)	Mean (Std. Dev)	Mean (Std. Dev)
Poor physical health	Self-reported number of days during the past month where physical health (i.e., injury, illness) was not good	4.092 (8.591)	4.348 (8.494)	4.446 (8.701)	4.173 (8.818)	4.345 (8.488)	4.072 (8.595)
Social support	Respondent always receives the social and emotional support needed, where 1 = yes; 0 = no	0.485 (0.500)	0.378 (0.485)	0.410 (0.492)	0.559 (0.497)	0.378 (0.485)	0.491 (0.500)
Education	The highest grade or year of school completed, where 1 = never attended school; 2 = grades 1–8; 3 = grades 9–11; 4 = grade 12 or GED; 5 = college 1–3 years; 6 = college 4 years or more	4.804 (1.090)	4.567 (1.043)	4.482 (1.107)	4.731 (1.152)	4.570 (1.041)	4.823 (1.090)
Income	Annual household income from all sources, where 1 = less than $10,000; 2 = $10,000–14,999; 3 = $15,000–19,999; 4 = $20,000–24,999; 5 = $25,000–34,999; 6 = $35,000–49,999; 7 = $50,000–74,999; 8 = $75,000 or more	5.560 (2.132)	4.242 (2.075)	3.888 (2.038)	5.471 (2.217)	4.253 (2.075)	5.669 (2.098)
Single mother	Respondent is a single female with a child(ren) present in her household, where 1 = condition present; 0 = condition not present	0.071 (0.257)	1.000 (0.000)	1.000 (0.000)	0.000 (0.000)	1.000 (0.000)	0.000 (0.000)
Hurricane exposure	Respondent resides in a locale exposed to least $10 million in damage caused by Hurricane Katrina/Rita, where 1 = condition present; 0 = condition not present	0.025 (0.155)	0.032 (0.177)	1.000 (0.000)	1.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Exposure intensity	Total crop loss and property damage in U.S.$, divided by 1 billion	0.029 (0.362)	0.037 (0.405)	1.139 (1.961)	1.178 (2.075)	0.000 (0.000)	0.000 (0.000)
Poor mental health	Self-reported number of days during the past month where mental health (i.e., stress, depression, and emotional problems) was not good	3.366 (7.623)	5.949 (9.634)	6.506 (10.270)	3.534 (8.104)	5.931 (9.612)	3.161 (7.393)

Table II. Comparison of Mean Poor Mental Health Days by Area, Period, and Vulnerability Status

	Exposed			Unexposed		
	Single Mothers	Others	*t*-Test (by Status)	Single Mothers	Others	*t*-Test (by Status)
Prehurricane period	4.825	3.279	−4.652***	5.909	3.162	−39.326***
	(9.037)	(7.751)		(9.551)	(7.371)	
	$N = 627$	$N = 5{,}598$		$N = 12{,}595$	$N = 161{,}089$	
Posthurricane period	6.363	3.596	−11.869***	5.977	3.153	−54.448***
	(10.181)	(8.144)		(9.659)	(7.391)	
	$N = 1{,}415$	$N = 13{,}800$		$N = 22{,}873$	$N = 309{,}085$	
t-test (by period)	−3.258***	−2.488***		−0.634	0.412	

Null hypothesis test of mean differences equal to zero, ***$p = <.01$.

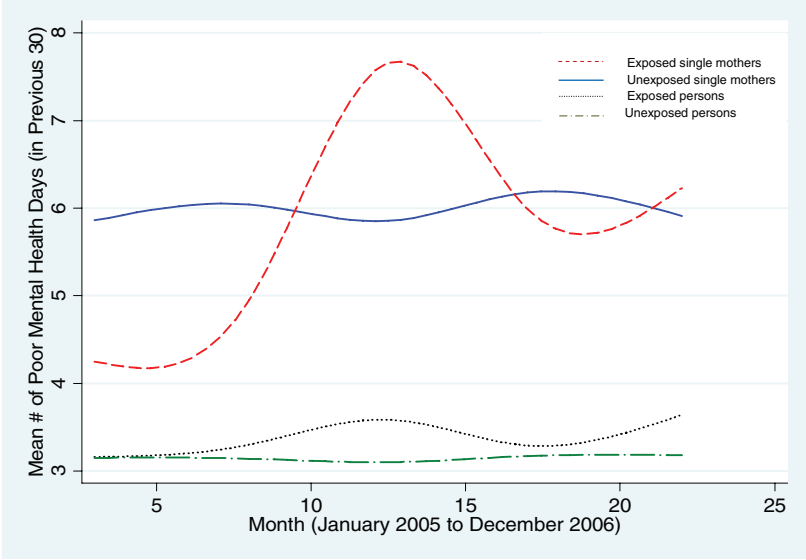

Fig. 1. Median spline of monthly mean number of poor mental health days for population groups.

than exposed others, with the mean number of mental health days almost doubling from the predisaster period. Also, it is worth noting that the rise in poor mental health days corresponds expectedly with the onset of the hurricane events. The amplification in mean poor mental health days for hurricane-exposed single mothers is especially striking when compared with both the steady line of unexposed single mothers through the exposure period, and the more modest rise in poor mental health days for exposed others through the observation period. In terms of the *time to recovery* dimension of mental health resilience, Fig. 1 shows that hurricane-exposed single mothers never fully return to predisaster mental health levels. Instead, we observe what appears to be a *new normal* state of population-level mental health for hurricane-exposed single mothers, one that is more in line with the population-level mental health of single mothers throughout the country.

In effect, Hurricanes Katrina and/or Rita cancelled whatever mental health advantage or protective mechanisms hurricane-exposed single mothers possessed before visited by natural catastrophe.[7] The same conclusion does not obtain for exposed others. Fig. 1 shows that exposed others gradually returned to predisaster mental health levels. Overall, our time-series results approximate the theoretical model of mental health resilience presented and demonstrate

[7]The precise reasons for the better initial state of population mental health for hurricane-exposed single mothers in the Gulf Coast are not fully understood. Postdisaster field research in New Orleans by a co-author of our study suggests that single mothers disproportionately suffered loss of networks, familiar surrounds, and cultural comforts. In addition, many experienced a separation from caregivers (grandparents, fathers—even out of household, which was very common). With the loss of social support, women in New Orleans became more like single mothers in other parts of the nation following Katrina.

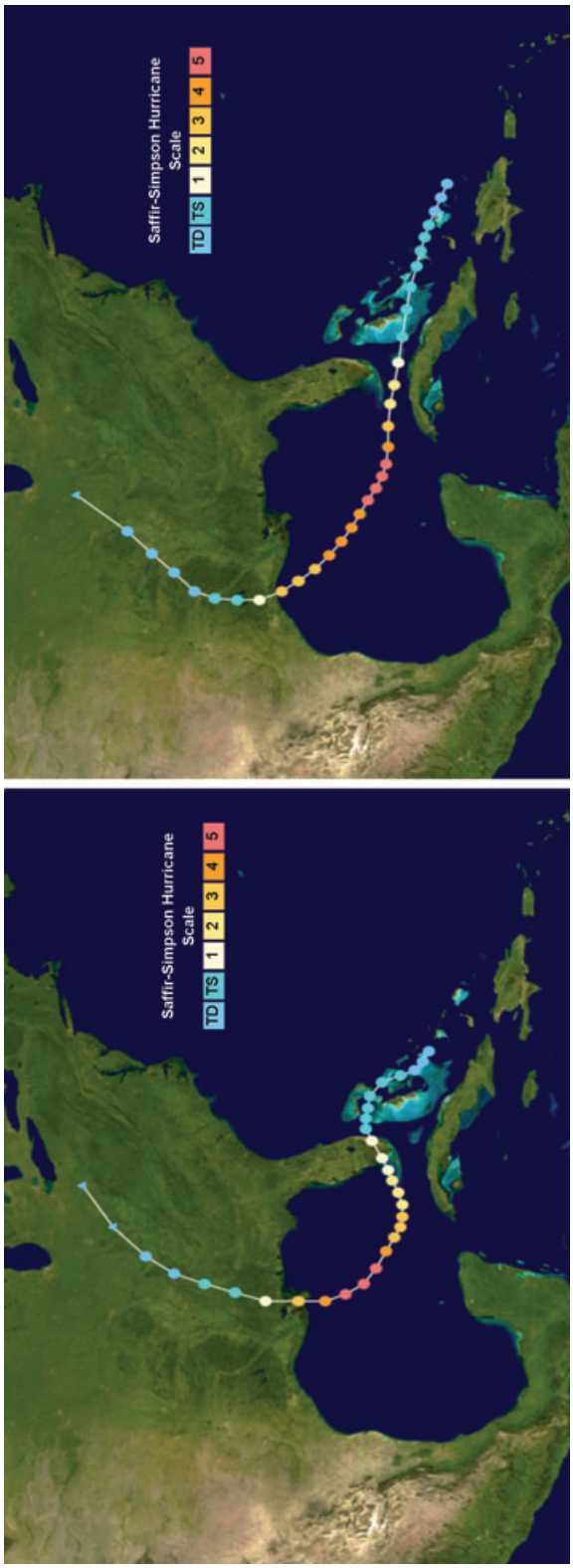

Fig. 2. Hurricane Katrina and Rita tracks with Saffir-Simpson scale of intensity.

that mental health resilience is conditioned by social vulnerability status.

Next, we analyze the relationship between hurricane exposure and mental health outcomes with statistical regression techniques to address whether observed differences by vulnerability status are caused by factors other than hurricane exposure. Table III reports negative binomial odds ratios predicting the count of poor mental health days as a function of hurricane exposure and other variables that plausibly account for variation in mental health condition. Three models are reported. In column 1, poor mental health days are modeled for all persons, in column 2 for all persons minus single mothers, and column 3 for single mothers only. The analytic emphasis is on the differences estimator (or the interaction term between area and time period) across demographic groups. Results show that exposure to Hurricanes Katrina and/or Rita increases the expected count of poor mental health days for all persons minus single mothers by a multiplicative factor of 1.140 (95% CI 1.029–1.263). For single mothers, hurricane exposure increases the expected count by 71.9% (95% CI 1.395–2.118). The differences estimator (point estimate) for single mothers is more than 4× larger than for exposed others.[8]

Other notable results are that for all persons observed, social support (OR = 0.446, 95% CI 0.439–0.454) and human capital measures of education (OR = .957, 95% CI 0.948–0.966) and income (OR = 0.927, 95% CI 0.923–0.932) significantly reduce the expected count of poor mental days, ceteris paribus.

Finally, we trace the destructive damage of each hurricane event and estimate how sensitive mental health outcomes are to the varying path intensity of each storm. Fig. 2 shows the spatial behavior of each hurricane event colored by Saffir-Simpson hurricane-intensity estimates. The logic of this final test is to observe whether the number of poor mental health days lived is sensitive to the destructive intensity of a hurricane event, and to observe whether intensity-varying hurricane-induced mental

[8]We test whether observed differences in interaction estimators by vulnerability status supersede chance. The relevant statistic is the z test. The numerator of z is the difference between two coefficients, and the denominator is the estimated standard error of the difference, calculated as the square root of the added sum of squared standard errors for coefficients of comparison. We do find significant differences in interaction estimators by vulnerability status ($z = -3.01$, $p = <.01$), suggesting that mental health resilience to a natural disaster event is, in fact, conditioned by vulnerability status.

Table III. Negative Binomial Regression Odds Ratios Predicting the Count of Poor Mental Health Days (Previous 30 Days)

	Poor Mental Health All Persons IRR (95% CI)	Poor Mental Health All Persons, Minus Single Mothers IRR (95% CI)	Poor Mental Health Single Mothers Only IRR (95% CI)
Poor physical health	1.053(1.053–1.054)***	1.054(1.053–1.055)***	1.042(1.040–1.044)***
	(0.000)	(0.000)	(0.001)
Social support	0.446(0.439–0.454)***	0.441(0.434–0.450)***	0.504(0.482–0.526)***
	(0.004)	(0.004)	(0.011)
Education	0.957(0.948–0.966)***	0.956(0.947–0.966)***	0.972(0.951–0.993)***
	(0.005)	(0.005)	(0.011)
Income	0.927(0.923–0.932)***	0.927(0.932–0.931)***	0.934(0.924–0.944)***
	(0.002)	(0.002)	(0.005)
Single mother	1.642(1.601–1.684)***		
	(0.021)		
Exposed area	0.990(0.912–1.075)	1.025(0.942–1.115)	0.705(0.587–0.847)***
	(0.042)	(0.044)	(0.066)
Postexposure period	1.000(0.983–1.018)	0.999(0.981–1.018)	1.014(0.973–1.057)
	(0.009)	(0.010)	(0.022)
Differences estimator	1.187(1.074–1.311)***	1.140(1.029–1.263)***	1.719(1.395–2.118)***
	(0.060)	(0.060)	(0.183)
/lnalpha	1.911(1.894–1.928)	1.965(1.948–1.983)	1.381(1.349–1.414)
	(0.009)	(0.009)	(0.017)
Alpha	6.760(6.643–6.878)	7.137(7.013–7.263)	3.980(3.852–4.111)
	(0.060)	(0.064)	(0.066)
Log likelihood intercept	−753,760.022	−674,003.585	−77,357.905
Log likelihood full model	−738,632.153	−661,056.843	−76,217.990
LR	30,255.737	25,893.485	2,279.828
Cragg & Uhler's R^2	0.070	0.065	0.070
N	433,151	401,559	31,592

Robust standard errors clustered by FIPS code in parentheses. $^{***}p < 0.01$; $^{**}p < 0.05$, $^{*}p < 0.1$.

health effects vary by vulnerability status. Insofar as mental health outcomes are sensitive to hurricane exposure, then the number of poor mental health days reported ought to correlate positively with the destruction visited on each area. That is, in areas hit hardest we ought to observe higher numbers of poor mental health days added.

As with Table III, Table IV reports results by demographic groups, including all persons, all persons minus single mothers, and single mothers only. Along the path of each storm, the mental health status of 20,908 persons is fully observed, including 1,985 single mothers. Results show that for every $1 billion (U.S. dollars, 2005) of property damage and crop loss suffered by an area, we observe a 5.4% (95% CI 1.016–1.094) increase in the expected count of poor mental health days among hurricane-exposed residents. For single mothers residing in the storm paths of Katrina and/or Rita, we observe an 8.4% increase in poor mental health days lived for every $1 billion of damage and loss experienced by an area. Both results corroborate the idea that fluctuations in mental health outcomes are, indeed, sensitive to storm intensity and loss.

5. SOCIOECONOMICS OF POOR MENTAL HEALTH

Poor mental health imposes psychic, social, and economic costs on individual sufferers, persons with whom an individual sufferer shares a primary social bond, and society as a whole. Studies of individual sufferers find that poor mental health status negatively impacts employment and income, among other things.[40–46] The micro-analytic logic for why population studies find an inverse relationship between mental illness and income is not fully understood, but most studies point to greater rates of related absences that hinder career progress alongside likely deterioration in on-the-job productivity ("presenteeism"), which have broader economy-wide effects. Indeed, such "presenteeism" may account for up to three-fourths of total productivity losses due to adverse mental health conditions.[47]

Table IV. Negative Binomial Regression Odds Ratios Predicting the Count of Poor Mental Health Days (Previous 30 Days) Along Hurricane Tracks

	Poor Mental Health All Exposed Persons IRR (95% CI)	Poor Mental Health All Exposed Persons, Less Single Mothers IRR (95% CI)	Poor Mental Health Single Mothers IRR (95% CI)
Poor physical health	1.054(1.051–1.057)***	1.056(1.053–1.059)***	1.039(1.031–1.048)***
	(0.001)	(0.002)	(0.004)
Social support	0.460(0.431–0.492)***	0.446(0.414–0.480)***	0.599(0.499–0.720)***
	(0.016)	(0.017)	(0.056)
Education	0.951(0.915–0.989)***	0.943(0.904–0.983)***	1.022(0.925–1.130)
	(0.019)	(0.020)	(0.052)
Income	0.930(0.913–0.947)***	0.931(0.913–0.949)***	0.930(0.893–0.969)***
	(0.009)	(0.009)	(0.019)
Single mother	1.661(1.512–1.825)***		
	(0.080)		
Exposure intensity	1.059(1.021–1.098)***	1.054(1.016–1.094)***	1.084(1.030–1.141)***
	(0.020)	(0.020)	(0.028)
/lnalpha	1.990(1.941–2.038)	2.062(2.014–2.110)	1.460(1.365–1.555)
	(0.025)	(0.025)	(0.049)
Alpha	7.312(6.968–7.672)	7.862(7.492–8.251)	4.307(3.916–4.737)
	(0.179)	(0.194)	(0.209)
Log likelihood intercept	−37,008.545	−31,943.136	−4,912.601
Log likelihood full model	−36,300.102	−31,344.776	−4,862.536
LR	1,416.888	1,196.718	100.130
Cragg & Uhler's R^2	0.067	0.063	0.050
N	20,908	18,923	1,985

Robust standard errors clustered by FIPS code in parentheses. $^{***}p < 0.01$; $^{**}p < 0.05$, $^{*}p < 0.1$.

To deepen the article's findings on the impact of Hurricanes Katrina and Rita on mental health outcomes by vulnerability status, we leverage established results from worker productivity studies to evaluate the economic costs of increased risk of poor mental health days on focal populations. Goetzel *et al.*[47] provide a meta-analysis of five particularly detailed productivity studies that distinguish narrower private absenteeism/short-term disability (STD) costs versus wider presenteeism effects that have broader societal impacts. This synthesis effectively produces a useful average and range of cost estimates at both the individual and economy-wide levels. While Goetzel and colleagues' estimates are posited in 2001 dollars, the analysis below normalizes these data to parallel the present study's 2006 time frame.

We analyze the more direct, individual-specific economic costs due to absenteeism and/or related STD that stem from hurricane exposure. Based on Table III's differences estimator findings, poor mental health days for the general population increase by 14%, while single mothers suffer a 71.9% increase in such episodes. Leveraging mean estimates for populations vulnerable to mental health disturbances, the average person in the overall population would be absent from work for 3.58 more days due to greater mental health disturbances over a given year, while single mothers would be absent 18.4 more days. Using a broad benchmark of $228.17/day in economic contributions by the average worker, an estimated $816.85 dollars are lost per person in the general population due to absences/STD, or $328 million across the entire sample population. More distressingly, $4,198.33 dollars are lost per single mother in the affected population or $132.6 million in that narrower population alone. Total losses from absences/STD are thus roughly $460.6 million.[9] These

[9]Such direct costs due to absences may be eclipsed by the broader economy-wide impacts of productivity losses inherent in "presenteeism." Using a parallel structure to the analysis for absenteeism, we find that the general population would lose an additional 0.168 hours/day of productivity due to hurricane-related mental health difficulties. Similarly, single mothers would lose 0.863 hours from their average work day from such productivity erosions. With hourly economic output assessed at a mean of $28.52, the average loss per general worker is $4.79/day, while the loss for single mothers is $24.61. Distributed across the expected

calculations show that natural disasters regressively tax human populations, with single mothers suffering disproportionately higher income losses following a disaster event.

6. CONCLUSION

Hurricanes Katrina and Rita, two of the most intense storms in recent U.S. history, imposed measurable psychological distress on exposed populations. Prior research has demonstrated the devastating psychological effects of the storm on children, African Americans, and the poor.[48] The present study shows that single mothers—who have been the focus of limited post-Katrina or Rita scholarly attention—are less shock resistant and experience a longer recovery time following exposure to disaster-related distress than affected populations as a whole.

The results are consistent with a two-dimensional conceptualization for assessing resilience among vulnerable populations.[10] Disaster-related distress outcomes varied significantly by vulnerability status with single mothers having manifestly lower *resistance capacity* than exposed others and the general population, as indicated by a sharp and substantial rise in the mean number of poor mental health days following Hurricanes Katrina or Rita. In terms of the *time to recovery* dimension, we find that the mean number of poor health days remains highly elevated for hurricane-exposed single mothers in comparison to unexposed single mothers and exposed others during the same period. In fact, hurricane-exposed single mothers never fully return to predisaster mental health levels but appear to be in a *new normal* state of population-level mental health, one that is significantly higher than the predisaster level, and more in line with the population-level mental health of single mothers throughout the country.

Poor mental health imposes psychic, social, and economic costs. Disasters are likely to generate cumulative disadvantages for single mothers that have compounding effects for children and within the broader community as well. Income and productivity losses experienced by single mothers are particularly regressive, depleting already lower stocks of money capital possessed by this socially disadvantaged population subgroup. In exploring single mothers, we address how patterns of resilience differ between this subgroup and the broader-exposed population. Additional research is needed to address how other relevant risk factors may moderate mental health outcomes within this population. Moreover, observed effects of single motherhood may be moderated by other unobserved factors, for example, the struggle to provide reliable care for young children when previous sources (day care centers, extended family members, schools) are no longer available. Finally, reported increases in poor mental health days for exposed single mothers and the general population may underestimate the true losses experienced by these harmed populations, as substantial fractions of the local population of harmed persons were geographically displaced by the hurricane events. Some unknown fraction of these aggrieved persons will show up in control group estimates.

working year, $1,149.60 dollars are lost per general worker, while $5,906.40 dollars are lost per single mother. Totaling across the sample populations, $461.6 million in economic losses are attributable to general population presenteeism; a further $186.6 million of economic output is lost amidst single mothers' particular struggles. As expected, such broader economy-wide productivity impacts are considerably larger than narrower absenteeism effects, totaling $648.2 million. Combining worker absences and economy-wide productivity impacts yields $1.109 billion of lost annual economic value due to mental health disturbances created by hurricane exposure. Over 58% of those economic losses stem from less obvious but likely more pernicious "presenteeism" sources, as affected workers try to continue in their traditional economic and social roles while their mental health struggles weigh them down both emotionally and professionally.

[10] A two-dimensional approach to assessing mental health resilience may be germane to community-level analyses as well. Like individuals, communities vary in the degree to which they depart from normal functioning following an exogenous shock and in the time it takes to return to preevent levels. Additionally, both communities and individuals diverge in the extent to which the resources necessary for survival are sufficiently robust and redundant to buffer or counteract the effects of a disaster and in the time it takes to marshal and mobilize necessary resources to return to preevent functioning.[8]

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