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May 2016

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May 9, 2016

Abstract

I explore the hypothesis that Hurricane Katrina in 2005 raised perceived background risks, which had spillover effects on behavioral health outcomes of mental health, substance use, and health insurance. I explore this hypothesis using Behavioral Risk Factor Surveillance System data for 2002-2007. I use a difference-in-difference model to estimate the effect that Hurricane Katrina had in the non-damaged storm surge region, in 90-day intervals leading up to and after the hurricane, compared to areas impervious to hurricanes. Within non-damaged counties at risk of any storm surge, I find causal evidence that Katrina increased poor mental health days by 8.8% for three months after Katrina, and increased smoking by 10% over nine months, which translates to 39.0 million extra days of poor mental health and 1.1 million extra smokers. Results suggest that perceived background risk increases may have important spillover effects on health for people far from the actual disaster, and highlight a hidden cost of the government's failures in managing Hurricane Katrina.

Keywords: Hurricane Katrina; perceived background risk; mental health; smoking; binge drinking; health insurance
JEL Classification Numbers: D81, I12, I13, Q54

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I Introduction

Due to its uniqueness, Hurricane Katrina (hereafter referred to as "Katrina") likely increased perceived background risk for individuals residing in areas with actual risk to future hurricanes, even if these individuals did not directly experience destruction from Katrina. 24/7 media coverage of the disaster may have reminded individuals that hurricanes can be deadly, levies can fail, and the government, including the Federal Emergency Management Agency (FEMA), may not provide protection. If perceived background risks change, this could have spillover effects in a variety of areas, including health. In this study, I explore possible spillover effects of an increase in perceived background risk on behavioral health outcomes of mental health, substance use, and health insurance coverage.

Katrina was a unique hurricane in terms of severity and media coverage. It was the deadliest natural disaster in the United States in nearly a century, causing 1,836 deaths in total. The city of New Orleans in Louisiana was struck on August 29, 2005, and the damage extended to states of Mississippi, Alabama, and Florida. 24/7 news coverage transferred images of Katrina-induced death and destruction to households across the United States. A few examples of this ubiquitous news coverage are that the *Los Angeles Times* had a Katrina front-page headline and lead image for 15 days straight, and the *New York Times* had a Katrina front-page headline for 13 out of 15 days (Kimball et al. 2006). In polling conducted a week following Katrina, 93% of Americans believed Katrina to be the worst natural disaster in their lifetime (Gallup News Service 2005a). The public was mostly unhappy with the government's response, with various aspects of government receiving approval ratings of between 36-42% for their response (Gallup News Service 2005b). Much blame was laid at the feet of FEMA, whose director resigned two weeks following the disaster.

To explore possible spillover effects of perceived background risk changes, I use individual-level data from the Behavioral Risk Factor Surveillance System from 2002-2007 for 1,299,101 adults ($\geq$ 18 years of age) residing in the continental United States. I exploit the fact that individuals reside in counties with different actual hurricane risks using county-level

meteorological and geographical data. After excluding counties directly damaged by Katrina (and other hurricanes shortly after Katrina), I use a difference-in-difference (DD) analysis to compare post-Katrina outcome measures for individuals residing in counties differentially at-risk to future hurricanes with individuals residing in counties largely impervious to future hurricanes.

A key challenge for my identification strategy is potential confounding from migration and economic factors. Katrina may have disproportionately disrupted the economies of coastal communities not directly damaged by Katrina, compared to economies further inland. Additionally, evacuees from Katrina settled disproportionately in coastal counties, especially Houston, Texas (McIntosh 2008; Hussey, Nikolsko-Rzhevskyy, and Pacurar 2011). Katrina evacuees may be different from non-Katrina evacuees in both observable and unobservable ways. While I can control for observable population differences brought about by Katrina evacuees moving disproportionately into the control and treatment groups, unobservable population differences could introduce bias into the analysis.

I mitigate possible confounding from unobserved differences in migration and economic climate after Katrina in several ways. First, I exclude counties that were directly damaged by Katrina, or that were damaged by two other hurricanes making landfall shortly after Katrina. These counties are likely to have been most significantly affected by migration and economic factors. My treatment group is therefore areas that are vulnerable to hurricanes but were not directly damaged by these hurricanes. In the analysis, I then control for individual-level observable characteristics associated with migration and economic factors, such as race/ethnicity, employment status, and household income. To get a sense of the magnitude in which unobserved factors may enter into the analysis, I check the balance of the data before and after Katrina based on key demographic characteristics. I do not observe substantial variation in observables before and after Katrina, suggesting unobserved differences are also likely small. To proxy control for any remaining unobservable differences in migration or economic climate, I control at the county level for number of evacuees per

capita and distance to New Orleans in the post period, and at the state level for unemployment rates. In these ways, I can isolate the effect of perceived background risk changes on behavioral health outcomes.

This paper is related to two strands of literature. The first strand explores the effects of background risk on risk aversion and decision-making in the presence of risk. New risk information, such as from an information campaign on radon exposure, has been found to raise perceived background risk (Smith and Johnson 1988). One study directly measured an increase in risk aversion in Germany, in particular closer to nuclear reactors, due to a nuclear disaster in Japan (Goebel et al. 2015). Other studies have explored how background risk influences decisions involving financial risk, finding decreased stock market participation (Heaton and Lucas 2000), increased insurance demand (Gollier and Pratt 1996), and decreased risk-taking in experimental games (Cameron and Shah 2013).

Related, several studies use home sales data and DD methodologies to estimate the impact of hurricanes as sources of new risk information on property prices. Following Hurricane Andrew that struck Florida in 1992 and controlling for damage and changes in insurance, property values were found to decline in Dade County, which was directly impacted. Property values also decreased in Lee County, a near-miss county, by less than in Dade County (Carbone, Hallstrom, and Smith 2006; Hallstrom and Smith 2005). These results suggest that households notice disasters, even "near miss" disasters, and update perceived background risk in response to this new information. Market responses follow. These responses appear to be temporary rather than permanent: property value differentials disappeared after five years (Bin and Landry 2013).

The second strand of literature relevant to my research relates to the mental and physical health of individuals directly impacted by large-scale disasters. Using longitudinal data, Smith found that longevity expectations declined for older adults in Dade County due to a direct hit from Hurricane Andrew (Smith 2008). Currie and Rossin-Slater used vital records data to explore the impact of exposure to hurricanes during pregnancy on the probability of

stress-related abnormal birth conditions. Stress was found to be a residual explanation on some abnormal birth outcomes after accounting for migration, changes in medical care, and changes in maternal behavior (Currie and Rossin-Slater 2013).

This paper attempts to explore the spillover effects of an exogenous increase in perceived background risk from Katrina on mental health, substance use, and health insurance. The paper exploits Katrina as a unique natural disaster with destructive force not seen in generations. I find causal evidence that mental health declined in storm surge counties relative to control counties for a period of about 3 months, and smoking increased for a period of about 9 months. I find little evidence that binge drinking or health insurance coverage increased due to Katrina.

II Conceptual Model

In a world of perfect information, individuals correctly estimate the probability of a disaster and FEMA's ability to respond. In this state of the world, perceived background risk would not change with a large-scale disaster because the probability of this disaster would have been perfectly anticipated. However, Katrina may have been a source of new information about actual risks in a world of incomplete information, which would increase the level of perceived background risk. This perceived background risk may affect individual's health directly, or indirectly through changes in property values, flood insurance premiums, or longevity expectations, for example.

Perceived background risk changes may diminish mental health because people feel more vulnerable. Perceived background risk could also be linked with decreased longevity expectations or housing values, which in turn could reduce mental health (Carbone, Hallstrom, and Smith 2006; Hallstrom and Smith 2005; Bin and Landry 2013; Smith 2008).

Perceived background risk could also affect substance use for a variety of reasons. Individuals may attempt to self-medicate poor mental health from perceived background risk

increases by using substances (Pesko and Baum 2016). Increases in financial distress, a particular component of broader mental health, have been associated with increases in smoking (Grafova 2011; Ayyagari and Sindelar 2010; Siahpush and Carlin 2006; Barnes and Smith 2009; Cotti, Dunn, and Tefft 2014). Increases in perceived background risk could also reduce longevity expectations, which in turn could reduce the costs of substance use in the short term, thus increasing substance use.

Increases in background risk have been found to encourage greater risk aversion in a variety of contexts (Heaton and Lucas 2000; Gollier and Pratt 1996; Cameron and Shah 2013), thus explaining how Katrina-induced perceived background risk increases could increase the demand for health insurance. While demand for many forms of insurance (e.g. home, health) may increase through this mechanism, the form of insurance I explore in this paper is health insurance due to my focus on spillovers affecting behavioral health and the availability of this outcome in my primary data. Additionally, demand for health insurance in particular could also increase to improve access to healthcare services to either improve mental health or reduce substance use, both of which may have increased through earlier mentioned channels.

In total, I explore the influence of perceived background risk on four outcomes: poor mental health, smoking, binge drinking, and health insurance. Perceived background risk could affect these outcomes either directly or indirectly (through changes in longevity expectations or property values, for example).

III Background on Hurricane Risks

Hurricanes/typhoons are rapidly-rotating storm systems formed over water with sustained winds of at least 74 miles per hour. Storm surge poses the greatest risk from hurricanes and occurs when a column of water pushed inside and in front of the storm is released over land, causing hydraulic impacts and debris collisions far inland. Storm surge from Ka-

trina was as high as 25-28 feet and pushed up to 20 miles inland. The United States is particularly vulnerable to storm surge, as much of the country's densely populated Atlantic and Gulf Coast coastlines are less than 10 feet above sea level (NOAA 2013). Further, residents may be unaware and uninsured against the dangers of coastal storm surge flooding because FEMA special flood hazard areas (SFHAs) are defined only for areas at-risk of fresh water flooding.[1] The percentage of homes in storm surge zones, but not in SFHAs, is greater than 50% for 11 of 14 major coastal metro areas (Botts et al. 2012). A secondary danger of hurricanes is wind damage, which can extend as far inland as Oklahoma, Arkansas, and Tennessee (Kaplan and Demaria 1995) and can spawn tornadoes. Hurricane-induced tornadoes are heavily concentrated in the immediate coastal areas and typically occur within 12 hours before to 48 hours after the hurricane makes landfall (Schultz and Cecil 2009).

Due to warmer climates and geographical considerations, southern coastal states are more prone to being hit by hurricanes than others. In the 10 years prior to Katrina, the states with more than two hurricane landfalls are Florida (9), North Carolina (6), and Louisiana (3). The states of Mississippi, South Carolina, Texas, and Virginia were each hit by one or two hurricanes during this time period. Prior to Katrina, the northeast states of New York, Connecticut, Massachusetts, and Rhode Island had not seen a hurricane since Hurricane Bob in 1991 (NOAA 2008).

IV Data

A Primary Data

The primary data are provided by the Behavioral Risk Factor Surveillance System (BRFSS). State health departments and the Centers for Disease Control and Prevention (CDC) collect these cross-sectional data on risky personal health behaviors via landline tele-

[1]SFHAs are defined by FEMA as areas with a 1% or greater chance of fresh water flooding in a given year. Since 1973, flood insurance has been required to purchase homes in the SFHA using a mortgage from a federally regulated or insured lender.

phone surveys of individuals aged 18 years and older. Cell-phone only households are not included, which systematically excludes 8% of adults from participating in the survey in 2005 (Blumberg and Luke 2014). The data are nation- and state-representative of the non-institutionalized population. The data identify 100% of respondents' states and counties of residence and date of interviews, as well as a variety of socio-demographic characteristics including gender, race/ethnicity, age, education, employment/labor force participation, marital status, and income. For the primary analysis, I use data from 2002 to 2007, with Katrina occurring on August 25, 2005. This permits me to explore the immediate impact of Katrina on outcomes.

Survey respondents are asked a standard question of recent emotional and mental distress: "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?" These data are heavily rightward skewed, with 67.5% of individuals reporting having 0 days of stress and 5.1% reporting having 30 days of stress. The remaining 27.4% report integer values between 1 and 29. I refer to this variable as "poor mental health" throughout.[2]

For smoking, survey respondents are asked if they have smoked 100 or more cigarettes in their lifetime and, if so, if they have smoked over the past 30 days. If the individual answers yes to both questions, then I classify them as a smoker.[3] For binge drinking, individuals are asked if they have consumed 5 or more drinks on any one occasion over the past 30 days, but starting in 2006 this number was reduced to 4 or more drinks for women. For health insurance, individuals are asked: "Do you have any kind of health care coverage, including health insurance, prepaid plans such as HMOs, or government plans such as Medicare?"

[2]This question was the most widely available question on mental health across the 5 years of data used in this analysis. It was a mandatory question for all years except 2002, when it was completed by only 23 states as part of an optional module. In 2004, a "Mental Illness and Stigma" section was completed by 11 states, and in 2006 an "Anxiety and Depression" section was completed by 36 states, but no optional modules were used in 2005 with additional mental health questions.

[3]Intensive margin cigarette smoking is unfortunately not provided in the BRFSS data.

B Secondary Data

Data from the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) system are used to determine counties at-risk of storm surge from a category 3 hurricane.[4] I use these data to proxy increases in perceived background risk following Katrina, which I argue is correlated with actual risk. In addition to strength, this system takes into account land elevation, unique bay and river configurations, water depths, rainfall, and physical features such as bridges, roads, and levees. The SLOSH data were overlaid with county borders to determine for each category of hurricane if any part of the county was in the SLOSH plane. Coastal counties are always in the SLOSH plane, and in some areas the SLOSH plane extends deeper inland.

A more complicated measure of risk from storm surge involves overlaying populations and storm surge percentages within census tracks of counties to derive a county-level percent population exposure to storm surge from a category 3 hurricane. In different analyses, I use both this measure and the cruder "any exposure" measure to form the treatment.

I use the inland wind decay model developed by Kaplan and DeMaria to identify counties outside of the storm surge region but potentially still vulnerable to wind damage, including tornado damage, from hurricanes (Kaplan and DeMaria 1995). This model takes into account increased penetration of dangerous wind speeds for stronger hurricanes, but it does not take into account the changing topography or other possible local factors that may affect wind speed. Similar to the SLOSH data, the wind data were overlaid with county borders to determine if any part of the county could be affected by strong gale strength wind damage of 47 miles per hour from a category 3 hurricane. This wind strength category was chosen because this is the point at which winds begin to cause structural damage. The wind data extend much further inland than in the SLOSH model and vary more greatly by hurricane

[4]Hurricane categories operate on a scale of 1-5, with five being the worst. Upon landfall, Katrina was a strong category 3 hurricane. From 1851-2004, only three category five hurricanes have struck the United States, (NOAA 2008) although many, including Katrina, have been category 5 hurricanes at some point at sea.

category strength. Since these "wind damage only" counties represent a level of risk from hurricanes below storm surge but above no risk, I exclude these counties from the analysis to more cleanly identify effects based on high risk or no risk.

To avoid confounding from the actual Katrina-induced disruption, three additional sources of data are used. The first identifies counties that received any federal assistance because of Katrina. These counties include all of Louisiana and Mississippi, west Alabama, and west and south Florida.[5] These counties are excluded from the analysis to avoid capturing disruption from the actual hurricane rather than changes in perceived background risk. A map showing counties at risk of storm surge and wind damage from a category 3 hurricane, as well as excluded counties receiving aid for Katrina, is presented in Figure 1.

[Insert Figure 1]

Two other hurricanes made landfall after Katrina in 2005—Hurricane Rita in Louisiana and Texas on September 24, and Hurricane Wilma in Florida on October 24. Similar to how I removed counties receiving any FEMA disaster aid assistance due to Katrina, I also remove counties receiving any disaster aid assistance due to these other hurricanes.

The second source of data to reduce Katrina-induced disruption is ZIP code-level FEMA application information for aid as of September 23, 2005, approximately one month after Katrina, providing evacuee information for 1.3 million applicants with valid ZIP codes in the continental United States. I was able to match 97% of these ZIP codes to a county.[6]

The third source of data to reduce Katrina-induced disruption is county-level distance data to New Orleans, which may proxy uncontrolled economic factors in the aftermath of Katrina.

Other merged data are used to control for time-varying policy and environmental controls. Monthly state-level unemployment data are used to construct a state-level unemployment

[5]In route to striking New Orleans on August 29, 2005, Katrina struck the southern coast of Florida on August 25, 2005.

[6]For cases in which an applicant's ZIP codes overlapped two or more county borders, I partially assigned the application to each county depending on number of residential ZIP codes in each county.

rate to control for spillover effects of unemployment beyond individual-level employment status. Income eligibility as a percent of the federal poverty line for low-income families was collected from various Kaiser Family Foundation reports and is controlled for in all regression analyses to control for possible Medicaid expansions occurring during this time (Kaiser Family Foundation, 2016). Cigarette prices from the Tax Burden on Tobacco (Orzechowski and Walker 2009) are included in the smoking prevalence model. The American Chamber of Commerce Researchers Association (ACCRA) Cost of Living Index beer prices were aggregated to the state level and were used as a proxy for alcohol prices in the binge drinking model. Smoke-free air law data for restaurants, bars, and private workplaces from the ImpacTeen project were included in both the smoking prevalence and binge drinking models. All monetary values were deflated to 2004 dollars using the consumer price index, city average.

V Empirical Framework

In this paper, I examine if mental health, substance use, and health insurance increased in non-damaged counties at-risk to storm surge from future hurricanes (compared to counties not at-risk). I estimate the following model:

$$\begin{aligned} y_{isctm} \;=\; & \alpha + X_i + \lambda_t + \lambda_c + \zeta_{sct} + storm\ surge_c * \lambda_m \\ & Katrina_{t-6} + \cdots + Katrina_t + \cdots + Katrina_{t+7} + \\ & \beta_1\ storm\ surge_c * (Katrina_{t-6} + \cdots + Katrina_t + \cdots + Katrina_{t+7}) + \\ & \beta_2\ evacuees\ per\ capita_c * (Katrina_t + \cdots + Katrina_{t+7}) + \\ & \beta_3\ distance\ to\ New\ Orleans_c * (Katrina_t + \cdots + Katrina_{t+7}) + \epsilon_{isctm} \end{aligned} \tag{1}$$

where y_{isctm} is one of four outcomes. It is either equal to 1 if individual i living in county

c of state s in month m of month-year t has health insurance, has smoked or binge drank in the past 30 days, or is equal to the number of days of poor mental health over the past 30 days (outcomes analyzed separately). I estimate this equation using a linear probability model so that results are easy-to-interpret marginal effects. I also use the population survey weights provided by BRFSS. I cluster-correct all standard errors at the level of county.

I analyze the effect of Katrina on outcomes in the storm surge region (compared to the control region impervious to hurricane damage) in 90 day intervals before and after Katrina occurred. This allows me to empirically explore the parallel trends assumption, as well as explore heterogeneity in effects across time after Katrina. I exclude the first 15 days after Katrina because the mental health and substance use questions asked about behaviors over the past 30 days; therefore, choosing the mid-point seemed appropriate so that respondents were answering for a time interval in which Katrina had occurred for a majority of the time. Therefore, the effect of Katrina in the post period is evaluated from days 15-104, 105-194, etc. I show in a sensitivity analysis that results matter little whether the first 15 days are included in the analysis or not.

I estimate these equations using individuals residing in either the non-damaged storm surge region (after removing counties receiving federal disaster assistance for Hurricanes Katrina, Wilma, or Rita) or the control region impervious to hurricanes (removing the "wind damage only" region). This permits me to more cleanly identify effects of Katrina on outcomes in places with risk to future hurricanes, compared to places without. For the health insurance outcome, I discard individuals 65 years of age and above, since these individuals will be eligible for Medicare and therefore I expect little variation in insurance coverage within this population.

X_i is a set of controls at the individual level: gender, race/ethnicity, household income, household income squared, top income category, age, age squared, education attainment, marital status, and employment status. Employment status, in particular, may have changed in the aftermath of Katrina; therefore, it is useful to control for this at the individual level.

Additionally, for the binge drinking outcome, I include an indicator for women post-2006 to control for the question wording change that reduced binge drinking for women from 5 to 4 drinks on any one occasion.

I also control for county fixed effects and year-by-month fixed effects. This removes unobserved variation across the United States that is unique to a particular year-month, as well as unobserved time-invariant variation unique to a particular county. Additionally, to remove unobserved seasonal variation unique to storm surge counties and control counties, I also include month fixed effects separately for the storm surge region and control region.

Fixed effects do not account for variation across both counties and time. I attempt to control for this using a variety of policy and environmental characteristics that could be both correlated with Katrina and the outcomes. This includes state-level unemployment rates, Medicaid general income eligibility as a percent of the federal poverty level, cigarette prices (smoking model), beer prices (binge drinking model), and smoke-free air laws (smoking and binge drinking model). I also control for distance to New Orleans and evacuees per capita in the post period, allowing heterogeneity within the post period across time to allow any effects to dissipate as evacuees relocate home and any short-term economic shocks from Katrina recede.

In addition to estimating equation 1 for the four outcomes, I also perform a secondary analysis that replaces the indicator variable $storm\ surge_c$ with the county-level percent population exposure to storm surge from a category 3 hurricane. Since the treatment is more finely allocated in this latter approach, I anticipate that estimated associations of Katrina on outcomes should increase if risk is the mechanism driving the relationship.

VI Econometric Results

Summary statistics for individuals residing in the non-damaged storm surge region and the control region are provided in Table 1. Individuals experienced an average of 3.4 days of

poor mental health per 30 days. 20.3% smoked over the past 30 days and 15.7% binge drank over the past 30 days. Among adults <65 years of age, 82.5% had health insurance. 24.4% of the population resided in a county at-risk to storm surge from hurricanes, and within these counties 41.1% of the population was vulnerable to such storm surge.

[Insert Table 1]

In Figure 2, I perform a balance check of key demographics (male, race/ethnicity, age, employment, and income) in the storm surge region in 90-day intervals before and after Katrina. Demographics may change noticeably in the post-Katrina period, perhaps because evacuees were disproportionately settling into the storm surge region versus the control region, or because of uncontrolled aspects of economic distress. While I control for observable demographics and state-level unemployment rates in the analysis, large changes in demographics could suggest changing unobservable characteristics that I cannot control for directly and which may introduce bias into the analysis. Fortunately, I see limited evidence that observables changed more significantly across Katrina than random noise (from changes at other periods of time). I also produced the same result for the control region in Figure 3 and again did not find significant differences across Katrina. The noise in Figure 3 for the control region was substantially reduced compared to in Figure 2 for the storm surge region by having 4 times as many observations. In sum, I see limited evidence that unobserved differences could introduce significant bias to the analysis. To proxy control any remaining unobservable differences in selective migration or economic distress, I control for distance to New Orleans and evacuees per capita in the post-Katrina period.

[Insert Figures 2 and 3]

Table 2 shows partial results from equation 1, exploring the effect of Katrina in 90-day intervals before and after Katrina in the storm surge region relative to the control region, compared to the reference group of the difference between these two regions 540 days (roughly

1.5 years) before Katrina. I first evaluate if parallel trends are present in the pre-period. Non-parallel trends could indicate the presence of a time-varying variable that differentially influences the control and treatment group, which is a threat to causal interpretation. While one coefficient in both the binge drinking model and health insurance model is statistically significant roughly 1 year before Katrina, the Wald test of joint significance of the 6 pre-Katrina time intervals suggests that I cannot reject the Null hypothesis that the trends are parallel for all four outcomes.

[Insert Table 2]

I turn to evaluating the effect after Katrina. In day 15-104 after Katrina, I observe that poor mental health days increased by 0.30 days per 30 days (8.8% of the mean, $p<0.10$) in the non-damaged storm surge region relative to the control region. Additionally, smoking increased by 2.4 percentage points (12.2% of the mean, $p<0.01$). While poor mental health appears to have declined to baseline by the second post-Katrina time period (105-194 days after Katrina), the increase in smoking persists. In the second post-Katrina time period, smoking was 2.0 percentage points higher in the storm surge region relative to the control region ($p<0.01$) and remained 1.7 percentage points higher ($p<0.10$) in the third post-Katrina time period. Taken together, these results suggest a role for addiction in prolonging smoking beyond the point at which poor mental health returned to normal levels.

We do not find evidence of an immediate increase in binge drinking or obtaining health insurance. Binge drinking may have even decreased in the third and fourth 90-day periods after Katrina ($p<0.10$) compared to 1.5 years before Katrina. Health insurance coverage did increase in the third 90-day period after Katrina by 2.4 percentage points (2.8% of the mean, $p<0.05$).

In Online Table 1, I show that the results are largely insensitive to including the first 15 days after Katrina as part of the first post period, rather than excluding these observations. Results were slightly attenuated in the first post-Katrina period, which is likely due to the questions asking about mental health and substance use over a 30-day period. This means

that respondents shortly after Katrina were answering about behaviors primarily in the pre-Katrina period, hence attenuating results towards the null of no effect.

In Table 3, I re-evaluate the results using county-level population exposure, rather than an indicator variable for the presence of any county-level exposure, as the treatment variable. A strength of this approach is that it allows me to observe if effect sizes increase since the treatment of actual risk from hurricanes is more precisely allocated. This alternative definition of the treatment does require re-testing the parallel trends assumption.

[Insert Table 3]

Under this alternative definition of the treatment group, the parallel trends assumption holds for all outcomes except smoking. This suggests caution in interpreting results from the smoking model when using population exposure as the treatment versus any exposure. I do find evidence of larger effect sizes when the treatment is more precisely defined. In the first 90-day period after Katrina, poor mental health days increased by 0.7 days per 30 days (20.2%, $p<0.01$). Smoking increased by 4.9 percentage points (24.9%, $p<0.01$), but this result is biased upward by pre-Katrina trends. Health insurance increases by 4.6 percentage points (5.4% of the mean, $p<0.01$) in the third 90-day period after Katrina. Binge drinking is now estimated to increase by 2.0 percentage points (16.4% of the mean) in the first 90-day period after Katrina, but this result was not statistically significant.

For both treatment definitions, I examined the coefficients on evacuees per capita and distance from New Orleans. In the first 90 day-period after Katrina, only distance was a statistically significant predictor of poor mental health (mental health declined closer to New Orleans). This may capture economic distress not controlled by other variables, or another explanation such as individuals living closer to New Orleans were more likely to have connections with people harmed by the hurricane. I remove any remaining confounding variation by controlling for these variables in the analysis. The relative lack of significant findings of these variables suggest that my strategy of excluding directly impacted counties was largely successful in removing confounding from migration and economic factors.

VII Discussion

This study uses an unprecedented large-scale disaster, Katrina, as a natural experiment to study how increases in perceived background risk affect mental health, substance use, and health insurance. Media attention may have contributed to individuals that live in counties vulnerable to hurricanes to focus on being harmed by a future hurricane rather than on the small probability of this occurring (Sunstein 2003). Economists have also found evidence for the substantial overweighting of small probabilities in deductible choices for home and auto insurance (Barseghyan et al. 2013).

Within non-damaged counties at risk of any storm surge, I find causal evidence that Katrina increased poor mental health days by 8.8% for about three months after Katrina, and smoking increased by about 10% over nine months. Approximately 44.4 million adults lived in the non-damaged storm surge counties in 2005, so estimates suggest that in the first 3 months after Katrina, 1.1 million extra individuals smoked and individuals experienced a total of 39.0 million extra days of poor mental health. To provide an illustration of the magnitude of the effect that Katrina had on smoking, a cigarette price increase of 30% would have been needed to offset this increase in smoking (using a consensus cigarette price elasticity of -0.4, IARC 2011). When adjusting for population exposure within these non-damaged storm surge counties, I find causal evidence that Katrina increased poor mental health days by 20.3% in the first three months. I also observe a 16.4% increase in binge drinking in the first three months, but this was not statistically significant.

These results suggest that the government failures in managing Katrina may have had a potentially large effect on mental health and substance use for people living far from the actual disaster. This highlights an important, if under-appreciated, role of the government and disaster-management agencies: preventing increases in perceived background risk that can deteriorate mental health and increase substance use.

The results of this study suggest that cigarette smoking returned to baseline 9 months after Katrina. Even short-term use of cigarettes can have substantial health consequences

and negative externalities according to a report issued by Doe and colleagues (2009). Smoking immediately increases blood pressure, heart rate, and constricts blood vessels, leading to increased risk for sudden strokes and myocardial infarction. Additionally, smoking immediately increases susceptibility to pneumonia. Smoking and second-hand smoke interferes with drug breakdown processes for certain blood-thinners, antidepressants, and anti-seizure medications, causing prescription drugs to not work as effectively and for drugs to potentially stay in the body at dangerous concentrations for longer. Finally, infants and children are especially susceptible to secondhand smoke exposure, so temporary smoking may have affected outcomes of birth weight, sudden infant death syndrome, and infant middle ear and respiratory infections (Doe et al. 2009).

I also find evidence that health insurance coverage increased in the third 90-day period after Katrina, by 5.4% in the results adjusting for population exposure to storm surge from hurricanes. These increases do not persist into other periods, however. On explanation could be that deteriorated mental health or increases in substance use raised temporary demand for health insurance to obtain access to health services to improve mental health or reduce substance use. The increase in health insurance coverage roughly coincides with mental health and substance use returning to baseline levels, adding support to this theory. However, the more likely explanation, perhaps, is that the increase in health insurance is not meaningfully associated with perceived background risk changes from Katrina.

As mentioned in the conceptual model, I cannot determine if increases in perceived background risk influenced these outcomes directly, or indirectly through changes in property values/insurance premiums, longevity expectations, or through changes in the other outcomes. The temporary increase in these measures, however, may lend credibility to the notion that perceived background risks influenced these outcomes directly, as opposed to first influencing property values prices, for example. One previous study found that it took five years before property values recovered following a "near-miss" disaster (Bin and Landry 2013), and my outcomes return to baseline over a 9 month period of time. However, my

study is incapable of answering this question definitively, and this would be an excellent subject for future research.

Research suggests that the most effective government response to the public's miscalculating of small probabilities may be information and education (Becker and Rubinstein 2011; Sunstein 2003). An example of a benefit of information and education is that following a Mississippi River flood, home prices fell only in flooded areas outside the SFHA, but prices did not fall in the SFHA. This may have been because individuals in the SFHA were more likely to know of flooding risks *ex-ante* because of notification and insurance requirements, and so home prices already reflected accurate background risk (Kousky 2010). Similarly, poor mental health and substance use may not have responded to Katrina as dramatically if individuals were better informed of accurate risks in advance. Mandating notification for home owners and renters living in the storm surge plane similar to the notification individuals receive when living in SFHAs may help prevent sudden mental health, substance use, and health insurance responses to unusually destructive hurricanes.

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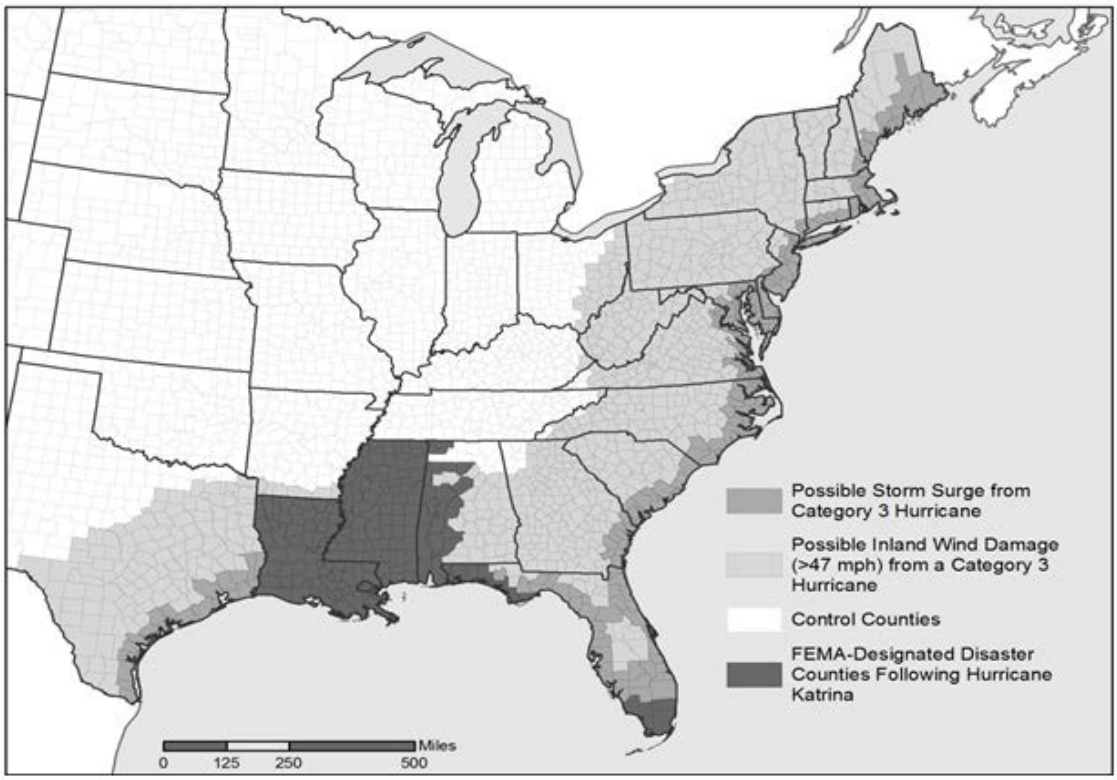

FIGURE 1. HURRICANE RISK REGIONS AND DIRECTLY IMPACTED COUNTIES

Notes: The storm surge counties are identified using the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) system maintained by the National Oceanic and Atmospheric Administration. The wind damage only counties are identified as counties outside of the storm surge region that are vulnerable to strong gale strength wind speeds of 47 MPH from hurricanes (Kaplan and DeMaria 1995).

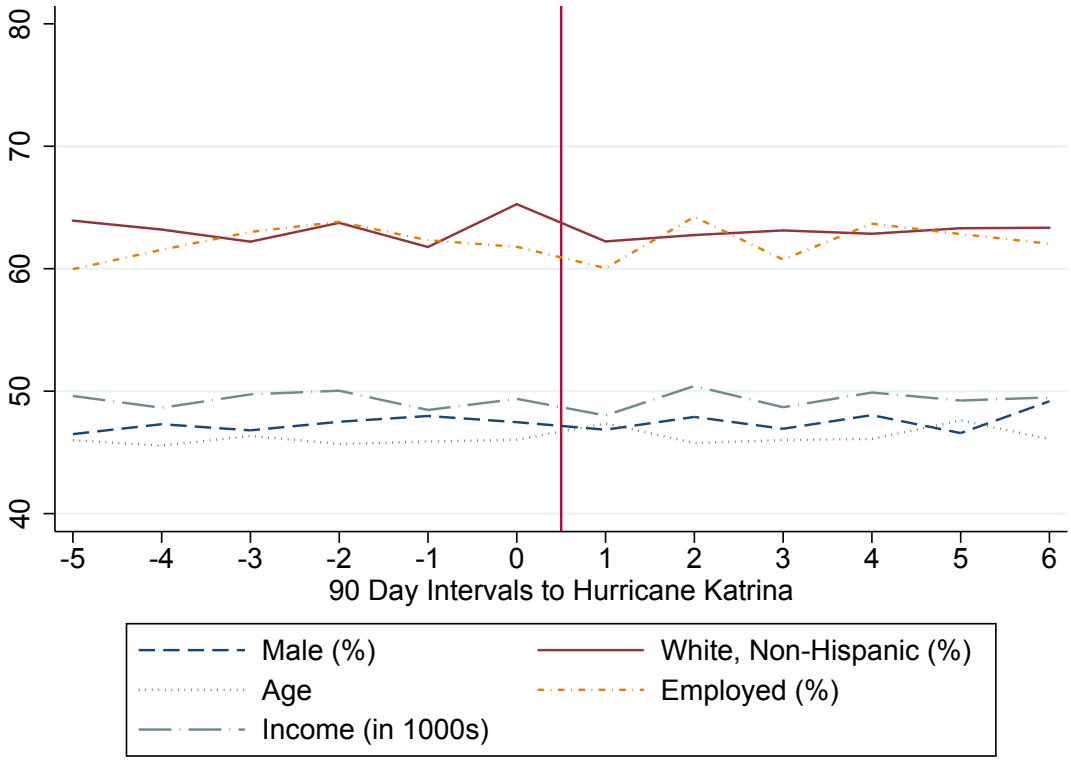

FIGURE 2. BALANCE CHECK OF KEY DEMOGRAPHICS IN NON-DAMAGED STORM SURGE REGION

Notes: The x-axis represents 90 day intervals to Hurricane Katrina, with 0 being days 0-59 before Hurricane Katrina, and 1 being days 15-74 after Hurricane Katrina.

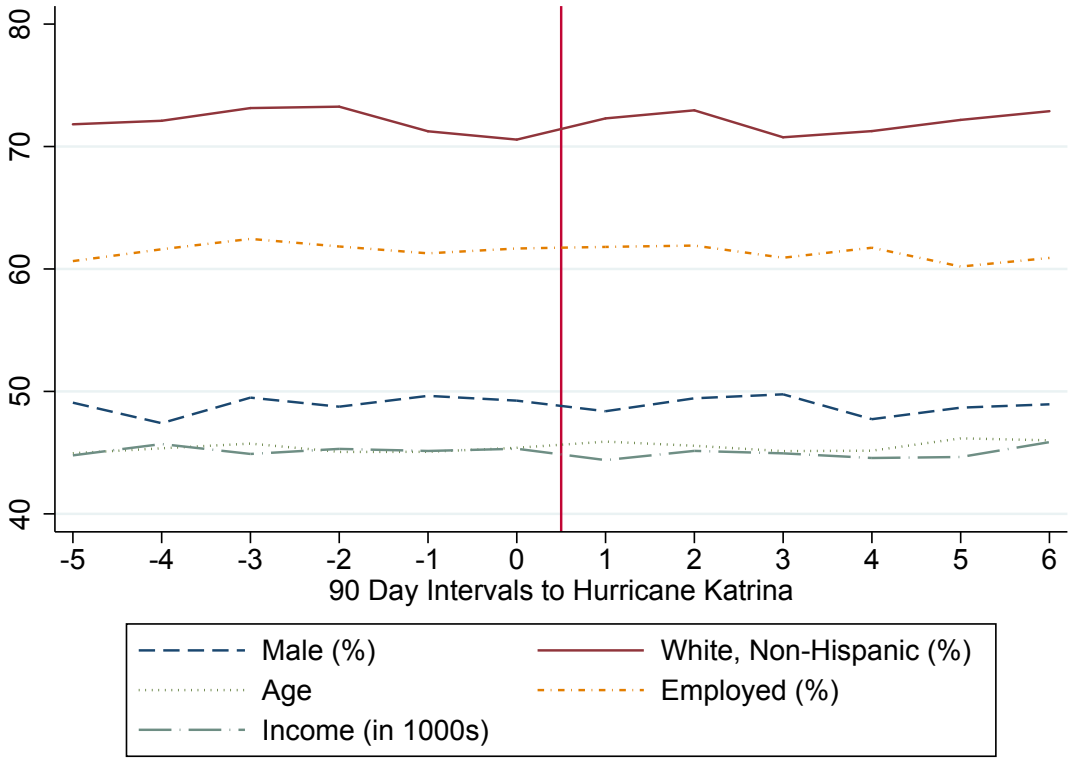

FIGURE 3. BALANCE CHECK OF KEY DEMOGRAPHICS IN CONTROL REGION

Notes: The x-axis represents 90 day intervals to Hurricane Katrina, with 0 being days 0-59 before Hurricane Katrina, and 1 being days 15-74 after Hurricane Katrina.

TABLE 1—DESCRIPTIVE STATISTICS FOR SAMPLE USED IN ANALYSIS, 2002-2007

	N	Mean	Standard Deviation
BRFSS			
Male (%)	1,299,101	0.486	-
Female (%)	1,299,101	0.514	-
White non-Hispanic (%)	1,299,101	0.701	-
Black non-Hispanic (%)	1,299,101	0.083	-
Asian non-Hispanic (%)	1,299,101	0.036	-
Native American non-Hispanic (%)	1,299,101	0.011	-
Hispanic (%)	1,299,101	0.138	-
Missing Race/Ethnicity (%)	1,299,101	0.031	-
Age	1,299,101	45.551	17.547
Junior High (%)	1,299,101	0.045	-
Some High School (%)	1,299,101	0.071	-
High School (%)	1,299,101	0.289	-
Some College (%)	1,299,101	0.269	-
College (%)	1,299,101	0.322	-
Missing Education (%)	1,299,101	0.004	-
Employed (%)	1,299,101	0.616	-
Unemployed (%)	1,299,101	0.053	-
Student (%)	1,299,101	0.046	-
Not Student, Not in Labor Force (%)	1,299,101	0.281	-
Missing Employed Status (%)	1,299,101	0.005	-
Married (%)	1,299,101	0.589	-
Divorced (%)	1,299,101	0.112	-
Widowed (%)	1,299,101	0.064	-
Unmarried and Other Marital Status (%)	1,299,101	0.232	-
Missing Marital Status (%)	1,299,101	0.003	-
Real Household Income (without imputation)	1,125,696	47,563	27,075
Real Household Income (with imputation)	1,299,101	46,552	26,211
Top Household Income Category (%)	1,299,101	0.233	-
Days Mental Health Not Good over Past 30 Days	1,191,228	3.399	7.419
Current Smoker (%) (Past 30 Days)	1,294,512	0.203	-
Binge Drinker (%) (Past 30 Days)	1,276,796	0.157	-
Health Insurance (<65 Years of Age) (%)	980,030	0.825	-
Merged Outside Data			
State-Level Unemployment Rate (%)	1,299,101	5.338	1.069
Real Price of Pack of Cigarettes (in dollars)	1,299,101	3.95	0.66
Real Price of 6-Pack of Heineken Beer (in dollars)	1,299,101	7.34	0.36
State-Level Smoke-Free Air Law Index (scale of 1-9)	1,299,101	3.620	3.381
General Medicaid Income Eligibility (% of Federal Poverty Level)	1,299,101	188.156	28.159
Reside in Category 3 Hurricane Storm Surge County (%)	1,299,101	0.244	-
Population Exposure w/in Storm Surge Counties (%)	342,524	0.411	0.264
County-Level Hurricane Katrina Evacuees Per 1,000	1,299,101	0.526	0.781
Distance to New Orleans	1,299,101	1,128	467

Notes: All prices are in 2004 dollars. Missing observations for poor mental health are mostly due to this outcome being collected by only 23 states in 2002.

TABLE 2—EVENT STUDY OF THE EFFECT OF HURRICANE KATRINA IN STORM SURGE COUNTIES, 2002-2007

	(1)	(2)	(3)	(4)
	Poor Mental Health	**Binge Drinking**	**Smoking**	**Health Insurance**
Pre-Hurricane Katrina				
450-539 Days Before HK * Storm Surge Region	0.200	-0.005	0.004	0.004
	[0.149]	[0.007]	[0.010]	[0.008]
360-449 Days Before HK * Storm Surge Region	0.223	-0.016*	0.011	-0.011
	[0.194]	[0.009]	[0.009]	[0.011]
270-359 Days Before HK * Storm Surge Region	0.100	0.001	0.005	-0.023**
	[0.166]	[0.009]	[0.010]	[0.011]
180-269 Days Before HK * Storm Surge Region	-0.156	-0.011	0.000	-0.007
	[0.195]	[0.007]	[0.008]	[0.010]
90-179 Days Before HK * Storm Surge Region	0.057	-0.009	0.002	0.009
	[0.193]	[0.008]	[0.008]	[0.008]
0-89 Days Before HK * Storm Surge Region	-0.086	-0.012*	0.008	-0.011
	[0.213]	[0.007]	[0.008]	[0.009]
P-value of Joint Significance	0.486	0.363	0.861	0.198
Post-Hurricane Katrina				
15-104 Days After HK * Storm Surge Region	0.293*	0.002	0.024***	-0.008
	[0.167]	[0.008]	[0.008]	[0.010]
105-194 Days After HK * Storm Surge Region	-0.067	-0.003	0.020***	0.011
	[0.163]	[0.007]	[0.007]	[0.009]
195-284 Days After HK * Storm Surge Region	0.061	-0.017*	0.017*	0.024**
	[0.188]	[0.010]	[0.009]	[0.009]
285-374 Days After HK * Storm Surge Region	-0.191	-0.016*	-0.012	-0.002
	[0.184]	[0.009]	[0.008]	[0.012]
375-464 Days After HK * Storm Surge Region	0.103	0.000	0.000	0.005
	[0.146]	[0.008]	[0.009]	[0.008]
465-554 Days After HK * Storm Surge Region	0.082	-0.003	0.013	0.004
	[0.192]	[0.009]	[0.009]	[0.011]
555+ Days After HK * Storm Surge Region	0.063	-0.010*	0.002	0.003
	[0.087]	[0.005]	[0.005]	[0.005]
Individual Characteristic Controls	Yes	Yes	Yes	Yes
State / County Controls	Yes	Yes	Yes	Yes
County Fixed Effects	Yes	Yes	Yes	Yes
Year-by-Month Fixed Effects	Yes	Yes	Yes	Yes
Risk Region-by-Month Fixed Effects	Yes	Yes	Yes	Yes
N	1,191,228	1,276,796	1,294,512	980,030
Dependent Variable Mean	3.345	0.122	0.197	0.849

Notes: Each column presents results from one regression model. Coefficients are in reference to the difference between the storm surge region and control region 1.5 years (540 days or more) before Hurricane Katrina. State / County Controls include distance to New Orleans in the post-Katrina period, evacuees per capita in the post-Katrina period, unemployment rate, Medicaid insurance eligibility, beer prices (binge drinking), cigarette prices (smoking model), and smoke-free air laws (binge drinking and smoking models). *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

TABLE 3—EVENT STUDY OF THE EFFECT OF HURRICANE KATRINA IN STORM SURGE COUNTIES BY POPULATION EXPOSURE, 2002-2007

	(1)	(2)	(3)	(4)
	Poor Mental Health	**Binge Drinking**	**Smoking**	**Health Insurance**
Pre-Hurricane Katrina				
450-539 Days Before HK * Population Exposure	0.249 [0.263]	-0.005 [0.013]	0.001 [0.016]	-0.004 [0.015]
360-449 Days Before HK * Population Exposure	0.347 [0.299]	-0.018 [0.014]	0.039** [0.017]	-0.031 [0.021]
270-359 Days Before HK * Population Exposure	0.291 [0.277]	0.007 [0.015]	0.024 [0.016]	-0.011 [0.017]
180-269 Days Before HK * Population Exposure	-0.006 [0.363]	-0.013 [0.013]	-0.007 [0.015]	-0.023 [0.018]
90-179 Days Before HK * Population Exposure	0.045 [0.345]	-0.006 [0.013]	-0.006 [0.014]	0.003 [0.013]
0-89 Days Before HK * Population Exposure	0.071 [0.399]	-0.003 [0.012]	0.023* [0.013]	-0.012 [0.017]
P-value of Joint Significance	0.818	0.801	0.081	0.647
Post-Hurricane Katrina				
15-104 Days After HK * Population Exposure	0.675** [0.262]	0.020 [0.016]	0.049*** [0.016]	-0.004 [0.018]
105-194 Days After HK * Population Exposure	-0.009 [0.270]	0.003 [0.013]	0.026** [0.013]	0.016 [0.015]
195-284 Days After HK * Population Exposure	0.231 [0.319]	-0.016 [0.014]	0.022 [0.017]	0.046*** [0.018]
285-374 Days After HK * Population Exposure	-0.150 [0.292]	-0.017 [0.015]	0.007 [0.014]	-0.006 [0.021]
375-464 Days After HK * Population Exposure	0.250 [0.272]	0.018 [0.015]	-0.003 [0.016]	0.017 [0.014]
465-554 Days After HK * Population Exposure	0.335 [0.379]	-0.004 [0.015]	0.024 [0.015]	0.010 [0.017]
555+ Days After HK * Population Exposure	0.245 [0.150]	-0.003 [0.010]	0.013 [0.009]	0.003 [0.010]
Individual Characteristic Controls	Yes	Yes	Yes	Yes
State / County Controls	Yes	Yes	Yes	Yes
County Fixed Effects	Yes	Yes	Yes	Yes
Year-by-Month Fixed Effects	Yes	Yes	Yes	Yes
Risk Region-by-Month Fixed Effects	Yes	Yes	Yes	Yes
N	1,191,228	1,276,796	1,294,512	980,030
Dependent Variable Mean	3.345	0.122	0.197	0.849

Notes: Each column presents results from one regression model. Coefficients are in reference to the difference between the storm surge region and control region 1.5 years (540 days or more) before Hurricane Katrina. State / County Controls include distance to New Orleans in the post-Katrina period, evacuees per capita in the post-Katrina period, unemployment rate, Medicaid insurance eligibility, beer prices (binge drinking), cigarette prices (smoking model), and smoke-free air laws (binge drinking and smoking models). *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

ONLINE TABLE 1—EVENT STUDY OF THE EFFECT OF HURRICANE KATRINA IN STORM SURGE COUNTIES, KEEPING 15 DAYS AFTER KATRINA, 2002-2007

	(1)	(2)	(3)	(4)
	Poor Mental Health	**Binge Drinking**	**Smoking**	**Health Insurance**
Pre-Hurricane Katrina				
450-539 Days Before HK * Storm Surge Region	0.198	-0.005	0.004	0.004
	[0.149]	[0.007]	[0.010]	[0.008]
360-449 Days Before HK * Storm Surge Region	0.227	-0.015	0.012	-0.010
	[0.194]	[0.009]	[0.009]	[0.011]
270-359 Days Before HK * Storm Surge Region	0.093	0.000	0.004	-0.023**
	[0.165]	[0.009]	[0.010]	[0.011]
180-269 Days Before HK * Storm Surge Region	-0.156	-0.011	0.000	-0.007
	[0.196]	[0.007]	[0.008]	[0.010]
90-179 Days Before HK * Storm Surge Region	0.055	-0.009	0.002	0.009
	[0.193]	[0.008]	[0.008]	[0.008]
0-89 Days Before HK * Storm Surge Region	-0.080	-0.012	0.009	-0.011
	[0.213]	[0.007]	[0.008]	[0.009]
P-value of Joint Significance	0.498	0.403	0.831	0.195
Post-Hurricane Katrina				
0-104 Days After HK * Storm Surge Region	0.292*	0.000	0.020***	-0.006
	[0.160]	[0.007]	[0.007]	[0.009]
105-194 Days After HK * Storm Surge Region	-0.067	-0.003	0.019***	0.011
	[0.164]	[0.007]	[0.007]	[0.009]
195-284 Days After HK * Storm Surge Region	0.060	-0.017*	0.017*	0.024**
	[0.188]	[0.010]	[0.009]	[0.009]
285-374 Days After HK * Storm Surge Region	-0.186	-0.015	-0.011	-0.002
	[0.185]	[0.009]	[0.008]	[0.012]
375-464 Days After HK * Storm Surge Region	0.095	0.000	-0.001	0.005
	[0.146]	[0.008]	[0.009]	[0.008]
465-554 Days After HK * Storm Surge Region	0.080	-0.003	0.013	0.004
	[0.192]	[0.009]	[0.009]	[0.011]
555+ Days After HK * Storm Surge Region	0.062	-0.010*	0.002	0.003
	[0.086]	[0.005]	[0.005]	[0.005]
Individual Characteristic Controls	Yes	Yes	Yes	Yes
State / County Controls	Yes	Yes	Yes	Yes
County Fixed Effects	Yes	Yes	Yes	Yes
Year-by-Month Fixed Effects	Yes	Yes	Yes	Yes
Risk Region-by-Month Fixed Effects	Yes	Yes	Yes	Yes
N	1,200,183	1,285,765	1,303,596	986,495
Dependent Variable Mean	3.346	0.122	0.197	0.849

Notes: Each column presents results from one regression model. Coefficients are in reference to the difference between the storm surge region and control region 1.5 years (540 days or more) before Hurricane Katrina. State / County Controls include distance to New Orleans in the post-Katrina period, evacuees per capita in the post-Katrina period, unemployment rate, Medicaid insurance eligibility, beer prices (binge drinking), cigarette prices (smoking model), and smoke-free air laws (binge drinking and smoking models). *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.