Do Natural Disasters Change Risk Perceptions and Policy Preferences about Climate Change?*

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Abstract

As effects from climate change are increasingly realized, concerns about the intensity and frequency of natural disasters are similarly rising. In an era of persistent climate inaction at the national level, whether and how tangible 'evidence' of climate impacts influences opinions about climate change is therefore important, particularly for understanding the potential for local climate action. We study the effect of exposure to natural catastrophes associated with climate change – such as floods, fires, severe storms, and hurricanes – on risk perceptions and policy preferences about climate change. We analyze US public opinion data at the county level from 2014 to 2018 using a difference-in-differences strategy and by building a matched sample that is representative of all counties, showing that exposure to natural disasters increases the likelihood of both believing that climate change will harm people and supporting the adoption of some measures to address it. Rather than purely driven by long-term ideological or partisan beliefs, this suggests that the climate change preference formation process can include updates based on individuals' personal circumstances.

Keywords: Climate Change, Natural Disasters, Risk Perceptions, Policy Preferences.

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1 Introduction

Unmitigated climate change promises a myriad of impacts to the environment and for society. Among its most consequential effects are climate variability and weather extremes that can lead to greater risks of some natural disasters with potentially devastating impacts (Van Aalst, 2006; Lippsett, 2012). Natural disasters – including droughts, floods, and hurricanes – already threaten human well-being and severe damage across the United States each year. In 2019, for example, homes and thousands of acres of land were engulfed by fires in the West and extreme flooding events inundated towns along the Eastern seaboard. There is substantial evidence that the global climate, which contributes to the advent of many types of natural disasters, is changing at present and will continue to transform well into the future. It is unsurprising that this knowledge is often accompanied by concerns about the potential for natural disasters that are expected to become increasingly intense and more frequent. The question seems to remain, however: can exposure to an array of natural catastrophes associated with a warming planet affect people's risk perceptions and policy preferences about climate change?[1]

The natural disaster literature related to the political sphere has experienced a notable growth in the last decade, though much of this research focuses on the impact of such events on incumbents' vote share (Healy and Malhotra, 2010; Gasper and Reeves, 2011; Achen and Bartels, 2016), turnout (Sinclair et al., 2011; Chen, 2013; Lasala-Blanco et al., 2017), citizens' attitudes (Carlin et al., 2014; Fair et al., 2017; Kosec and Mo, 2017), and the blame attribution process (Malhotra and Kuo, 2008; Maestas et al., 2008; Gomez and Wilson, 2008). Relatively less is known about the effect of natural catastrophes on concerns and policy opinions about about climate change.[2] Importantly, though, there is evidence that individuals can perceive a changing climate (Howe et al., 2013) and that such events may contribute to changing beliefs about global warming, including whether it is happening (Howe and Leiserowitz, 2013; Zaval et al., 2014; Myers et al., 2013).

[1] For practical reasons, we use the terms terms global warming and climate change interchangeably throughout this paper.

[2] One notable exception is Konisky et al. (2016), though they focus on concerns about climate change but not on victims' policy preferences.

However, these studies often focus on the repercussions of only one or a few types of natural disasters such as flooding (Whitmarsh, 2008; Spence et al., 2011). Further, although there are some exceptions, including Myers et al. (2013), much of the relevant literature uses cross-sectional rather than longitudinal data and does not provide clear causal evidence about the relationship between natural disasters and public opinion about climate change.

Exploring people's opinions about climate change is important for several reasons. For example, discussions about climate change often dominate the political agenda, both in the US and across the world. When an issue becomes more salient, we expect it will have greater relevance for voters (Petrocik, 1996; Bélanger and Meguid, 2008). Therefore, individuals' views about climate change may be an important predictor of electoral choices. Research also suggests that voter preferences have a relevant role for explaining the policy decisions that are ultimately adopted (Brooks and Manza, 2008; Lupu and Pontusson, 2011). Individuals that may be more conscious of climate change through tangible trends such as more frequent experiences with natural disasters, for example, might then contribute to the adoption of mitigation measures. Considering the time-sensitive nature of effective climate action, such a relationship could be especially consequential.

We focus on risk perceptions and policy preferences about climate change in this paper. As many of the political debates about changes in global weather patterns include whether they will cause harm to humans (i.e., risk perceptions) and what actions, if any, should be taken to address it (i.e., policy preferences), understanding the causal link between natural disasters and public opinion on these topics is therefore highly relevant. While perspectives about climate change are often explained in part by long-term factors such as partisanship and ideological stances (Fielding et al., 2012), exposure to tangible 'evidence' of climate change via natural disasters may also affect opinions regarding climate change and appropriate mitigation measures.[3]

We propose three explanations for how natural disasters might affect these opinions. The first is

[3]Although it is difficult to link a disaster event to global warming, natural disasters that are becoming more severe and frequent are trends consistent with a changing climate. Therefore, although climate change cannot be personally experienced, an increase in declared flooding disasters and other natural catastrophes overall could be considered tangible 'evidence' of climate change effects. Said otherwise, "[c]limate change itself cannot be directly experienced but its impacts can" (Whitmarsh, 2008, 367).

biased assimilation, which refers to instances when information is interpreted to fit with prior-held beliefs (Lord et al., 1979). Although victims of disaster may have ‘evidence’ about the consequences of climate change, they could reconcile such information with their ideological beliefs, ultimately leaving their risk perceptions and policy preferences unchanged. The second explanation, selective persuasion, describes situations when individuals update their risk perceptions but not their preferences. This may happen because the latter are much ‘sticker’ and harder to modify, tending to be better explained by slow-moving variables such as partisanship instead (Campbell et al., 1960). Third, double persuasion refers to exposure to natural disaster shifting both risk perceptions and policy preferences. There is some evidence that suggests individuals can update their policy preferences after shocks that significantly deteriorate their living conditions, including unemployment (Margalit, 2013) and crime victimization (Visconti, 2019). Each of these explanations offers theoretically plausible accounts to understand reactions to natural disasters associated with climate change, so we use this study to learn whether reactions to catastrophes are better represented by a biased assimilation, selective persuasion, or double persuasion explanation.

We study the relationship between natural disasters and our outcomes of interest using public opinion data regarding global warming at the county level from the Yale Project on Climate Change Communication (YPCCC) project, which was gathered from thousands of respondents and extrapolated via multilevel regression and poststratification (Howe et al., 2015). Analyzing data at the county level has several advantages. For example, traditional survey data measured with nationally representative surveys do not necessarily capture the geographic variability across counties in the US. This issue becomes particularly relevant when studying the impact of natural disasters because not all counties have the same probability of being exposed to a catastrophe. Therefore, only considering a national survey comprised from a relatively small number of counties could obscure the analysis. Further, given persistent climate inaction at the national level, exploring risk perceptions and policy preferences about climate change at the local level may be important for better understanding the potential for local action as the global climate continues to change.[4]

[4]Although we use data at the county level, we often discuss individuals and people’s opinions. We do that because that data represents an average of what individuals at the local level believe.

Notably, however, studying the impact of natural disasters comes with multiple methodological challenges that should be considered. First, although the origin of extreme weather events might be exogenous, some areas of the country may be more likely to be exposed than others. Therefore, exposed and unexposed areas could be different based on their observed as well as unobserved covariates. To address this concern, we implement a difference-in-difference (DID) design. By assuming that the outcomes move in parallel trends when there is no treatment, this allows us to engage in an analysis even with control and exposed groups that have different characteristics (Angrist and Pischke, 2014).

We find that exposure to natural disasters at the county level in the two years prior to a survey year affects risk perceptions about climate change. Further, our findings indicate that exposure to natural catastrophes at the country level also changes policy preferences. These results provide support for a double persuasion explanation – exposure to natural disasters can make people more conscious about the risks associated with climate change *and* more likely to support mitigation measures.

This paper aims to offer several contributions to the existing literature. First, given the relatively limited empirical work identifying causality between climate opinions and a range of natural disasters associated with climate change, we advance this research agenda by providing evidence from a difference-in-difference design to document this causal link, and we construct a representative matched sample as robustness check. Given the relative paucity of national climate action to date and the rapidly closing window for effective mitigation efforts, we also hope to provide additional insights into the potential for local climate efforts with our attention to county-level public opinion and disaster data. Finally, we offer evidence that supports the double persuasion explanation, which suggests that natural disasters can change victims' risk perceptions as well as their policy preferences about climate change to better understand the factors that affect public opinion about climate change, which is known to the United Nations as the most relevant political issue of our time.[5]

[5] See: "United Nations: Climate Change."

2 Theoretical Explanations

We present three main explanations for how risk perceptions and policy preferences may shift because of exposure to natural disasters that are associated with climate change, as illustrated in Figure 1, and aim to explore which of these seems to better reflect actual responses to natural disasters. Importantly, we consider both risk perceptions and policy preferences in broad terms here, examining potential changes on average. While we recognize that there may be differences based on the type of concern (e.g., personal harm or consequences for others) or policy alternative and we recognize that it could be useful to develop diverse theoretical expectations for each, we begin at the most basic level to further explore the causal relationships that may exist and provide foundational insights that could guide future research agendas.

The first explanation that we consider is *biased assimilation*, which refers to "[t]he tendency to interpret new evidence in a manner that allows maintenance of one's prior belief" and may explain instances when exposure to natural disaster changes neither risk perceptions nor policy preferences (Druckman and McGrath, 2019, 113). As shown in the first panel of Figure 1, an extreme flooding event, for example, may not necessarily change concern about climate change or result in a greater conviction to take mitigation action (Whitmarsh, 2008). There is substantial evidence suggesting that people tend to evaluate empirical evidence in a biased way, especially when they hold strong opinions (Lord et al., 1979; Munro and Ditto, 1997; Dandekar et al., 2013). Given the partisan and controversial nature of climate change at present, it therefore seems reasonable to expect that disaster victims might interpret such information in a biased manner. For example, an individual who does not believe climate change is human driven might interpret a severe flooding event as an 'act of God' or a random event not necessarily connected with human activities. In this case, we would expect no changes in risk perceptions or policy preferences.

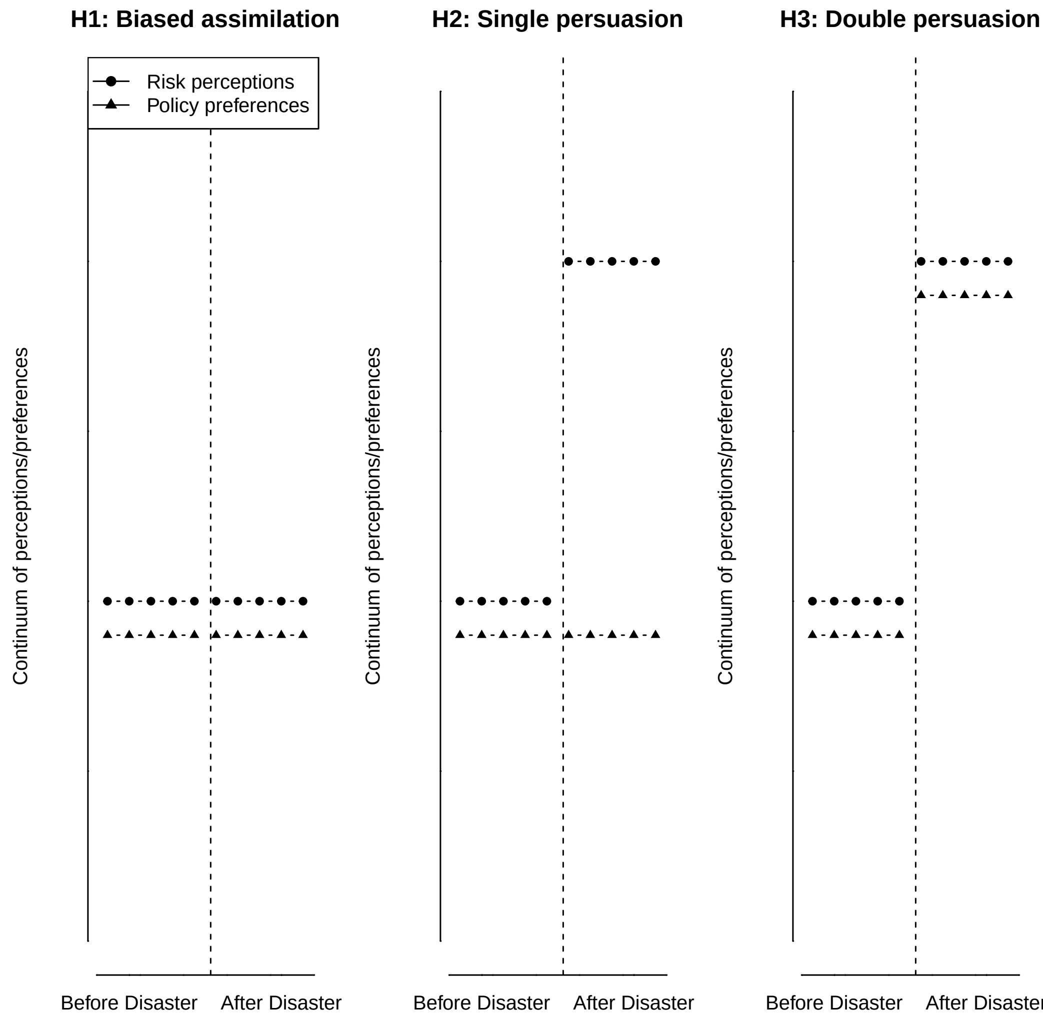

Figure 1: Theoretical explanations

On the other hand, given some evidence that suggests natural disasters may elicit meaningful changes in concern about climate change (Spence et al., 2011), we also propose that natural disasters could change risk perceptions. Given the relatively sticky nature of policy preferences, however, individuals' risk perceptions may change without also shifting their preferences about mitigation measures. Often, policy preferences tend to be explained by long-term variables such as people's ideologies (Jost, 2006) or partisanship (Campbell et al., 1960). For instance, individuals that place themselves on the left side of the ideological continuum are more likely to support redistribution (Alesina and Giuliano, 2009) and welfare policies (Shapiro, 2009) when compared with those who find themselves on the right side. Therefore, because we would not expect a natural disaster to modify the political identity of citizens, we might also expect that they would not update their political preferences regarding climate change. Indeed, there are some findings that suggest natural disasters do not change victims' policy preferences about climate change (Whitmarsh, 2008). We refer to such a scenario wherein risk perceptions change but not policy preferences as *single persuasion*, illustrated in the second panel of Figure 1.

It also seems plausible, though, that exposure to natural disasters would elicit meaningful changes in risk perceptions as well as policy preferences about climate change, which we refer to as *double persuasion.* This may occur because natural disasters are "easily observable variations" that "have been shown to affect political preferences" (Druckman and Lupia, 2016, 15). Further, individuals' risk perceptions and policy preferences might be motivated by self-interest and, as a result, will be updated when individuals' standards of living are affected, or if they feel vulnerable to changing circumstances (Erikson and Stoker, 2011). Therefore, the post-disaster context might motivate victims to re-evaluate and update their previous opinions. Even if individuals are myopic (Healy and Malhotra, 2009), they could also be persuaded and update their priors based on the existence of new and relevant information such as tangible 'evidence' of climates change. We can understand this as a learning process based on the assimilation of new information (Gerber and Green, 1999), following a Bayesian learning approach.

3 Data and Design

Studying the political effects of natural disasters, albeit a topic of interest for many scholars and policymakers alike, is not a simple task. There may be hidden biases when correlating exposure between an extreme whether event and political outcomes, for example, which could confound our analysis and, ultimately, undermine important inferences. To address such omitted variable concerns, we exploit cross-time and cross-country variation in exposure to natural disasters in the US using a generalized difference-in-difference design (i.e., two-way fixed effect regression).

This design relies "on the assumption that the important unmeasured variables are either time-invariant group attributes or time-varying factors that are group invariant" (Wing et al., 2018, p.457). Therefore, under the parallel trend assumption, any divergence from these paths can be interpreted as a treatment effect (Angrist and Pischke, 2014). While it is impossible to randomly assign a natural disaster to some locales but not others, this design strengthens our causal claims regarding the relationship between natural disasters and public opinion about climate change. This is in contrast to other designs that control for an array of cross-sectional covariates alone.

The primary outcomes of interest are risk perceptions and policy preferences about climate change. Such concerns and opinions, however, are not constant across, or even within, states. Rather, because there is considerable variation in public opinion regarding a changing global climate across the United States (Howe et al., 2015), relying on aggregate national- or state-level data could obscure important insights at a local level. For example, although 57 percent of adults across the country believe, on average, that global warming is human caused, that conviction falls to 44 percent in West Virginia; it remains mostly true, however, in Kanawha County (53 percent), home to West Virginia's capital city (Marlon et al., 2018).[6]

To account for such variation and explore effects at the county-level, we draw on a series of nationally representative public opinion surveys conducted for the Yale Project on Climate Change Communication and the George Mason Center for Climate Change Communication (Howe et al., 2015). This data set is constructed and frequently updated using multilevel regression and post-stratification (MRP), which draws on responses from thousands of individuals and "individual-level demographic predictors, state-, district-, and county-level random effects, random effects based on the year of the survey and survey mode, and geographic-level covariates" (Howe et al., 2015, 597).[7] We focus on survey data for 2014, 2016, and 2018. Estimates reflect data for all counties and county-equivalents across the US.

To explore risk perceptions about climate change, we use the estimated percentages of respondents that believe global warming will cause a moderate or great deal of harm to them personally

[6] Based on 2018 data.

[7] In 2018, n > 22,000 respondents. See Marlon et al. (2018) and Howe et al. (2015) for more information.

(Personal), people in the US (United States), or future generations (Future Generations). While many express concerns about the realization of climate impacts in the future and for others, there is often less concern about personally experiencing adverse consequences.[8] Analyzing these outcomes therefore allows us to explore different types of risk perceptions that may be affected differently by exposure to a natural disaster.

We also consider an array of policy preferences, including both general mitigation measures and more specific policy proposals in our study. For example, we explore support for funding renewable energy sources broadly (Fund Renewables) using support for a policy to "[f]und more research into renewable energy sources, such as solar and wind power." Whether respondents agreed generally with managing carbon dioxide (CO_2) that is a primary contributor to climate change (Regulate CO_2) was assessed using support for a policy to "[r]egulate carbon dioxide (the primary greenhouse gas) as a pollutant." While it is useful to understand whether respondents agree with emissions regulation and turning to more renewable energy sources in principle, it is also critical to gauge whether there is support for proposals that would, if implemented, meaningfully facilitate climate mitigation. More specific policy proposals are therefore also considered, such as restrictions emissions from some coal-fired power plants (Limit CO_2), which was assessed via support for a proposal to: "[s]et strict carbon dioxide limits on existing coal-fired power plants to reduce global warming and improve public health. Power plants would have to reduce their emissions and/or invest in renewable energy and energy efficiency. The cost of electricity to consumers and companies would likely increase." Finally, we consider support for implementing renewable portfolio standards (Support RPS) via responses to "[r]equire electric utilities to produce at least 20% of their electricity from wind, solar, or other renewable energy sources, even if it costs the average household an extra $100 a year." See Appendix A for full question wording and response options.

We provide summary statistics for the outcomes of interest in Table 1. Although the majority of respondents (63 percent) believe that global warming will harm future generations and those in the United States generally (51 percent), only a minority (35 percent) express concern that it will harm

[8] See Table 1.

them personally. Therefore, while many seem to subscribe to the scientific consensus that climate change is happening and presents a considerable threat to human health and well-being, there often remains a disconnect between a warming planet and risks for oneself. Further, most support all of the aforementioned policy proposals, on average. For example, many indicate support for funding renewables (79 percent) and regulating CO2 emissions generally (72 percent). There is less support, however, for the more fleshed out proposals on "strict" limits on some emitters (61 percent) and implementing renewable portfolio standards (59 percent). Taken together, this seems to suggest that, while many agree in principle with taking measure to reduce greenhouse gas emissions, there is relatively less support for policy proposals that have explicit restrictions or expectations that could be accompanied by personal costs.

Table 1: Descriptive Statistics

Variables	Mean	SD	Max	Min
Personal	0.35	0.05	0.59	0.25
United States	0.51	0.05	0.73	0.39
Future Generations	0.63	0.06	0.82	0.47
Limit CO_2	0.61	0.07	0.86	0.32
Regulate CO_2	0.72	0.04	0.85	0.57
Support RPS	0.59	0.05	0.76	0.45
Fund Renewables	0.79	0.04	0.91	0.61
Natural Disasters	0.43	0.50	1	0

The treatment reflects exposure to one or more natural disasters in the two years prior to a survey year (2014, 2016, 2018). For example, a county that experienced a major flooding event in 2012 and/or 2013 would be considered treated for the 2014 survey year. We use a two-year treatment to avoid overlap between the surveys. We construct the treatment variable using Federal Emergency Management (FEMA) data for federally declared disasters that could be associated with climate change, which includes: floods, severe storms, tornadoes, tsunamis, ice storms, mud/landslides, snow storms, fires, hurricanes, and coastal storms per county in a given year.[9] While individuals in one region of the country may be more likely to experience certain kinds of natural disasters more than others (e.g., hurricanes), each of these disasters could be influenced by climate change and, therefore, are considered together here. This is in contrast to many other studies that consider only one or several natural disasters, such as flooding (Whitmarsh, 2008; Spence et al., 2011). In Appendix C, we summarize the research connecting these different types of disasters with climate change. Disasters without a clear connection to climate change (e.g., earthquakes, chemical incidents, terrorist attacks) were excluded and used in a falsification test in Appendix F.

Notably, assessing the relationship between our outcomes of interest and the treatment relies on the assumption that individuals connect a disaster in their county with climate change and update or maintain their opinions accordingly (Druckman and Lupia, 2016). Because we cannot directly observe whether individuals form such an association, however, we estimate the intention to treat (ITT). More specifically, we study the effect of being assigned to associate a natural disaster with climate change via the effect of exposure. Although some may have direct experience with the effects of a natural disaster, exposure is defined broadly here to indicate that individuals live in a county with a declared disaster event and, presumably, witnessed its effects. The ITT estimand is useful for this study because it is commonly used to explore the effectiveness of an intervention, which may include both compliers and non-compliers, and whether it changes outcomes in a 'real-world' setting. Non-compliance is therefore less of a concern when this estimand is applied instead of an average treatment effect that assumes all units have received the treatment (Gerber and Green, 2012). Simply put, using the ITT estimand allows us to better explore the impact of exposure to a natural disaster on people's climate change risk perceptions and policy preferences at the county-level, the aim of this study. As shown in Table 1, 43 percent of the units of observation (county-years) were exposed to a disaster that could be associated with climate change.

The unit of analysis is county-year, meaning that each outcome represents the percentage of the public that supports a statement in a given county in a given year. For example, Guadalupe

[9] FEMA and the Federal Government cannot vouch for the data or analyses derived from these data after the data have been retrieved from the Agency's website(s) and/or Data.gov.

County, New Mexico in 2014 is one unit of observation in our sample. To identify the political effects of natural disasters that can be associated with climate change, we compare differences in risk perceptions and policy preferences between those counties exposed to a declared natural disaster and those that were not exposed. This design is implemented using the following OLS regression:

$$Y_{it} = \alpha + \beta T_{it} + \sigma_i + \omega_t + \varepsilon_{it} \tag{1}$$

Y represents the outcome of interest (i.e., risk perceptions or policy preferences) in county i and year t. T corresponds to a binary indicator that identifies whether at least one disaster occurred in that county. σ represents county fixed effects and ω_t are year fixed effects. β is the coefficient of interest.

It is important to note here that there are two main concerns when estimating uncertainty. First, the assignment of weather events can be highly correlated across space (Cooperman, 2017). Second, having data collected across time can imply serial correlation (Pindyck and Rubinfeld, 1998). Therefore, the standard errors need to account for both spatial and serial correlation. We compute Conley standard errors, which allows for spatial correlations between counties whose centroids are within 100 km of each other and a lag length of 4 years. This nonparametric estimation was developed by Hsiang (2010) and implemented in R by Christensen and Fetzer (2017). In Appendix G, as a robustness check, we also compute heteroscedasticity-consistent standard errors that allow us to account for the uncertainty associated with using estimates as outcomes (Lewis and Linzer, 2005), and we follow a more standard approach by clustering standard errors at the level of treatment assignment (i.e., county). The main findings are not conditional on how we estimate uncertainty.

4 Results: Main analysis

Our analysis using a generalized difference-in-difference design suggests that exposure to one or more natural disasters increases the perceived threat of climate change. We present the results of the effect of exposure to natural disasters in Figure 2. The first panel shows that exposure to natural disasters elicited a 0.04 (CI: [0.02-0.06]) standard deviation unit increase in the concern that climate change will produce personal risk. Exposure similarly raises concerns about harm to the US by 0.02 (CI: [-0.0004-0.05]) and future generations by 0.02 (CI: [-0.004-0.05] standard deviation units.

The second panel of Figure 2 indicates that one or more declared disasters in a county also increases support for some mitigation measures. Regarding the more general policy measures, exposure to the treatment elicited a 0.02 (CI: [-0.0004-0.04]) standard deviation unit increase in support for funding renewable energy. The effect for regulating CO_2 is only 0.01 (CI: [-0.02-0.04]) standard deviation units, however, which is the only clear null result. We suggest that this could be a consequence of a ceiling effect, as there is often robust support for such broad measures. Aggregated at the national level in 2018, for example, support for regulating CO_2 broadly had 77 percent approval (Marlon et al., 2018). Notably, though, we find that natural disasters increase approval for both of the more specific policy proposals. For "strict" limits on existing coal-fired power plants by 0.10 (CI: [0.06-0.14]) standard deviation units and increase support for renewable portfolio standards by 0.06 (CI: [0.03-0.09]) standard deviation units.

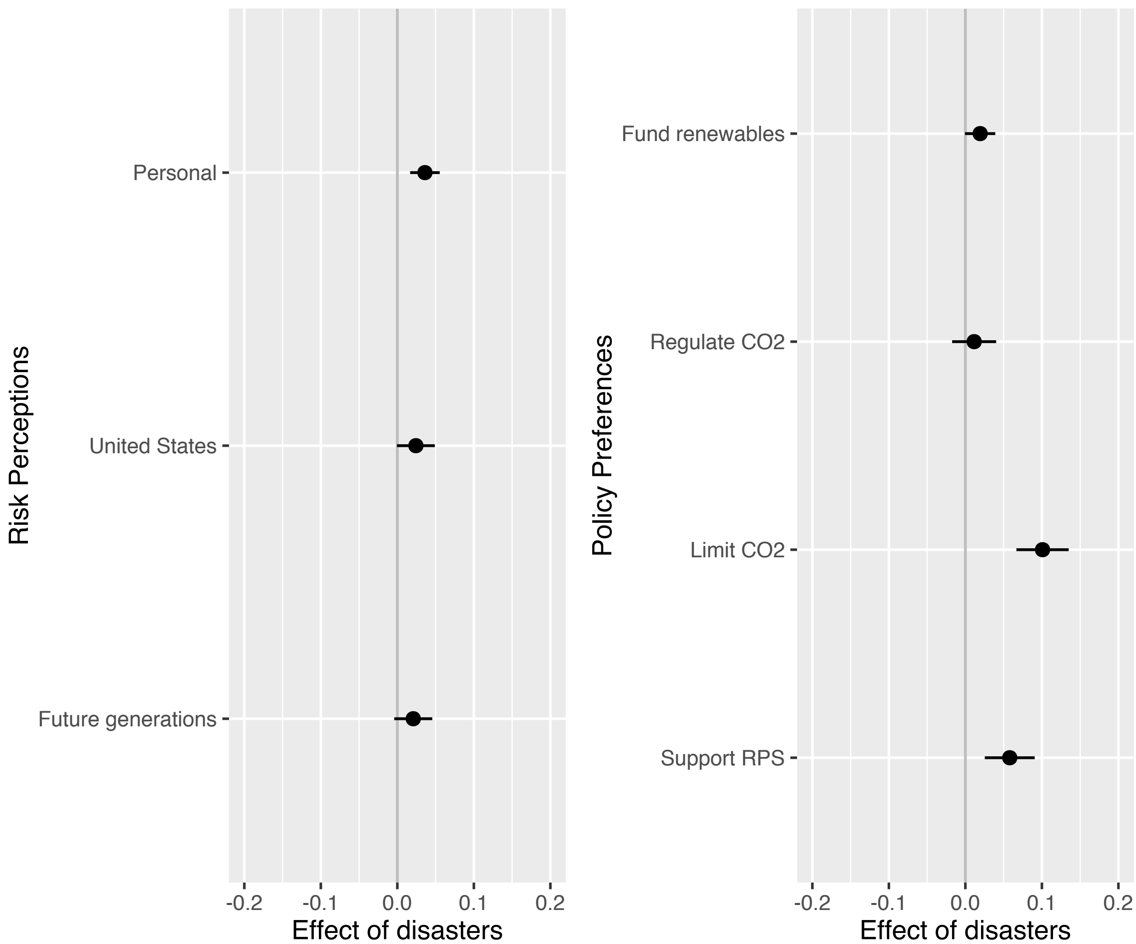

Figure 2: Results using a difference-in-differences design

Taken together, these results suggest that exposure to natural disasters that may become worse as a result of a changing climate increases personal concern about the threat of climate change as well as support for mitigation measures. This change occurs even though the more fleshed out mitigation proposals (Limit CO_2, Support RPS) would be accompanied by financial costs for many American households. To provide additional context to these results, an increase in support for limiting CO_2 of 0.1 standard deviation units due to exposure to disasters translates to almost 1.5 million adults in the U.S. between 2014 and 2018 becoming more likely to support a policy measure that places limits to CO_2 emitters. Therefore, although the effect sizes are not especially large, that nearly half of the counties were exposed to a natural disaster suggests that a non-trivial proportion of U.S. citizens are changing their minds about the risks of climate change and measures to mitigate its effects. Importantly, these changes extend beyond pro-environmental statements (e.g., regulating CO) to include greater approval for proposals with measurable steps toward regulating greenhouse gas emissions and shifting to renewable energy sources in lieu of a dependence on fossil fuels. Because more frequent and severe disastrous weather events are anticipated in the future, these findings seem to suggest that support for mitigation measures will continue to grow as the effects of climate change are increasingly realized.

5 Robustness check

As a robustness check for our main analysis using a difference-in-difference design, we use recent advances in optimal matching and mathematical programming to construct a matched sample that is representative of all US counties and to adjust for approximately 300 covariates (Visconti and Zubizarreta, 2018; Bennett et al., 2019). Although matching is not necessarily an identification strategy alone (Sekhon, 2009; Keele, 2015), it presents strong evidence that the results reported above are consistent across different approaches.

5.1 Constructing a representative matched sample

We know that random assignment is the best approach for learning about the impact of a particular treatment on outcome(s) of interest (Gerber and Green, 2012; Morgan and Winship, 2014). Randomization is not a feasible option for studying the causal effect of negative effects such as disasters. One alternative is to construct an observational study that resembles a simple randomized experiment (Rosenbaum, 2010). We therefore use matching to construct a group of expose and unexposed counties that are balanced across hundreds of covariates.

Traditional matching techniques (e.g., propensity score matching) do not guarantee the achievement of covariate balance, though, and they can even increase important differences between groups in some instances (King and Nielsen, 2019). Further, such approaches tend to require multiple iterations and substantial guesswork to be able to construct a matched sample (Hainmueller, 2011). In contrast, then, we use cardinality matching, which allows us to find the largest matched sample that achieves our researcher-defined covariate balance requirements (Zubizarreta et al., 2014). In this analysis, we define the standardized differences between the matched treated and control groups to be no greater than 0.1 for all 300 of the covariates in our study. Cardinality matching then finds the sample with the maximum number of observations that meets these mean balance constraints.

There still remain some concerns regarding matching, however, that are important to address here. Perhaps the most relevant issue is that we are losing information when pruning units to achieve covariate balance. In particular, even though the matched sample may be balanced according to researcher-defined requirements, it might be markedly different from the unmatched or original sample. To address this potential problem, we further construct a representative matched sample. Specifically, we extend cardinality matching to "anchor the matched samples so that they are not only balanced but also balanced around the distribution of a target population of policy interest" (Visconti and Zubizarreta, 2018, p.224). In other words, our treated and control groups will be similar across more than 300 covariates in addition to being similar to target population, which is the original or unmatched sample of counties in this case. We use the mean balance constraint for approximately 300 covariates.[10] Specifically, the three groups of interests (i.e., all the counties, matched treated, and matched control) cannot have imbalances larger than 0.1 standard deviation units for each covariate (see Bennett et al. (2019) for more details).[11] The representative matched sample has 4400 units, 52 percent of the original sample.

In Appendix B, we describe each of the 300 covariates used. As a summary, we constrain by demographic (e.g., total, female, Hispanic, black, and white population), political (e.g., turnout, democratic and republican vote share since 1980), economic (e.g., income, crime, and poverty), and climatologic (e.g., temperature and climate zone) considerations. Further, we pay strong attention to the geographic location of counties when constructing the matched sample, which allows

[10] All of them are continuous, ordinal, or binary so the mean balance constraint is a meaningful requirement.

[11] We use the designmatch package in R to construct the representative matched sample (Zubizarreta and Kilcioglu, 2016).

us to compare places located in the same regions but with different exposure to disasters. This is a crucial element of our robustness check design, as we avoid having a treated and control group with very different probabilities to be exposed to a disaster because of their geographic locations. To do this, we generated percentiles for latitude and longitude, and then 100 binary indicators for each of them to identify the percentile of longitude and latitude for each county, which allow us to adjust for geographic location such as exposure to natural disasters is not correlated with the geographic location of counties.

We present the mean for ten selected pretreatment covariates in our original sample (all the counties) as well as the matched control and matched treated groups. We describe and report the results for the other 290 covariates in Appendix E. Table 2 shows that the three groups are comparable in terms of their observed characteristics, which is the primary goal of constructing a representative matched sample.

Table 2: Description of the Representative Matched Sample

Covariate	All counties	Exposed matched	Control matched
Republican 2008	57.23	56.90	57.47
Democratic 2008	40.92	41.24	40.67
Income	55577.23	55246.15	55246.15
Poverty	16.44	16.75	16.75
White	83.07	82.38	82.38
Births	13.16	13.12	13.12
Median age	40.35	40.34	40.44
Metropolitan area	0.22	0.22	0.22
Mountain division	0.07	0.07	0.07
New England division	0.01	0.01	0.01

5.2 Effect estimates

First, we estimate the effect of natural disasters on risk perceptions about global warming, drawing on the inferential approach described in Rosenbaum (2002). This uses a Wilcoxon's signed-rank test statistic to test the sharp null hypothesis of no treatment effect. Importantly, the Wilcoxon test is less dependent on distributional assumptions and allows us to implement a sensitivity analysis for hidden biases (Rosenbaum and Silber, 2009) (see Appendix D). This test provides both point estimates and confidence intervals.[12]

As illustrated in the first panel of Figure 3, we find that exposure to one or more natural disasters increases concern for personal risk from climate change as well as perceptions about harm to the United States and future generations. These results are congruent with those in our main analysis using a difference-in-difference design, suggesting that these findings are robust.[13] Based on our sample and multiple analyses, exposure to natural disasters increases concern about a variety of risks about climate change at the county-level.[14] In the second panel, we present the results regarding policy preferences in Table 3. Again, these results are similar to our aforementioned findings - exposure to natural disasters changes some policy preferences.

[12] We derive a point estimate by solving Hodges and Lehmann's estimating equation, and obtain a 95 percent confidence interval by inverting the test.

[13] Personal: 0.08 (CI: [0.03-0.12]), United States: 0.07 (CI: [0.02-0.12]), Future Generations: 0.05 (CI: [-0.005-0.10]).

[14] Fund Renewables: 0.02 (CI:[-0.03-0.08]), Regulate CO_2: 0.02 (CI:[-0.02-0.06]), Limit CO_2: 0.10 (CI:[0.06-0.14]), and Support RPS: 0.10 (CI:[0.06-0.14])

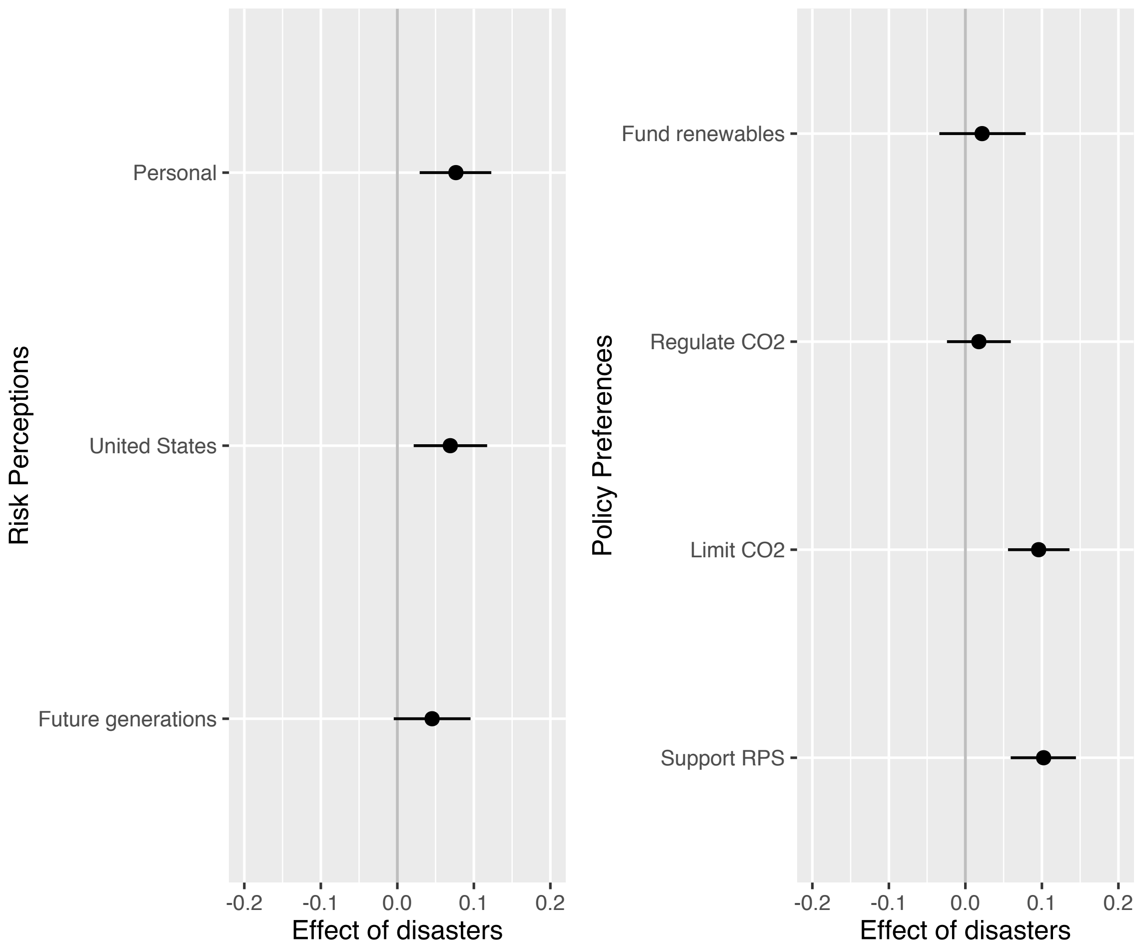

Figure 3: Results using cardinality matching

To sum, the results for both our main analysis and robustness check are congruent overall. This demonstrates the robustness of the main findings and corroborates our conclusion that natural disasters can change both risk perceptions and some policy preferences about climate change.

6 Discussion and Conclusions

As the global climate continues to change, some types of natural disasters may become more prevalent and severe. Whether and how such catastrophes influence risk perceptions about global warming as well as support for mitigation measures are, therefore, increasingly relevant questions. We aim to contribute to the literature studying such questions, engaging with several analytical approaches and drawing on 2014 to 2018 county-level public opinion surveys as well as data on federally declared disasters across the United States.

Rather than seek to confirm one expectation for how public opinion might respond to relevant natural disasters, we propose several theoretical possibilities and provide empirical evidence to identify which theoretical accounts has the most explanatory insight. If neither risk perceptions nor policy preferences change, we suggest the relationship may be represented by a biased assimilation argument. Instances when risk perceptions are affected but not policy preferences may be better represented by a single persuasion argument. If, however, both outcomes changed following exposure to a natural disaster, double persuasion may provide the best fitting explanation. Recognizing the complexity of understanding individuals' cognitive responses to climate change (Druckman and McGrath, 2019), we believe this findings can provide an important foundation to this research agenda and will help guide future studies to examine these relationships further.

Using a difference-in-difference design, we explore the effect of exposure to one or more natural disasters that could be associated with climate change, finding that it significantly increases an array of risk perceptions about climate change. For example, concern about harm to the US as well as future generations rose following exposure to a disaster event. Perhaps most interesting, the perception of personal risk also significantly increased. Although there is evidence that direct experience with natural disasters may change some opinions about climate change, there seems to be less of a consensus about how it may influence those in industrialized countries, like the US (Howe and Leiserowitz, 2013). This is especially relevant given the disproportionate greenhouse gas contributions of industrialized states and the relatively low level of personal concern about climate change across the United States, on average (Marlon et al., 2018). Drawing on this evidence, we suggest that natural disasters can, in fact, raise alarm about climate effects for oneself.

While it also increased support for funding renewable energy sources more broadly, it did not significantly change approval for regulating CO_2 generally. We suggest this may be because of a ceiling effect, as more broad measures without any clear losses may be more palatable than policies that more clearly delineate changes for industry or lifestyles. That our results demonstrate a change for more specific policy proposals may, then, have substantial implications. It could indicate that natural disasters serve as a shock that increases public support for more effective policy proposals that place clear limits on emitters and set greater expectations for renewable energy usage, even with some costs to the average American.

We further substantiate these findings by constructing a representative matched sample using approximately 300 covariates. Importantly, the results between our main analysis using a difference-in-differences design and the robustness check are similar overall, suggesting that our findings are robust and congruent across different approaches. Overall, these results support our double persuasion explanation – that natural disasters are powerful shocks, which can increase concern about climate change as well as develop conviction to mitigate its potentially catastrophic effects.

We believe these findings offer several important contributions. First, rather than studying only one or several types of natural disasters, we consider a range of natural disasters that could be associated with climate change in the United States. Although it is certainty important to understand how each type of natural disaster may affect public opinion, it is also essential to acknowledge that, as climate change continues, associated catastrophes will likely become more frequent and intense. Whether that means more fires in the West and floods in the East, then, Americans in most counties will be exposed to events that our results suggest are already changing perspectives about climate change and raising support for certain policy proposals. Importantly, the effects we report are for policies that extend beyond support for climate action in principle; the are policies that respondents affirmed even with the knowledge that it could be accompanied by costs to them, presumably supporting the notion that effective climate mitigation is worth some financial costs.

Finally, we provide insights into potential policy changes that may occur in the future, particularly at the local level. Given evidence that public opinion is already shifting after exposure to natural disasters, it seems plausible that policymakers will respond to increasing support for climate action. However, because disaster events may be especially frequent and severe in some areas, changes public opinion may not necessarily be uniform across the country, which could mean that climate action occurs at a more local level. Therefore, while the ultimate implementation of policies is influenced by a myriad of factors and the window for effective climate action is believed to be closing, our analysis suggests that tangible 'evidence' of climate change may cause changes in public opinion that could, perhaps, forestall some of the most devastating climate impacts.

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