Signals of Doom: Wildfire Smoke, Climate Change, and Media Coverage

Guilherme Fasolin[1‡]
Sofia Berrospi[1]
James Bisbee[1]

[1]Department of Political Science, Vanderbilt University

[‡]To whom correspondence should be addressed: guilherme.n.fasolin@vanderbilt.edu

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Abstract

What are the consequences of wildfire smoke pollution for climate change attitudes? As the United States faces an alarming increase in air pollution related to wildfires, there is a growing academic and policy interest in understanding how these events influence public attitudes and support toward climate policies. Prior research assumes that direct experience with climate hazards leads individuals to update their attitudes and preferences, yet the results are mixed and inconsistent. We argue that this inconsistency partly arises from overlooking the role of media in shaping climate change opinions, particularly considering the cognitive effort required for individuals to assess the complexity of climate change and its effects. We theorize that media coverage of wildfires will influence public concern about climate change, with varying effects across U.S. regions. Our study, utilizing individual-level panel data, geocoded wildfire smoke data, and local media coverage, reveals that direct exposure to climate hazards does not increase climate change concern. Rather, individuals adjust their levels of concern in response to media coverage, particularly in liberal areas where emphasis on the climate-wildfire connection is prominent. In contrast, conservative media coverage tends to diminish public concern about climate change. Taken together, these findings underscore the role of media in shaping public attitudes toward climate change and highlight the potential for wildfires to exacerbate political polarization on the issue.

Keywords: Wildfires smoke, climate change, public opinion, media coverage

Introduction

The costs of climate change are wide-ranging, but also abstract. Although increasing temperatures is the first-order outcome, these are increases of fractions of a Celsius degree per year on average. Second-order outcomes such as extreme weather are more dramatic, but harder to directly connect with global warming. And third-order outcomes such as wildfires are harder still, requiring an individual to make the mental connection from a warming climate to hotter, drier summers which provide abundant fuel for the fires which are invariably started by catalysts unrelated to global warming (although in the typical case of irresponsible humans, perhaps spiritually related).

These abstract qualities complicate efforts of governments, non-state actors, and organized interests to overcome the barriers to collective action that prevent an effective policy response. To do so, they require wide-ranging agreement from the public that it is necessary to shoulder costs today in order to prevent more catastrophic costs tomorrow. But if the costs of climate change are uncertain in the minds of the public, broad public support will not manifest.

We evaluate a growing consensus in the literature which argues that directly experiencing climate change increases the salience of the topic among voters. We posit that individuals require narratives that link their experiences of climate events to the political topic of climate change. Our argument rests on the assumption that phenomena like wildfires are, by themselves, insufficient to activate the considerations necessary to shift politically relevant attitudes. We use local news coverage of wildfires to test our intuition, demonstrating that 1) wildfires prompt increased news coverage of these events in local media markets, 2) this coverage is more likely to emphasize climate change as an explanation for the wildfires in more liberal areas, and 3) that individuals living in these areas become increasingly concerned about climate change when the media creates a narrative that links their experiences to the

political issue. Importantly, however, our results suggest that events like wildfires might even *increase* political polarization over the importance of climate change, as consumers of conservative media grow *less* concerned about climate change in response to these signals.

By relying on a panel survey where the same individuals are observed over time, we find little evidence of an effect of wildfire smoke exposure on attitudes about climate change by itself. However, we do find systematic relationships that are consistent with the powerful mediating role of news media. Taken together, our findings highlight the importance of incorporating elite cues into our understanding of how global warming's consequences are translated into politically-relevant attitudes.

1 Concern, pessimism, and climate change

Climate change has been a politicized issue in advanced industrial democracies like the United States for decades. Despite this politicization there have been a number of studies arguing that personal experiences with climate change are nevertheless important predictors of beliefs. Egan and Mullin [2012] take advantage of the exogeneous nature of temperature to that a change of two standard deviations from the daily average local temperature is associated with an increase of 3.8 percent in the probability of believing global warming exists, although demonstrate that these effects are ephemeral even over periods with more consistent abnormal temperatures. Hazlett and Mildenberger [2020] examine the relationship between exposure to environmental threats, in this case wildfires, and political behavior in the form of ballot support to 4 environmental initiatives in California, concluding that groups exposed to wildfires support ballots on the environment by 6 percentage points more, and the effects are greater for groups that are closest to the wildfires. Marlon et al. [2021] focus on perceived experience, which comes before belief formation, and attempt to predict variation in perceptions of global warming using 7 different measures of climate indicators. Regression

results show that only the hot dry days anomaly variable has a significant association with perceived global warming.

Despite this growing body of evidence, there nevertheless remains some debate over the influence of objective measures of exposure and changes in attitudes. Xia et al. [2022] conduct a meta analysis of 302 studies, finding only weak support for a positive association between exposure to climate change indicators and climate change awareness, concluding that experiencing climate change may not be sufficient to influence an individual's awareness of the issue. Another review by Egan and Mullin [2017] concludes that partisanship and ideology explain the majority of variation in attitudes related to the climate, although noting the importance of risk perception as a moderator.

The outstanding puzzle is therefore where and when exposure to climate change should influence individual attitudes. Our contribution foregrounds the crucial role played by media coverage and elite cues, which help translate the objective outcomes of climate change into politically relevant attitudes. We describe the theoretical intuition in more detail in the following section, but the big picture argument is that climate change's objective outcomes are too complicated for the average individual to distill into a clear, policy-relevant piece of information they use to update their beliefs. Media coverage that draws these connections for them is necessary for the objective measure to have an impact, and remains an underappreciated part of the extant literature linking exposure to climate change with attitudes.

2 Theoretical Intuition

The rise in wildfires across North America is attributable to climate change, according to the scientific consensus. This consensus highlights four aspects of climate change that contribute to the spread, intensity, and duration of wildfires over recent years.

Firstly, rising temperatures resulting from global warming contribute to drier conditions, particularly in regions that are already prone to wildfires. Higher temperatures accelerate the evaporation of moisture from vegetation, soils, and water bodies, creating an environment that is more susceptible to ignition and rapid fire spread. Consequently, even a small spark can trigger larger and more destructive wildfires in these parched landscapes.

Secondly, climate change influences the availability and distribution of precipitation. Changes in rainfall patterns can lead to prolonged droughts, amplifying the likelihood of wildfires. Regions experiencing prolonged dry spells are particularly vulnerable as the lack of moisture reduces the moisture content in vegetation, turning them into potential fuel for fires. Furthermore, altered precipitation patterns can create conditions that favor the growth of highly combustible vegetation, further exacerbating the fire risk.

Thirdly, climate change affects wind patterns, which play a crucial role in fire behavior. Changes in wind speed and direction can influence how wildfires spread and their intensity. Stronger winds can cause fires to spread more rapidly, making them harder to contain and control. Additionally, altered wind patterns can carry smoke and pollutants over vast distances, affecting air quality and posing health risks to communities far from the actual fire zones.

Lastly, the cumulative impact of climate change on ecosystems also contributes to the wildfire problem. Climate change disrupts ecological systems, leading to changes in vegetation types, insect infestations, and disease outbreaks. These disturbances can result in the proliferation of dead and dry biomass, providing ample fuel for wildfires. Furthermore, the loss of plant and animal species due to climate change can disrupt the delicate balance of ecosystems, further increasing the vulnerability of landscapes to fire.

A simple rational actor model of attitude formation would argue that exposure to wildfires induces individuals to update their beliefs about climate change, and adopt more

progressive stances on combating global warming. At the risk of belaboring the intuition, those living in areas affected by climate change's negative consequences are faced with either incurring the related costs (damage to property, health risks, etc.) or incurring relocation costs. In either setting, reallocating government resources to offset personal costs is the rational response to this signal.

This view is challenged by the cognitive effort required to draw the preceding connections between climate change outcomes and individual welfare. Each of the four components of the scientific consensus requires at least a passing familiarity of scientific concepts to understand, and a much deeper education to fully engage with the evidence. We assume that individuals do not exert this effort on their own when exposed to wildfire smoke. Instead, we argue that media coverage of the wildfires does this work for them, summarizing the relevant aspects of the scientific consensus and explicitly drawing the link between the wildfires and global warming.

However, we expect that different outlets will cover the wildfires in different ways. All else equal, one might expect that a more liberal outlet will highlight the climate change connection, while a more conservative outlet will emphasize other dimensions of the wildfires. At the extreme, a conservative outlet might respond by actively rejecting the climate change connection drawn by others. An individual's response to wildfire smoke exposure is therefore partially or wholly mediated by the coverage of the wildfires by the news that they follow.

To give a bit more structure to this argument, we adopt the Bayesian model of preference formation introduced in Druckman and McGrath [2019] which defines an individual's beliefs about climate change as a function of their priors on this issue, defined formally as $\pi_i(\mu) \sim \mathcal{N}(\hat{\mu}_{i,0}, \hat{\sigma}^2_{i,0})$, and a new signal, defined as $x \sim \mathcal{N}(\mu_x, \hat{\sigma}^2_{i,x})$. The parameter $\hat{\sigma}^2$ captures the variance associated with either the prior or the signal and may be referred to as

the "credibility" [Druckman and McGrath, 2019]. The individual's posterior belief is thus:

$$\pi_i(\mu|x) \sim \mathcal{N}\left(\hat{\mu}_{i,0} + (x - \hat{\mu}_{i,0})\left(\frac{\hat{\sigma}^2_{i,0}}{\hat{\sigma}^2_{i,0} + \hat{\sigma}^2_{i,x}}\right), \frac{\hat{\sigma}^2_{i,0}\hat{\sigma}^2_{i,x}}{\hat{\sigma}^2_{i,0} + \hat{\sigma}^2_{i,x}}\right)$$

Conditional on a given prior, there are two components of the signal that matter for the individual's posterior belief: the credibility parameter $\sigma^2_{i,x}$ and the location of the signal itself, x. Coverage of the wildfires by a liberal outlet will carry the same signal x_L, highlighting the connection to climate change, but will be interpreted differently depending on the identity of the individual i. If i is also a liberal, they will assign high credibility to the coverage (i.e., have a low value of σ^2_{i,x_L}) and thus their posterior will be heavily influenced by x_L. Conversely, a conservative i will assign low credibility to the coverage (i.e., have a high value of σ^2_{i,x_L}) and thus move only minimally in the direction of x_L. Figure 1 visualizes the intuition, underscoring the crucial role played by media in helping the public update their attitudes in response to wildfires.

3 Data

To assess whether exposure to climate hazards affects climate change concern and whether media coverage is crucial in establishing this link, we merged individual-level panel data from the United States with geocoded data on smoke from wildfires, in the zip code tabulation area (ZCTA) where each respondent lives, as well as local media coverage of wildfires within the respondent's Designated Market Area (DMA). In the following subsections, we present detailed information on this different data and how we operationalize the variables that are of particular interest to our study.

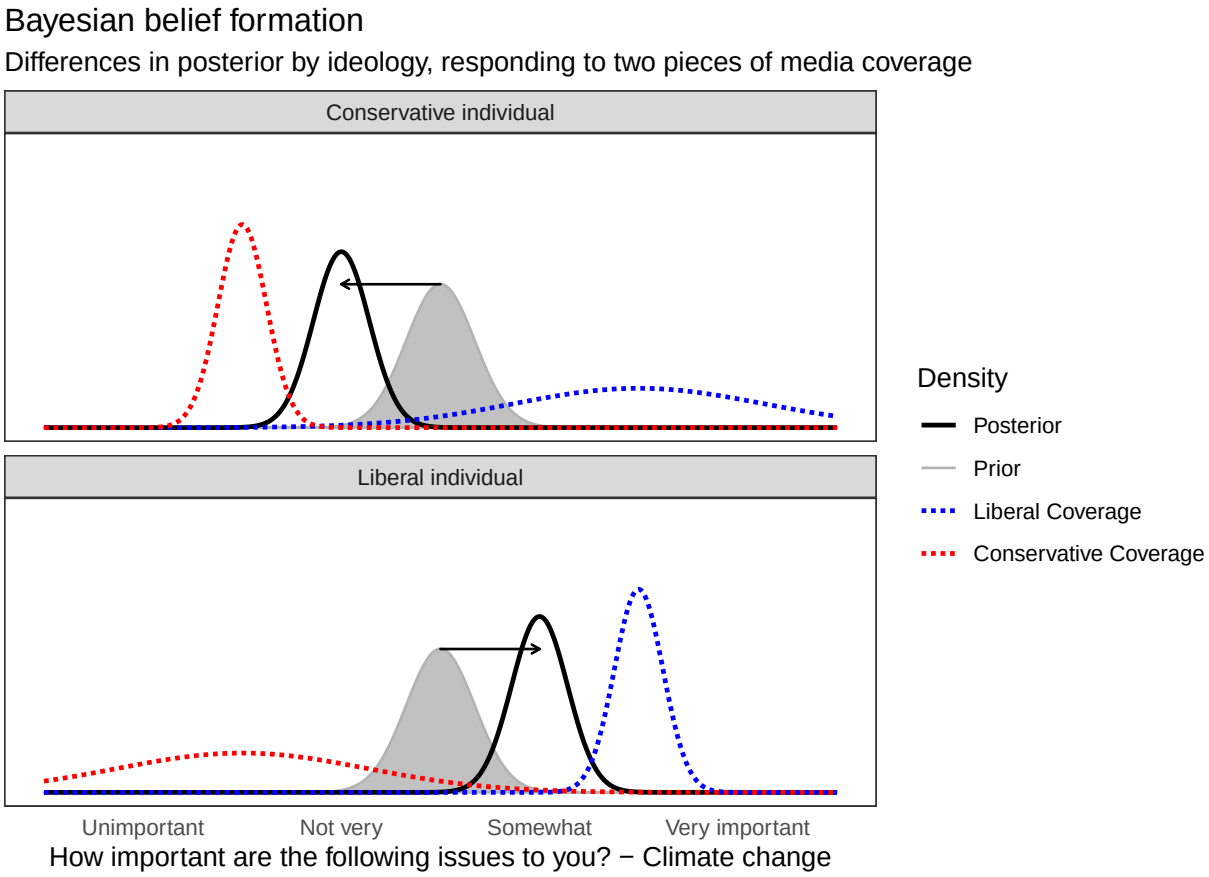

Figure 1: Updating process by conservative (top panel) and liberal (bottom panel) individuals, responding to media coverage of wildfires by conservative (red dotted line) and liberal (blue dotted line) media.

3.1 Panel Survey Data

The panel survey data comes from the Views of the Electorate Research (VOTER) survey, a longitudinal panel survey of thousands of Americans interviewed multiple times since 2016 [Democracy Fund Voter Study Group, 2021]. This panel was conducted online by YouGov, utilizing a stratified matching procedure to achieve nationally representative samples. The data utilized in this study comprises interviews with 5,495 participants in 2016, 2017, and 2020, after accounting for attrition.[1] We obtained a restricted version of this dataset in which

[1]The main analyses are based on respondents who completed all three survey waves. However, we also test the robustness of results for those who completed only two.

respondents are geolocated to their zip code, allowing us to merge the survey data with both wildfire smoke exposure at the zip code tabulation area (ZCTA) and media coverage at the DMA.

Within the panel, climate change concern is measured using a question that asks respondents to rate the importance of climate change. The exact wording is: "How important is climate change to you?" Response options range from "Very Important" (1) to "Unimportant" (4). We converted the responses into a binary measure, where high climate change concern (1) represents respondents who selected "Very Important", while low climate change concern (0) corresponds to the other response options.[2] Descriptive visualization of the distribution of our outcome by wave of the survey and partisanship of the respondents are presented in Figure 2.

3.2 Climate Hazard: Wildfire Smoke

Wildfire smoke is our proxy for exposure to climate hazards. We used data from the Stanford Echolab[3], which estimates daily, local-level ambient fine particular matter ($PM_{2.5}$) attributable to wildfire smoke across the contiguous U.S. from 2006-2020 over a 10km-by-10km grid. Our main results use these data aggregated to the zip code tabulation area (ZCTA), measured daily from January 1st 2006 to December 31st, 2020. We plot the average and total fine particulate matter ($PM_{2.5}$) by day across all ZCTAs in Figure 3, shaded red rectangles indicating the periods during which our respondents were surveyed.

The comparison between the average and total $PM_{2.5}$ reveals some important aspects of the identifying variation in our data. Specifically, while the United States writ large experienced the largest volumes of fine particulate matter in 2020 overall, this was driven largely by historic wildfires in California that affected only a small fraction of ZCTAs. Conversely,

[2] We also assess the robustness of the results using the original scale (1-4).

[3] `https://github.com/echolab-stanford/daily-10km-smokePM`

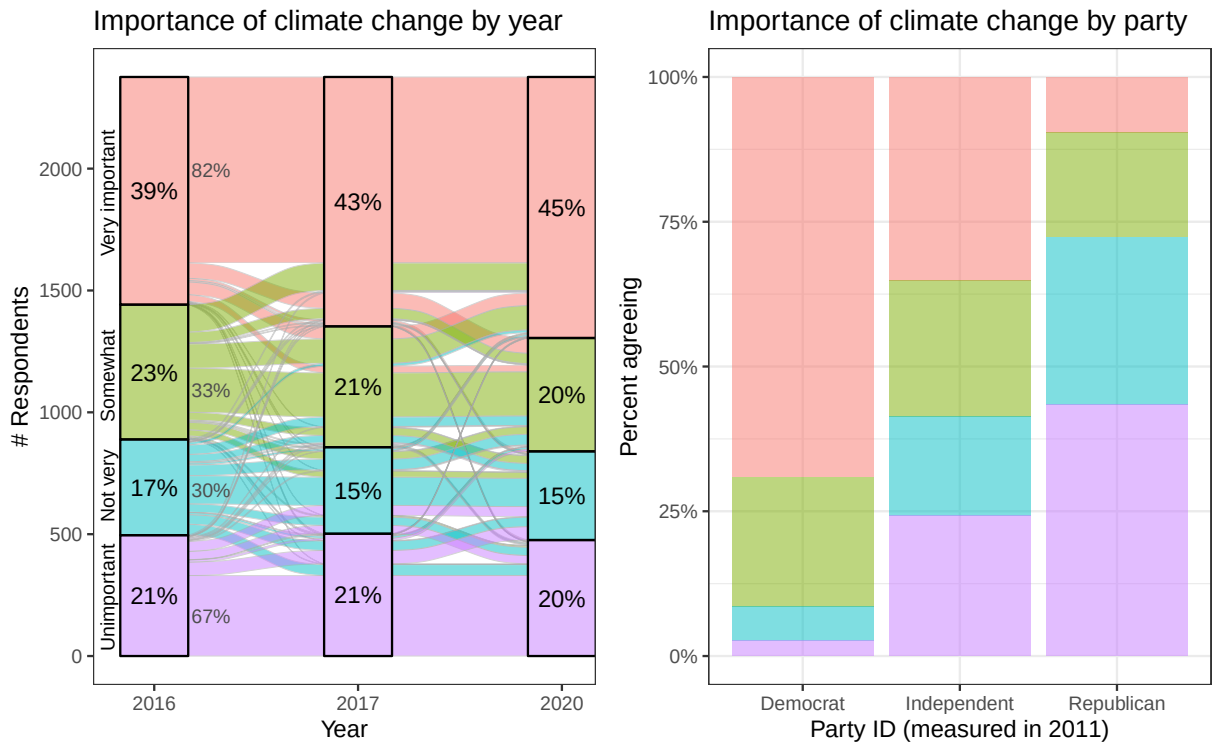

Figure 2: Distribution of attitudes on climate change by year (left panel) and by party (right panel). Gray percentages next to the left column indicate the proportion of respondents who maintained their responses across all three waves of the survey (left panel).

while the total $PM_{2.5}$ in the year preceding the 2016 survey wave was the lowest in our data, the average was much higher, reflecting the greater number of ZCTAs that had some wildfire smoke exposure. These conclusions are reflected in Figure 4 which plots total coverage by $10km^2$ squares in the six months preceding the survey waves in 2016, 2017, and 2020.

We define exposure in two ways to ensure that our results are not susceptible to the particular definitions used in the estimations. First, we rely on an indicator of the difference between the mean of $PM_{2.5}$ measured during the twelve months prior to the survey data collection and the average value of $PM_{2.5}$ from the baseline period of 2006 to the survey date. For example, if the survey was conducted in December 2016, data from December 2015 to December 2016 is used to represent the most recent exposure conditions for survey respondents. Then the exposure is calculated as the difference between December 2015 and

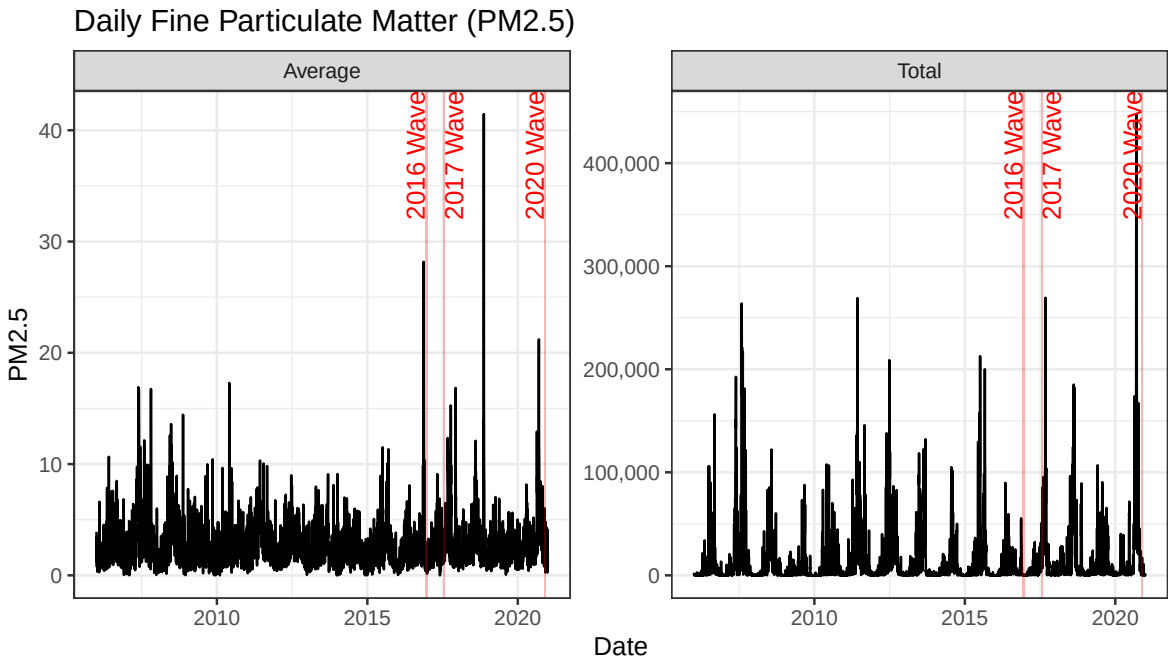

Figure 3: Daily fine particulate matter ($PM_{2.5}$) over period of analysis.

December 2016 values compared to the average value for the entire base period ranging from 2006 to December 2015. Second, we also conceive of exposure as an indicator for any days over three years prior to the survey where $PM_{2.5}$ was greater than 10, 20, 30, 40, 50, 70, and 100 in respondent's ZCTA. These numeric thresholds are indices created by the U.S. government to report air quality. Overall, a value over 50 corresponds to an ambient air concentration considered unsatisfactory, with values above 100 considered unhealthy. Importantly, these data are the $PM_{2.5}$ measures attributable *specifically* to wildfire smoke, meaning that a value of 50 is *in addition to* other sources of $PM_{2.5}$.

3.3 Media Coverage

To test the hypothesis that media coverage serves as a crucial factor for individuals connecting exposure with climate hazard and climate change beliefs, we employ data from media coverage of wildfire events in the United States from 2006-2020. First, we searched for U.S.

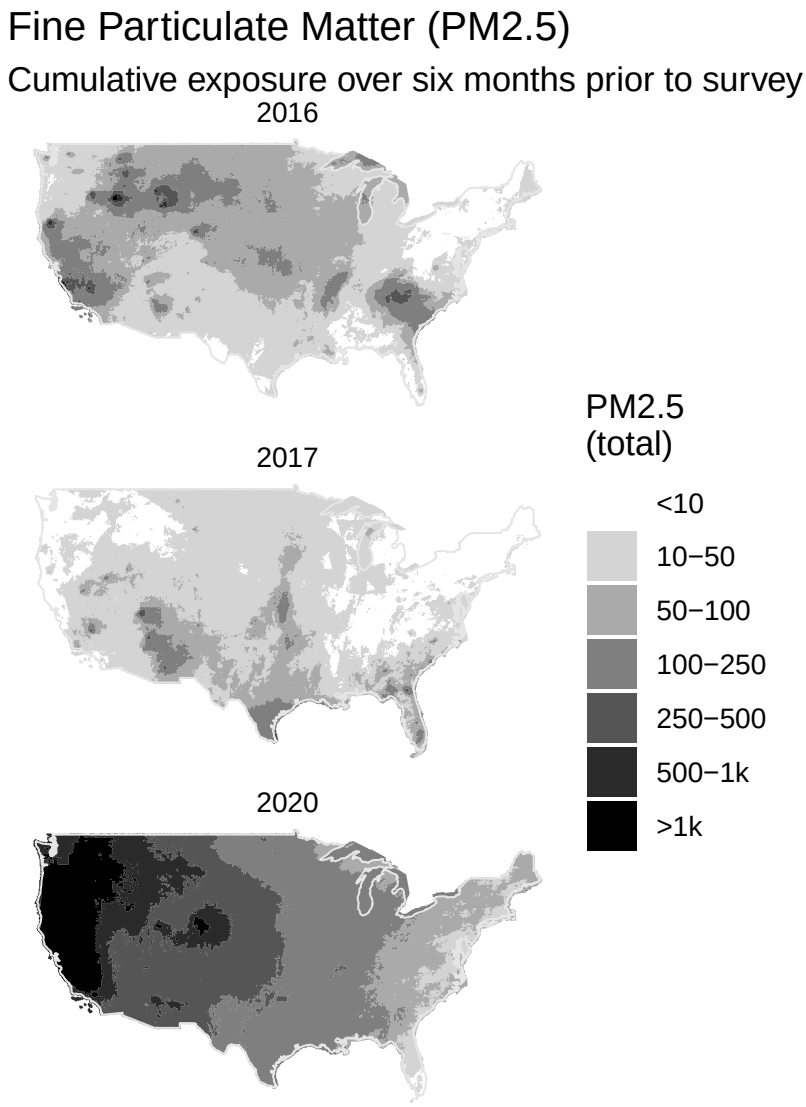

Figure 4: Cumulative fine particulate matter ($PM_{2.5}$) in 2016 and 2020, up to start of survey wave (November 30th).

newspaper articles using the terms "wildfires" and "wildfire smoke" from the ProQuest TDM Studio database, which resulted in over 26,000 newspaper articles from 2006 to 2020. Then we convert this processed corpus into a document matrix format and estimate a topic model via Latent Dirichlet Allocation (LDA, Blei et al. 2003) to determine topics in coverage across articles and over time. Following best practices laid out in Roberts et al. [2013] we evaluate perplexity scores over a range of different choice of k, the number of topics to estimate and determined that 100 optimizes on the trade-off between perplexity and parsimony. Inspec-

tion of the topics indicated that topic 5 was most associated with coverage that referenced climate change, based on the highest scoring words, reference to the original documents that scored highly on this topic, and the geographic distribution of the coverage (see Figure 5).

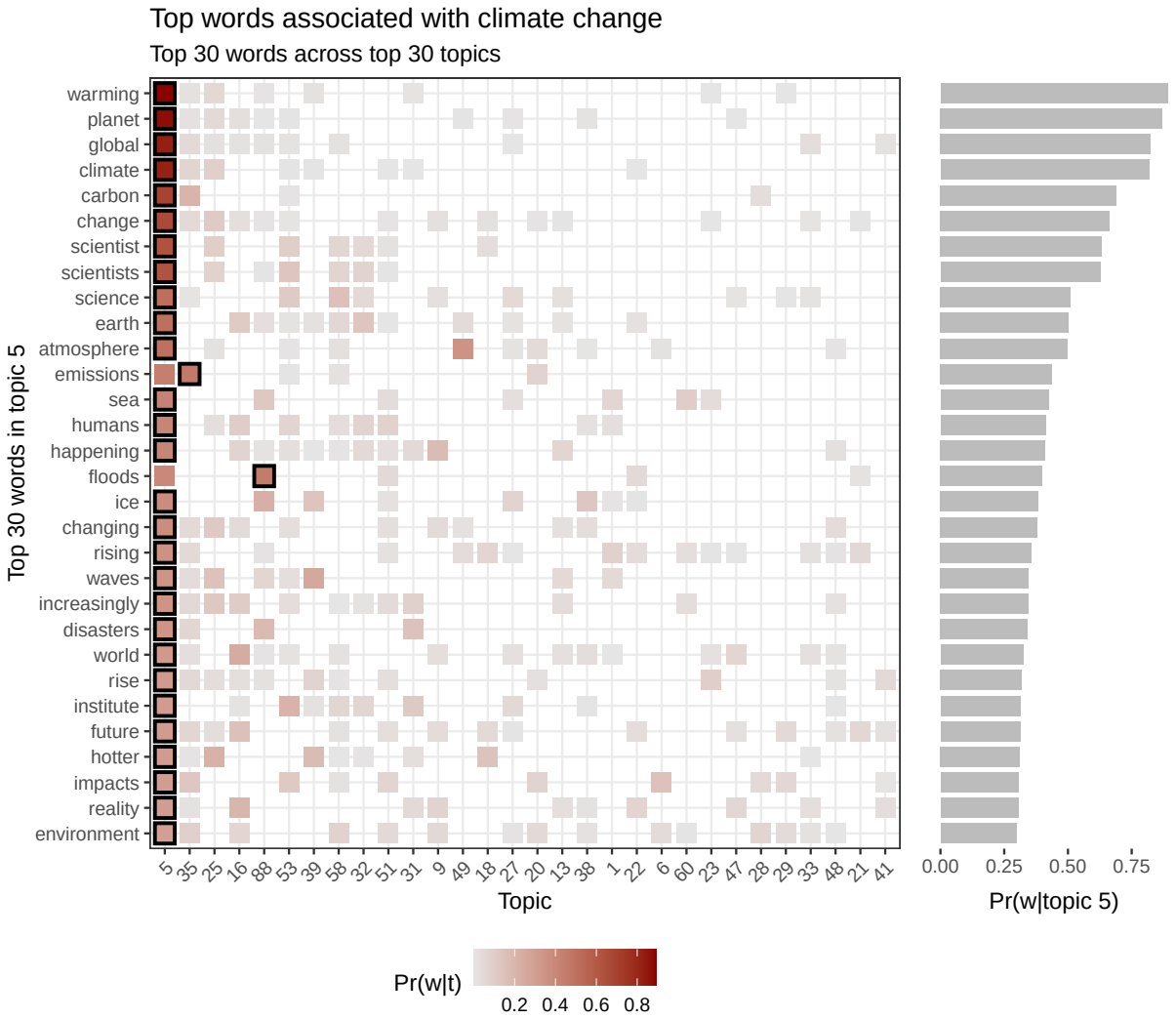

Figure 5: Top 30 words associated with Topic 5, broken out across their top 30 most likely topics. Left panel: Tiles are shaded by the probability of observing a given word (y-axis) as a function of being in a given topic (x-axis). Black borders indicate the topic for which a given word is most strongly associated. Right panel: Probabilities specific to Topic 5.

To assign these measures of media coverage of the wildfires to our survey respondents, we rely on similar strategies to those described above. Specifically, we calculate the total number of articles over the preceding k periods prior to when the respondent responded to

a given wave of the VOTER survey, as well as either the summed probability of topic 5 appearing in this coverage, or the average. We assign each respondent to these cumulative measures according to their DMA. Figure 6 visualizes the distribution over the three waves of our survey data.

4 Methods

4.1 Causal Assumptions

We merge the three preceding sources to create a hierarchical dataset in which individuals (indexed by i) are nested within ZCTAs (indexed by z) which are themselves nested within DMAs (indexed by d). Our causal interpretation hinges on the assumption that wildfire smoke is as good as randomly assigned to a ZCTA. Given recent research on the climate-induced changes in wind patterns, we feel reasonably confident in this assumption.

However, two threats to identification remain even if we can be confident in this assumption of random assignment to wildfire smoke. The first is a selection concern in which changes in attitudes among those living in smoke-exposed areas might reflect compositional changes, not attitude changes. For example, if those less concerned about climate change are also those who are willing or able to move away from smoke-exposed areas, we will find evidence of an increase of concern despite the representative individual's attitudes not changing. To overcome this challenge, we rely on the panel nature of our data and restrict attention to only those respondents who do not move over the period of our analysis.[4]

The second threat relates to our argument that media coverage of the wildfires is the primary mechanism by which smoke exposure influences attitudes. Even if we believe that

[4]We also predict movers as a function of smoke exposure, finding little evidence that wildfire smoke is prognostic of the decision to move to a different part of the country.

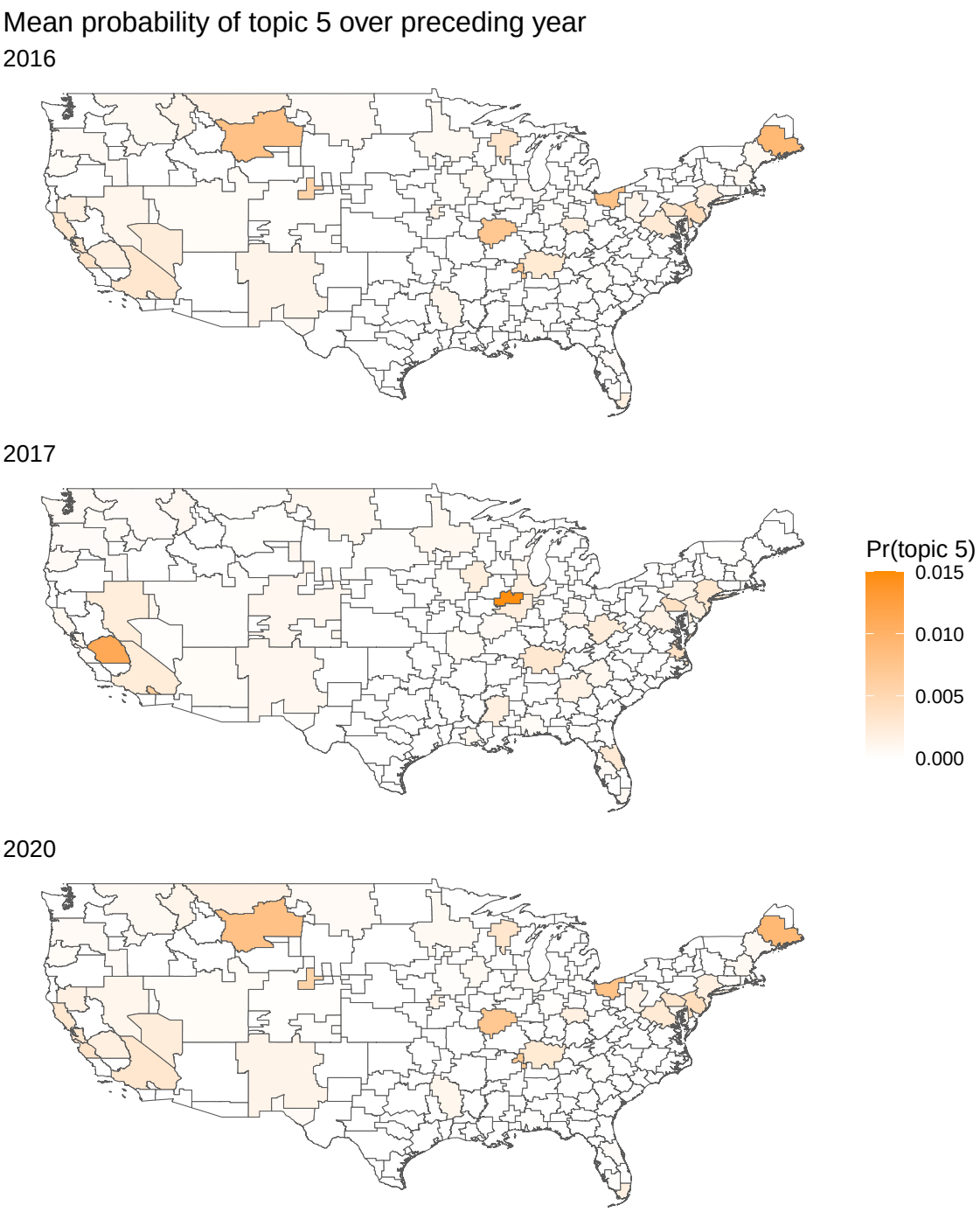

Figure 6: Media coverage of wildfires using the climate change topic, averaged over the year preceding when the respondents took the survey in 2016, 2017, and 2020.

smoke exposure itself is random with respect to potential outcomes among both individual attitudes *and* media coverage, this is not enough to causally identify the mediating pathway

of media. We need a second source of random variation in media coverage that is orthogonal to both wildfires and to attitudes to satisfy the sequential ignorability assumption discussed in Imai et al. [2010]. Without this, we can only provide descriptive evidence that is consistent with a causal story in which wildfires induce changes in local media coverage, which then influence the attitudes of respondents we observe over three waves from 2016 to 2020.

4.2 Specifications

With the preceding discussion in mind, we turn now to describing the actual specifications we bring to the data. Our primary analysis connecting attitudes to wildfire smoke predicts attitudes on climate change for respondent i in year t in ZCTA z as a function of their exposure to wildfire smoke, or:

$$attitude_{izt} = \alpha_i + \delta_t + \beta_1 exposure_{zt} + \varepsilon_{izt} \tag{1}$$

where α_i are individual fixed effects, δ_t are year fixed effects, and $\frac{1}{k}\sum_{t\in\{t-k,t\}} \mathbb{I}(smoke_{rt})$ is the proportion of days in which the respondent i's region r was covered with wildfire smoke over the preceding period k. Our main results set z to the centroid of the respondent's zipcode and k to the preceding year.

Under the assumption that prevailing winds are as good as random from the perspective of the survey respondent, we argue that the β_1 coefficient can be interpreted as the causal effect of wildfire smoke on opinions about climate change. We further augment this claim by isolating identifying variation in the over-time change in an individual's attitudes via individual fixed effects α_i. Substantively, Equation 1 compares how views on climate change shifted among those who were and were not exposed to wildfire smoke. Insofar as those who were not exposed to the smoke are valid counterfactuals for how the exposed respondents views would have changed over the period of analysis, we believe our causal interpretation

is solid.

Our second analysis again predicts climate change attitudes, except here we predict these as a function of media coverage, measured as either the total number of articles covering the wildfires, or as the net probability that this coverage used the climate change frame which we operationalize using topic 5 from our LDA model. Here, we define exposure to media coverage at the DMA level, reflecting that this is the unit at which our predictor varies. Consequently, we cluster our standard errors at the level of the DMA instead of the individual. Similarly, our third specification for estimating the relationship between wildfires and media coverage is similar except that our smallest units of analysis are now the DMAs, indexed by d.

$$coverage_{dt} = \alpha_d + \delta_t + \beta_1 exposure_{dt} + \varepsilon_{dt} \tag{2}$$

Finally, we put all both pieces into a single model, predicting individual attitudes as a function of wildfire smoke exposure and media coverage of wildfires. We run this as an interacted specification, but acknowledge that we are unlikely to capture the average causal mediation effect (ACME), given the implausibility of the sequential ignorability assumption. Nevertheless, we argue that the descriptive evidence is illuminating insofar as it highlights the importance of internally valid survey experimental evidence confirm the patterns we document here.

5 Results

5.1 Main Natural Experiment Results

Table 1 presents the effects of wildfire smoke exposure on climate change concern. We used two different measures of exposure to estimate this relationship. In models 1 to 3, we estimate

the effect of exposure on climate change concern by counting the number of days over the 30, 180, and 365 days prior survey where $PM_{2.5}$ was greater than 50, which is ambient air concentration index considered unsatisfactory.[5] Models 4 to 6 follow the same logic and and measure the effect of exposure on climate concern based on the previous 30, 180, and 365 days, but now using the mean deviation of $PM_{2.5}$ compared to the historic period baseline. As Table 1 shows, exposure to wildfire smoke has no significant effect (5% level) on public concern on climate change, regardless of the timing or measure of exposure.

Table 1: Effect of Wildfire Smoke Exposure on Climate Change Concern

Dependent Variable:	Climate Change Concern			Climate Change Concern		
Model:	(1)	(2)	(3)	(4)	(5)	(6)
Variables						
Days over 50	-0.0447	0.0021	0.0022			
	(0.0490)	(0.0032)	(0.0032)			
Mean Deviation				0.0037	0.0008	0.0018
				(0.0070)	(0.0034)	(0.0076)
Fixed-effects						
Individual	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
Fit statistics						
Observations	6,729	6,729	6,729	6,729	6,729	6,729
R^2	0.85135	0.85132	0.85132	0.85132	0.85130	0.85130
Within R^2	0.00039	0.00015	0.00016	0.00013	1.87×10^{-5}	1.77×10^{-5}

Clustered (id) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

5.2 Media Narratives

Turning to the analysis of media coverage, we start by predicting the number of articles containing the terms "wildfires" or "wildfire smoke" as a function of the prevalence of wildfire

[5] In the appendix, we demonstrate that these results hold for higher threshold indices such as 70 and 100, as well as for a time horizon of up to three years before the survey collection.

smoke coverage. Our initial analyses use the full panel dataset of DMAs by day since 2006. We implement DMA and date fixed effects to identify overtime variation within DMAs while controlling for secular trends by day. Standard errors are clustered at the DMA. As illustrated in the first column of Table 2, there is a statistically significant and positive association between wildfire smoke and media coverage of wildfires. The association persists regardless of whether we aggregate the outcome and explanatory variable to the week, month, quarter, or year; as well as if we log both variables to express the association in terms of elasticities. Perhaps unsurprisingly, local news covers wildfires when their readership is exposed to wildfire smoke.

Table 2: Number of articles containing wildfire keywords as a function of smoke exposure

Dependent Variables:	scale(nArticles)				log(nArticles+1)
Model:	(1)	(2)	(3)	(4)	(5)
Variables					
scale(smokePM_pred_s)	0.1412***	0.2809***	0.3032***	0.2347***	
	(0.0390)	(0.0731)	(0.0791)	(0.0760)	
log(smokePM_pred_s+1)					0.1547***
					(0.0328)
Fixed-effects					
DMA	Yes	Yes	Yes	Yes	Yes
date	Yes	Yes	Yes	Yes	Yes
Fit statistics					
Observations	1,108,845	37,105	12,505	3,280	3,280
R^2	0.07488	0.27364	0.40249	0.61108	0.75346
Within R^2	0.01854	0.07623	0.09768	0.07163	0.02481

Clustered (DMA) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

But what is the nature of this coverage? To investigate, we characterize the content of the coverage using a topic model [Blei et al., 2003]. Analysis of the perplexity suggests that roughly 100 topics optimizes on the trade-off between model fit and parsimony (see SI section XX). Detailed inspection of the topics themselves indicates that topic #5 is the one most associated with climate change and global warming (see SI section XX). We calculate

the average topic loading for the climate change topic per DMA-by-day, as well as the sum of topic loadings, and again calculate the association between media coverage of wildfires that discusses climate change, and exposure to wildfire smoke. Again we find a statistically significant positive association (see Figure 7).

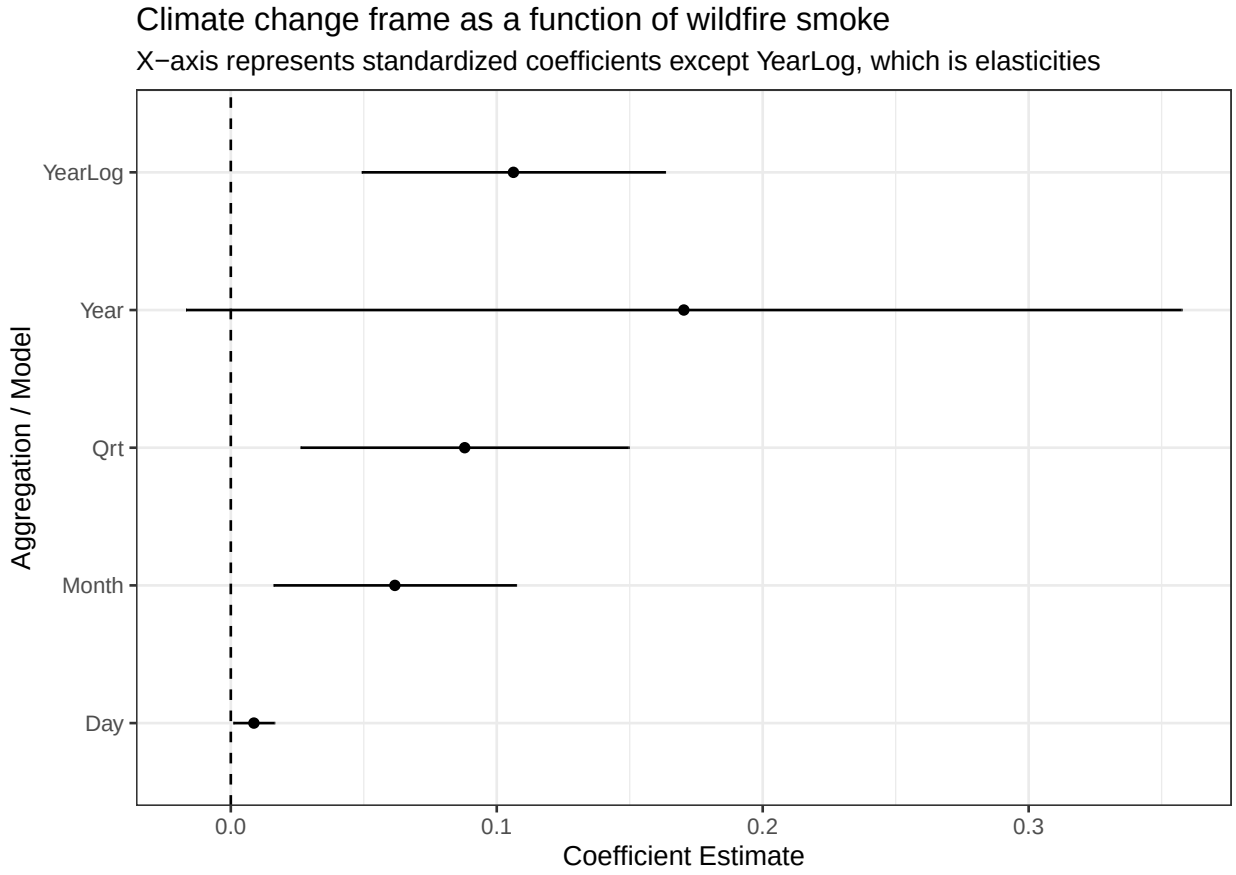

Figure 7: Probability that the media coverage of wildfires uses a climate change frame (x-axis), aggregated over different periods (y-axis).

While the preceding analyses hold constant time-invariant DMA characteristics via the fixed effects specification, we might suspect that more Republican-leaning areas are less likely to frame their coverage of wildfire smoke with reference to climate change, given the ideological right's historic skepticism about humanity's responsibility for global warming. To investigate, we interact the wildfire smoke with the DMA's aggregate support for George W. Bush in the 2004 election.[6] Figure 8 plots the marginal "effects" of the interacted regression,

[6]We use the 2004 presidential election results in order to avoid post-treatment bias. DMA-level support

using data aggregated to the month. As illustrated, DMAs that lean more Republican are less likely to see coverage of wildfires in their area that make reference to climate change than DMAs that lean more Democratic.

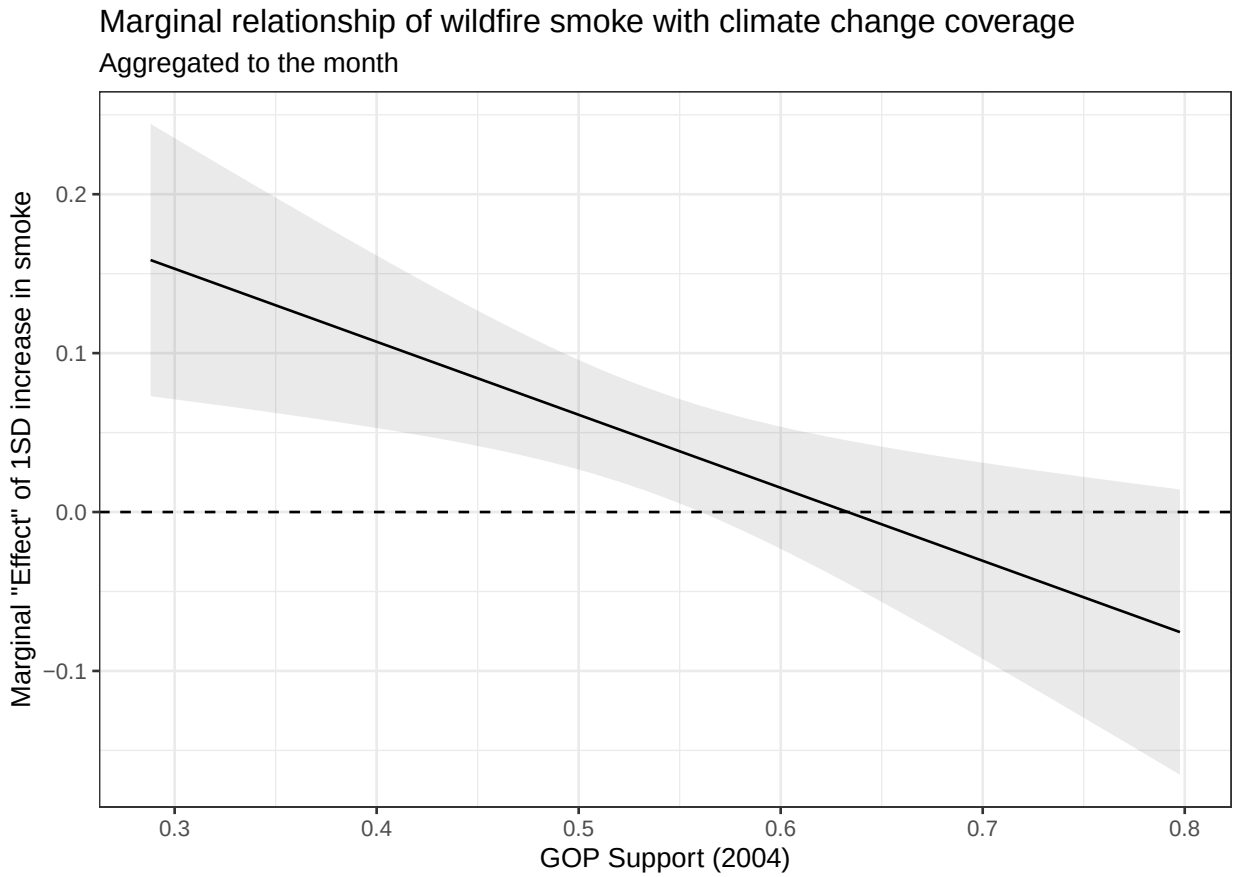

Figure 8: MFX plot of wildfire smoke exposure on media coverage of wildfires that emphasizes climate change (y-axis) as a function of Republican support for George W. Bush in the 2004 presidential election (x-axis).

5.3 Attitudes and Media

If attitudes are not correlated with wildfire smoke exposure per se, are they related to media coverage of the wildfires? To test, we predict belief that climate change is a "very important" issue as a function of the respondent's exposure to media coverage of wildfires over variety

is calculated as a function of county-level votes aggregated up to the larger geographic unit.

of periods prior to when they answered the survey. As above, the panel nature of our data combined with respondent fixed effects means that we are identifying variation in attitudes as a function of variation in media coverage within each respondent. We examine both the total number of articles (black points in Figure 9) and the climate change frame (gray points in Figure 9). As illustrated, there is a small but systematic positive association between concern about climate change and exposure to the climate change frame in local media coverage of wildfires, although this relationship doesn't achieve statistical significance until we aggregate over more than one month of coverage prior to when the survey was taken.[7]

We also observe the respondents' self-reported viewership of a number of different news television programs in the first wave of the survey, broken out into whether it is daily, morning, evening, late night, or Sunday news programs, along with the name of the program and the outlet with which it is associated. We also have self-reported consumption of local television and newspapers. We start by applying correspondence analysis to the matrix of respondents (rows) and outlets watched (columns). Correspondence analysis, similar to factor analysis, derives latent dimensions by identifying clusters of similarly grouped rows across columns. We plot both the first and second dimensions in Figure 10, revealing clear patterns along the first dimension that correspond to ideology, and suggestive patterns along the second dimension that might be considered measures of local versus national news consumption.

We interact both the first and second dimensions with our measure of the climate change frame for media coverage, revealing a significant negative interaction effect for the ideology dimension, and an insignificant negative interaction effect for the nationalized news dimension (see Figure 11). Substantively, this pattern is consistent with a story in which respondents who consume more right-wing news are less influenced by climate change nar-

[7]Shorter aggregation periods result in almost no media coverage for many respondents, since the surveys were taken in November of 2016, 2017, and 2020, while the wildfire season typically ends in the early fall.

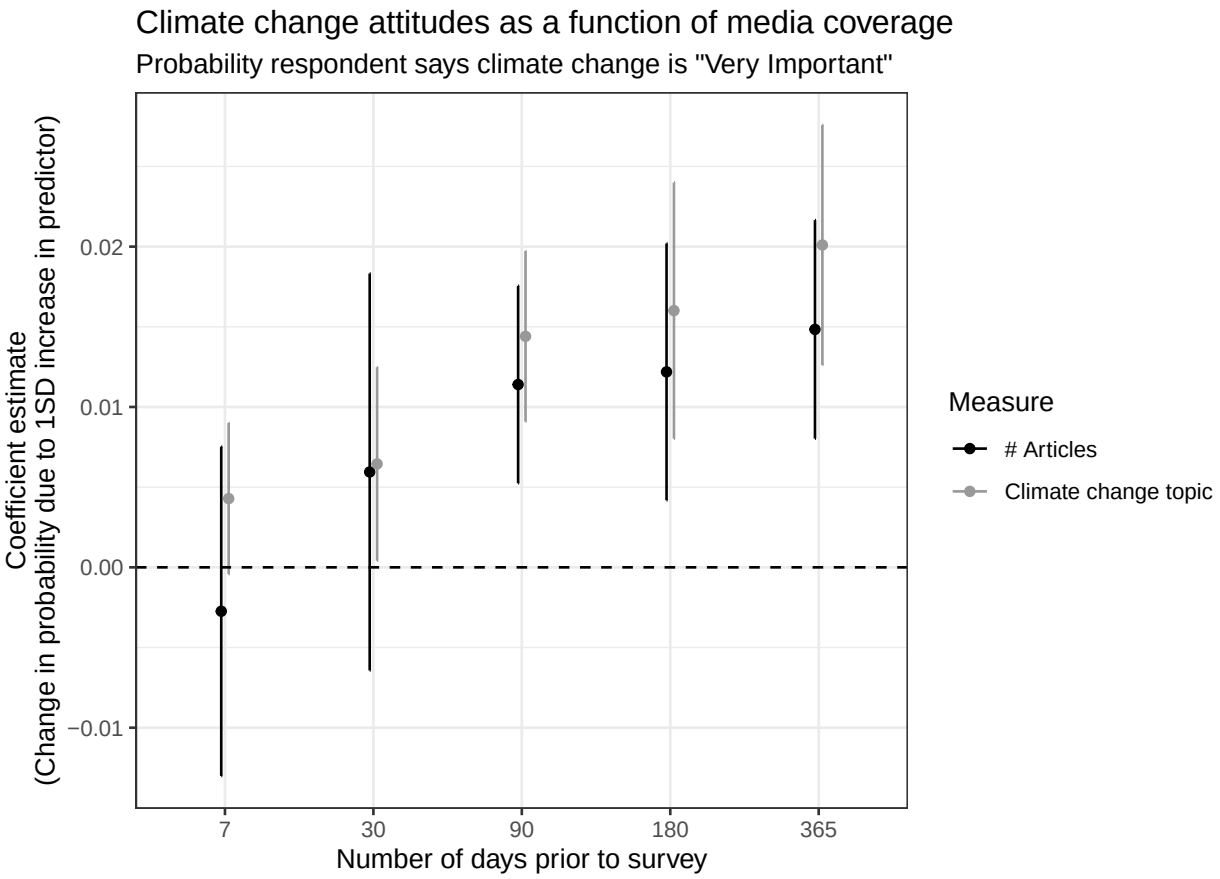

Figure 9: Coefficient estimates (y-axis) characterizing the change in the probability a respondent says that climate change is a "very important" issue associated with a 1 standard deviation increase in either the number of articles written about wildfires (black points) or the topic model probability for the climate change topic (gray points), aggregated over different periods prior to when the survey was taken (x-axis).

ratives found in media coverage of wildfires in their DMA.

To put more substantive meaning on these results, we plot the interacted results from a selection of media consumption choices, including Fox News, MSNBC, and local TV and newspapers. Specifically, we create an indicator for each station that takes on the value of 1 if the respondent watches one or more programs on that station, and zero otherwise. We also create a similar dummy indicator for whether the respondent reads the local newspaper or watches the local evening news one day per week or more. We plot the interaction results in Figure 12, revealing that only consumption of Fox News programs significantly reduces

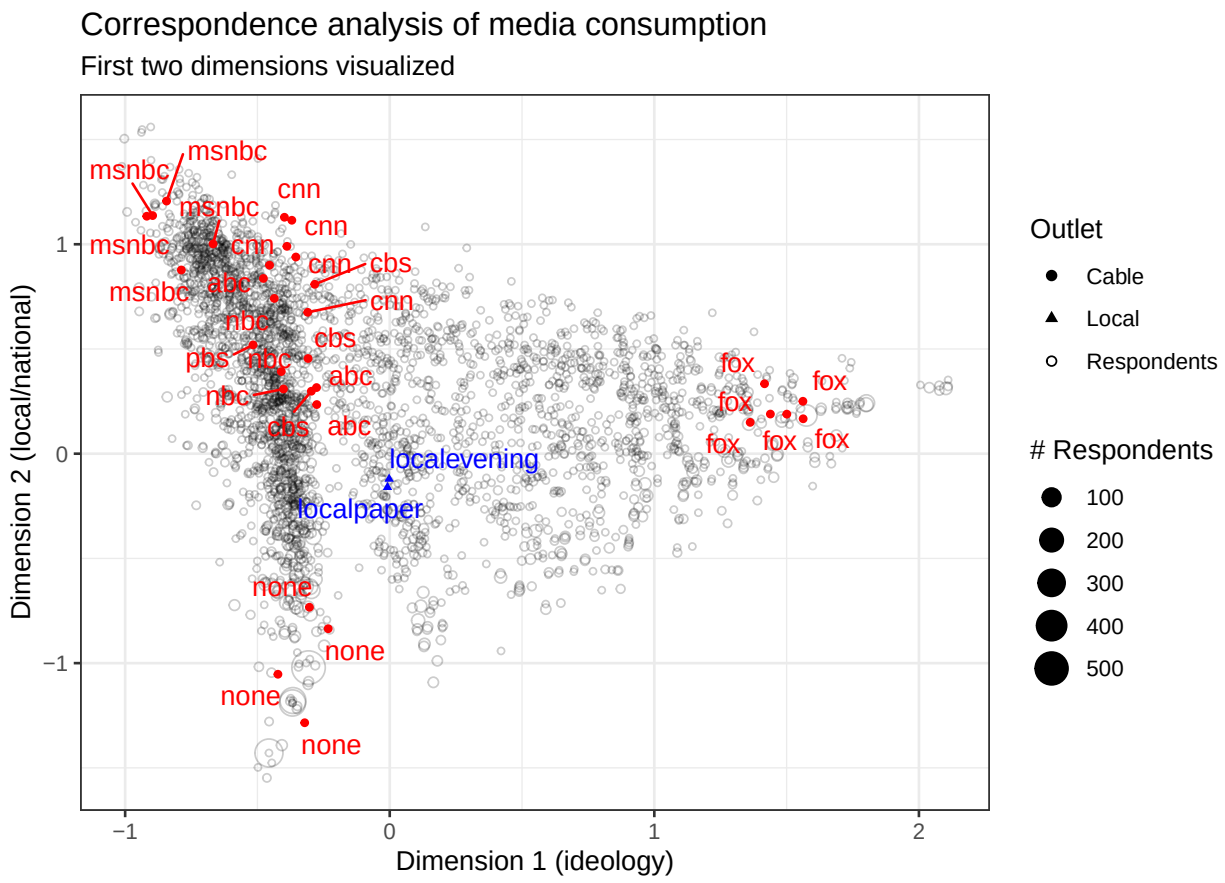

Figure 10: First two dimensions of correspondence analytic solution (x and y-axis, respectively). Hollow gray points are respondents (sized by the number of respondents at a given coordinate), red circles are cable news programs, and blue triangles are local news sources.

with the relationship between climate change coverage of wildfires and attitudes. Conversely, consuming local news increases the relationship between climate change frames and attitudes, although this is only statistically significant at the 10% threshold for local evening news.

5.4 Attitudes, wildfires, and media coverage

Thus far, our empirical evidence can be summarized as follows. First, we find no relationship between exposure to wildfire smoke and attitudes on climate change, where individual-exposure is defined at the zip code tabulation area (ZCTA). Second, we find a positive association between wildfire smoke and media coverage of wildfires, as well as a positive

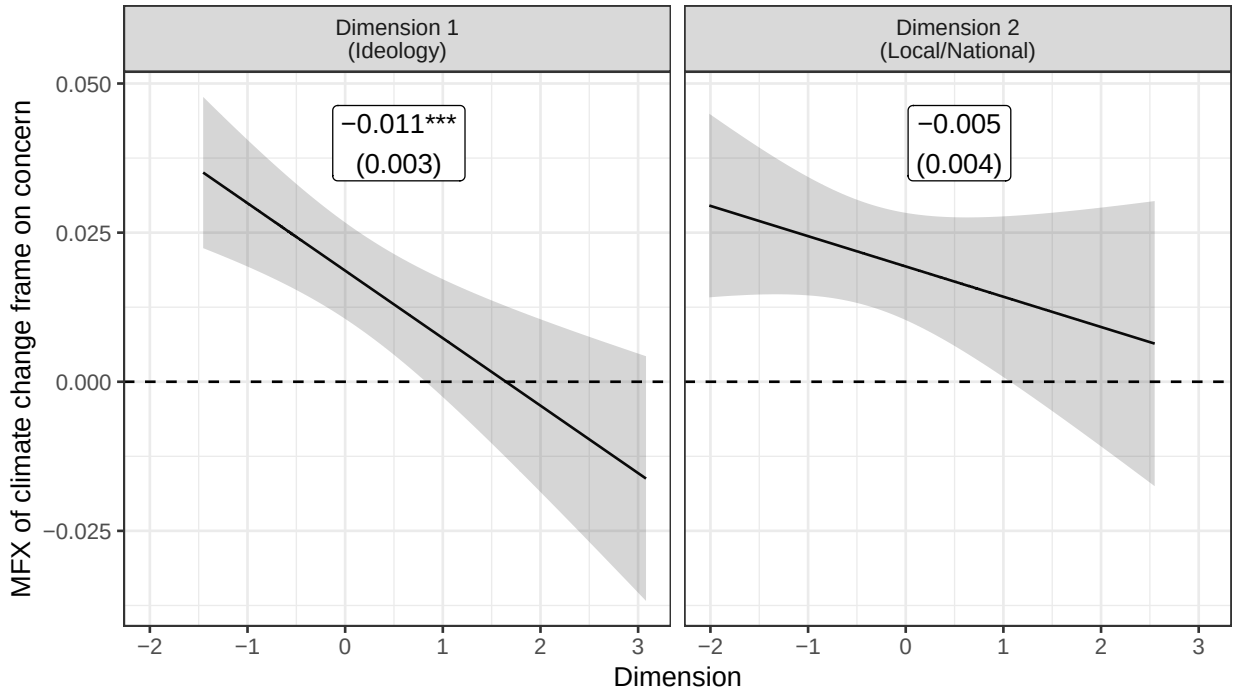

Figure 11: Marginal effects of climate change narratives of wildfires across respondent news consumption, reduced to its first two dimensions from correspondence analysis.

association between wildfire smoke and media coverage that emphasizes climate change, where media-exposure is defined at the designated market area (DMA). The strength of this positive association between the climate change frame and wildfire smoke is declining among more Republican parts of the country, measured using the average of county-level 2004 presidential voting patterns. Third, we find a positive association between media coverage of wildfires and attitudes on climate change, where media coverage is again measured at the DMA level. As with the media coverage outcome, we again note that the strength of this association is moderated by pre-treatment consumption of media, especially Fox News programming, measured in 2011.

We now turn to a descriptive triple interaction, in which we predict concern about climate change as a function of wildfire smoke exposure (calculated as the logged sum of total $PM_{2.5}$ over the past two years), media coverage emphasizing climate change (calculated as the average probability of the topic over the preceding year), and the 2011 measure of how much

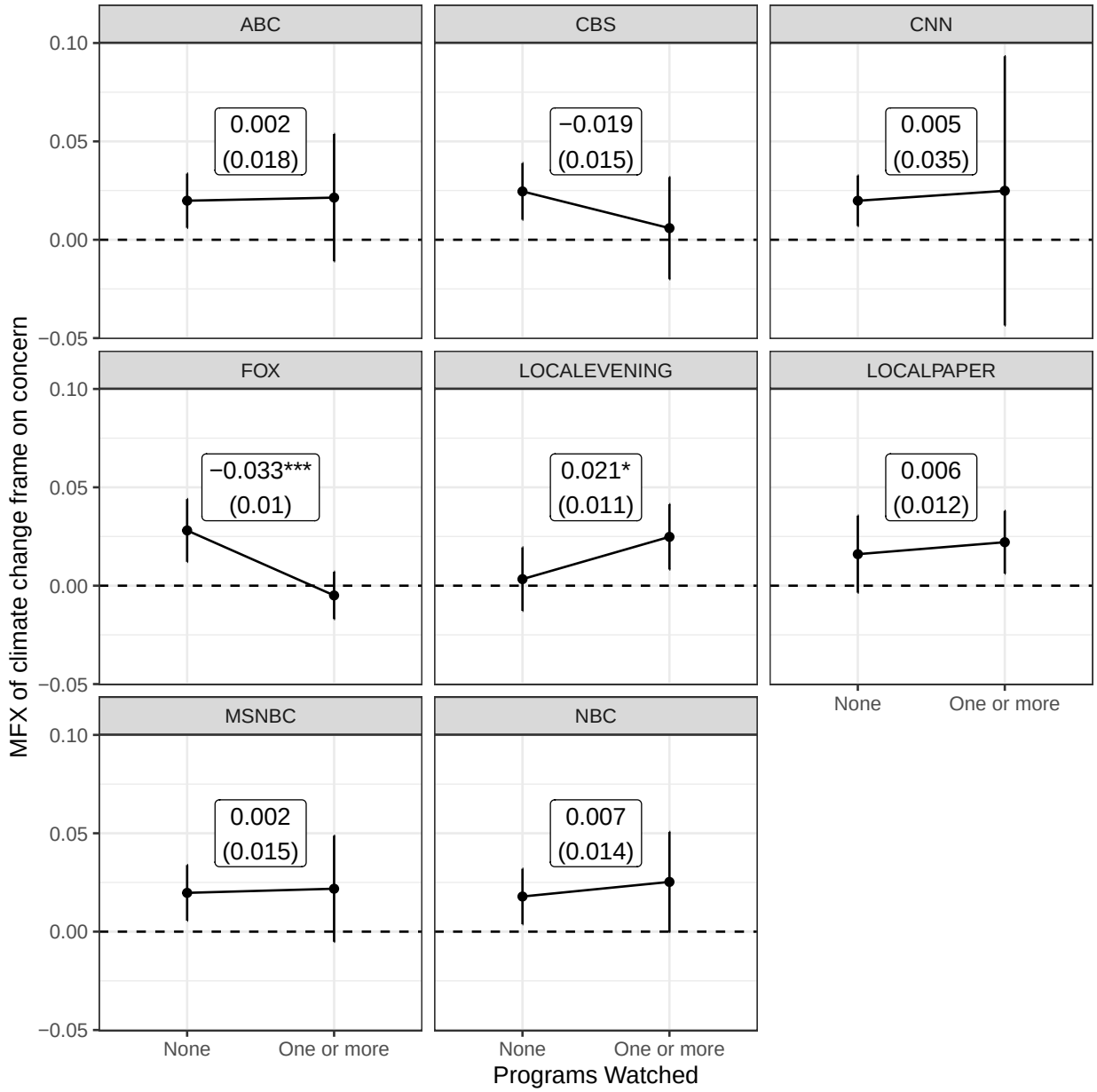

Figure 12: Marginal effects of climate change narratives of wildfires across respondent news consumption, disaggregated by the station watched or local news.

conservative content the respondent consumes (dichotomized such that values of the first dimension from the correspondence analysis which are greater than zero are scored as 1, and 0 otherwise). As shown in Figure 13, a powerful pattern emerges. Specifically, wildfire smoke and media coverage combine to reduce concern about climate change *among respondents who consume a conservative media diet*. As illustrated in the left panel of Figure 13, the effect

of smoke exposure on concern is insignificant among both types of respondents when the media coverage does not emphasize climate change. However, as media coverage increases the climate change frame, consumers of conservative media content begin to reduce their expressed concern about climate change in response to wildfire smoke exposure. Similarly, the right panel of Figure 13 indicates that the climate change frame increases concern among both types of respondents when there is little exposure to wildfire smoke, but that consumers of conservative media start to reduce their concern in response to media frames as their exposure to wildfire smoke increases. Notably, there is no interaction effect between media frames and smoke exposure among non-conservative media diet respondents.

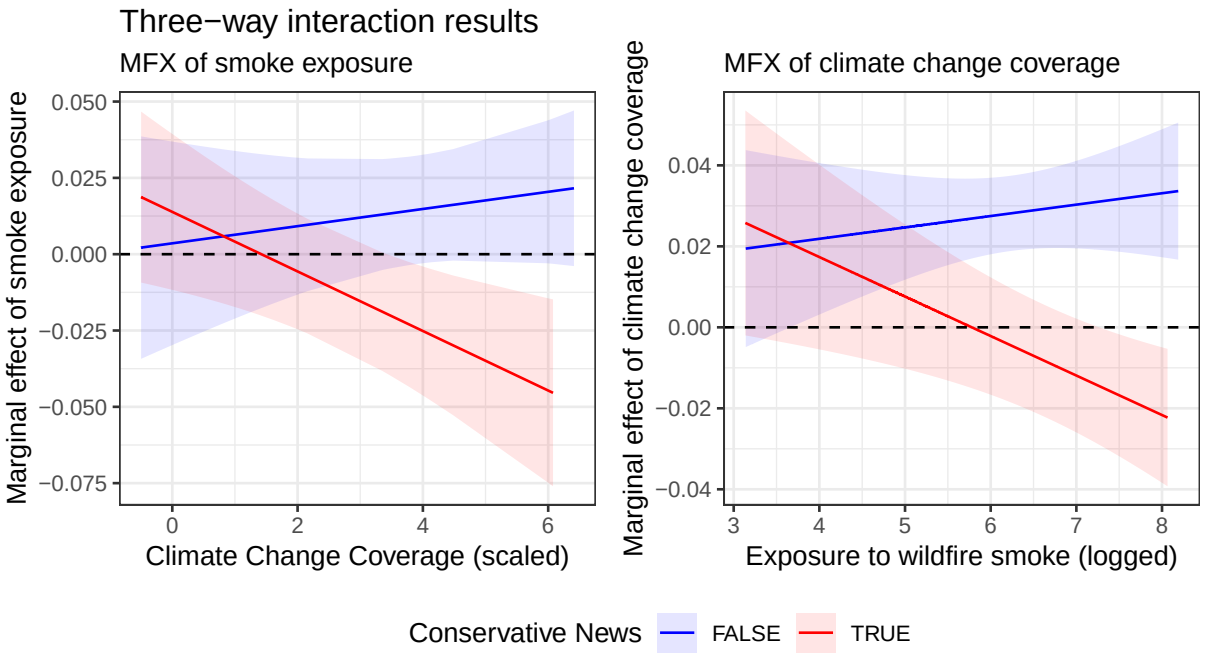

Figure 13:

These patterns are consistent with a story in which conservative media largely ignores the topic of climate change until climate disasters occur. When this happens, it appears that they begin to talk about the natural disaster, and indeed perhaps climate change as a topic, but do so in a way that reduces concern about climate change among their viewers. The result suggests that the interaction between climate change signals like wildfires and

media coverage of these events serves to further polarize the public in terms of their climate attitudes.

6 Conclusion

As wildfires become more frequent and severe in the United States, personal experience with these events may emerge as a critical motivational factor in increasing climate chance concern and corresponding support for policies aimed at adapting to their adverse impacts. While a growing body of literature has presented evidence that direct exposure to climate hazards increases concern about climate change, many studies do not explore whether individuals' responses to these events are partially or wholly mediated by media coverage. Given the complexity of climate change and its effects, we argue that voters will rely on media coverage to draw the connection between wildfires and climate change. However, because different outlets may emphasize wildfire coverage differently, we expect that their effects on public concern about climate change will vary across regions. More specifically, we predict that individuals in liberal areas will show increased concern about climate change when local media coverage emphasizes the link between wildfire smoke and climate change, whereas the opposite effect is expected in conservative areas.

Through a combination of individual-level panel data with geocoded data on smoke from wildfires, as well as local media coverage of wildfires, our study provides the first systematic test of the role of media in shaping climate change concern. Departing from growing consensus on personal experience studies, our results show that individuals do not directly increase their climate change concern in response to climate shocks. In fact, people living in areas exposed to wildfire smoke only update their climate change concern when local news intensifies their coverage of the wildfire events. However, these effects vary across areas. In more liberal regions, we observe that individuals tend to heighten their concern about

climate change when the local media coverage emphasizes climate change as an explanation for wildfires. In contrast, consumers of conservative media reduced concern about climate change following such coverage. Taken together, our results suggest that media not only serves as a crucial mechanism for shaping individuals' concern about climate change by connecting wildfires with global warming but also suggests that climate hazards like wildfires may exacerbate political polarization regarding the importance of climate change.

This paper makes two major contributions to literature. First, this study is the first to theorize the role of media in shaping climate change attitudes and provide systematic evidence to support this claim. While previous studies acknowledge the importance of media in shaping public opinion on climate change, these assertions have been made without empirical testing. Second, this study provides a potential explanation for the mixed and inconclusive findings in the literature regarding the relationship between exposure and climate change opinion [Howe et al., 2019]. While a growing consensus shows a positive association between direct exposure and climate preferences, a non-trivial number of studies do find similar results Perhaps this discrepancy may be attributed to the fact that voters cannot translate experience with climate hazards into climate change attitudes without mediators factors such as media. Thus, our study offers a theoretical and methodological framework for future research to investigate how local media coverage can influence climate change opinion.

Of course, this study is not without limitations at this stage. First, our media analyses are not causally identified, suggesting that the results should be viewed as suggestive rather than definitive evidence of the role of media in shaping climate change attitudes. Moving forward, implementing an appropriate causal design will involve either an internal valid survey experimental or leveraging exogenous variation in media coverage that allows us to causally identify their effects. Second, our panel covers only a relatively short period, limiting our ability to fully comprehend the evolution of beliefs on climate change over time. A longer panel would provide us the opportunity to determine when individuals cease updating their

beliefs on climate change. Investigating the temporal evolution of updating should be the focus of future studies on climate change preferences, as there is currently a lack of evidence on how preferences updating evolves.

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