The role of news and social pressure in shaping U.S. public opinion on climate change

Online appendix

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1 Introduction

This online appendix supplements more details for the contents that are not included in the main text due to the constraints on length. The online appendix is organized as follows. In Section 2, we present both the forward and backward processes for assigning values to hyperparameters of subjective importance. How we use climate disasters and climate-related policy events to derive news number and news objective importance is explained in Section 3. We list all potential models and select our baseline model in Section 4. A complete version of sensitivity analysis is shown in Section 5. All the policies we experiment with are presented in Section 6.

2 Subjective importance

We work both forwards and backwards to find plausible values for hyperparameters.

2.1 Equations

The following are the equations for composed parameters and functions.

$$
\begin{aligned}
\alpha_{\ell j}(\tau) &= \phi_{\ell j} + \theta_{\ell j}\bar{c}_j(\tau) \qquad (\ell = 1, ..., 4),\\
\phi^*_{\ell d} &= \phi_{\ell d} + \theta_{\ell d}\beta_{0d}, \qquad \theta^*_{\ell d} = \theta_{\ell d}\beta_{1d},\\
\phi^*_{\ell r} &= \phi_{\ell r} + \theta_{\ell r}\beta_{0r}, \qquad \theta^*_{\ell r} = \theta_{\ell r}\beta_{1r},\\
\Phi^{(h)}_{2j}(\tau) &= \phi^*_{2j}\bar{r}^{(h)}(\tau) + \phi^*_{3j}\bar{p}^{(h)}_{+}(\tau) + \phi^*_{4j}\bar{p}^{(h)}_{-}(\tau),\\
\Theta^{(h)}_{2j}(\tau) &= \theta^*_{2j}\bar{r}^{(h)}(\tau) + \theta^*_{3j}\bar{p}^{(h)}_{+}(\tau) + \theta^*_{4j}\bar{p}^{(h)}_{-}(\tau),\\
f_1\left(\bar{m}^{(h)}(\tau), \bar{c}_j(\tau)\right) &= \phi^*_{1j}\bar{m}^{(h)}(\tau) + \theta^*_{1j}\bar{m}^{(h)}(\tau)B^*(\tau),\\
f_2\left(\bar{r}^{(h)}(\tau), \bar{p}^{(h)}(\tau), \bar{c}_j(\tau)\right) &= \Phi^{(h)}_{2j}(\tau) + \Theta^{(h)}_{2j}(\tau)B^*(\tau),\\
\delta^{(h)}_{0j}(\tau) &= \phi^*_{1j}\Phi^{(h)}_{2j}(\tau),\\
\delta^{(h)}_{1j}(\tau) &= \phi^*_{1j}\Theta^{(h)}_{2j}(\tau) + \Phi^{(h)}_{2j}(\tau)\theta^*_{1j},\\
\delta^{(h)}_{2j}(\tau) &= \theta^*_{1j}\Theta^{(h)}_{2j}(\tau),\\
\frac{\bar{m}^{(h)}_j(\tau)}{\bar{m}^{(h)}(\tau)} &= \delta^{(h)}_{0j}(\tau) + \delta^{(h)}_{1j}(\tau)B^*(\tau) + \delta^{(h)}_{2j}(\tau)(B^*(\tau))^2.
\end{aligned}
$$

2.2 Values for the underlying hyperparameters

We implement experiments in two ways. One is a forward process, in which we first give values to all underlying hyperparameters, and then compute the composed parameters. The other is a backward process, in which we first design the particular coefficients of the outcome equations.

2.2.1 Forward process

We first look at extrema to obtain the bounds for the results that exhibit monotonicity. Therefore, we experiment with two news items: a positive one h_1 with $\bar{r}^{(h_1)}(\tau) = 1$, $\bar{p}_+^{(h_1)}(\tau) = 1$, $\bar{p}_-^{(h_1)}(\tau) = 0$, and another negative one h_2 with $\bar{r}^{(h_2)}(\tau) = 1$, $\bar{p}_+^{(h_2)}(\tau) = 0$, $\bar{p}_-^{(h_2)}(\tau) = 1$. The power balance $B^*(\tau)$, including Trump effect, is set from -1 to 1.2, with a step size of 0.1. After a series of experiments, a set of underlying parameters that lead to reasonable results is shown in Table 1.

Table 1: Values of the hyperparameters

β_{0d}	β_{1d}	ϕ_{1d}	θ_{1d}	ϕ_{2d}	θ_{2d}	ϕ_{3d}	θ_{3d}	ϕ_{4d}	θ_{4d}
-0.50	-0.07	0.10	-1.20	0.07	-1.10	0.03	-0.60	0.04	-0.70
β_{0r}	β_{1r}	ϕ_{1r}	θ_{1r}	ϕ_{2r}	θ_{2r}	ϕ_{3r}	θ_{3r}	ϕ_{4r}	θ_{4r}
0.50	0.04	1.10	-1.05	0.90	-0.87	0.46	-0.45	0.50	-0.48

After calculation, we obtain the composed parameters of news items h_1 and h_2 from the perspective of democratic media:

$$
\begin{aligned}
\phi_{1d}^* &= 0.70, & \theta_{1d}^* &= 0.084,\\
\phi_{2d}^* &= 0.62, & \theta_{2d}^* &= 0.077,\\
\phi_{3d}^* &= 0.33, & \theta_{3d}^* &= 0.042,\\
\phi_{4d}^* &= 0.39, & \theta_{4d}^* &= 0.049,\\
\Phi_{2d}^{(h_1)}(\tau) &= 0.95, & \Theta_{2d}^{(h_1)}(\tau) &= 0.119,\\
\Phi_{2d}^{(h_2)}(\tau) &= 1.01, & \Theta_{2d}^{(h_2)}(\tau) &= 0.126,
\end{aligned}
$$

$$
\begin{aligned}
\delta_{0d}^{(h_1)}(\tau) &= 0.665, & \delta_{1d}^{(h_1)}(\tau) &= 0.1631, & \delta_{2d}^{(h_1)}(\tau) &= 0.0100,\\
\delta_{0d}^{(h_2)}(\tau) &= 0.707, & \delta_{1d}^{(h_2)}(\tau) &= 0.1730, & \delta_{2d}^{(h_2)}(\tau) &= 0.0106.
\end{aligned}
$$

$\phi_{1d}^* = 0.7$ means that in the first stage of adjustment, editor from democratic media multiplies the objective importance by 0.7 when power balance is equal to 0, and an increase of 1 unit in power balance leads to an increase of $\theta_{1d}^* = 0.084$ in the measurement.

In the second stage of adjustment, for the news item with 1 unit of positivity, we obtain:

$$\begin{aligned}\Phi_{2d}^{(h_1)}(\tau) &= 0.62\bar{r}^{(h_1)}(\tau) + 0.33\bar{p}_{+}^{(h_1)}(\tau)\\ &= \left(\frac{62}{95}\bar{r}^{(h_1)}(\tau) + \frac{33}{95}\bar{p}_{+}^{(h_1)}(\tau)\right) \times 0.95,\\ \Theta_{2d}^{(h_1)}(\tau) &= 0.077\bar{r}^{(h_1)}(\tau) + 0.042\bar{p}_{+}^{(h_1)}(\tau),\\ &= \left(\frac{11}{17}\bar{r}^{(h_1)}(\tau) + \frac{6}{17}\bar{p}_{+}^{(h_1)}(\tau)\right) \times 0.119.\end{aligned}$$

According to the above equations, editor from democratic media further adjusts the importance value of positive news item in stage one by multiplying 0.95 when power balance is equal to 0, and 62/95 of the effect is provided by reliability, while 33/95 of the effect is provided by positivity. Furthermore, an increase of 1 unit in power balance leads to an increase of 0.119 in the effect, with 11/17 of the effect provided by reliability, and 6/17 of the effect provided by positivity.

Also, in the second stage of adjustment, for the news items with 1 unit of negativity, we obtain:

$$\begin{aligned}\Phi_{2d}^{(h_2)}(\tau) &= 0.62\bar{r}^{(h_2)}(\tau) + 0.39\bar{p}_{-}^{(h_2)}(\tau)\\ &= \left(\frac{62}{101}\bar{r}^{(h_2)}(\tau) + \frac{39}{101}\bar{p}_{-}^{(h_2)}(\tau)\right) \times 1.01,\\ \Theta_{2d}^{(h_2)}(\tau) &= 0.077\bar{r}^{(h_2)}(\tau) + 0.049\bar{p}_{-}^{(h_2)}(\tau),\\ &= \left(\frac{11}{18}\bar{r}^{(h_2)}(\tau) + \frac{7}{18}\bar{p}_{-}^{(h_2)}(\tau)\right) \times 0.126,\end{aligned}$$

whose interpretations are analogous to those of the positive news item.

For republican media, the composed parameters of news items h_1 and h_2 are :

$$\begin{aligned}\phi_{1r}^{*} &= 0.575, & \theta_{1r}^{*} &= -0.042,\\ \phi_{2r}^{*} &= 0.465, & \theta_{2r}^{*} &= -0.035,\\ \phi_{3r}^{*} &= 0.235, & \theta_{3r}^{*} &= -0.018,\\ \phi_{4r}^{*} &= 0.260, & \theta_{4r}^{*} &= -0.019,\\ \Phi_{2r}^{(h_1)}(\tau) &= 0.700, & \Theta_{2r}^{(h_1)}(\tau) &= -0.053,\\ \Phi_{2r}^{(h_2)}(\tau) &= 0.725, & \Theta_{2r}^{(h_2)}(\tau) &= -0.054,\end{aligned}$$

$$\begin{aligned}\delta_{0r}^{(h_1)}(\tau) &= 0.403, & \delta_{1r}^{(h_1)}(\tau) &= -0.0599, & \delta_{2r}^{(h_1)}(\tau) &= 0.0022,\\ \delta_{0r}^{(h_2)}(\tau) &= 0.417, & \delta_{1r}^{(h_2)}(\tau) &= -0.0615, & \delta_{2r}^{(h_2)}(\tau) &= 0.0023.\end{aligned}$$

We can then obtain:

$$\begin{aligned}
\Phi_{2r}^{(h_1)}(\tau) &= 0.465\bar{r}^{(h_1)}(\tau) + 0.235\bar{p}_{+}^{(h_1)}(\tau) \\
&= \left(\frac{93}{140}\bar{r}^{(h_1)}(\tau) + \frac{47}{140}\bar{p}_{+}^{(h_1)}(\tau)\right) \times 0.70, \\
\Theta_{2r}^{(h_1)}(\tau) &= -0.035\bar{r}^{(h_1)}(\tau) + (-0.018)\bar{p}_{+}^{(h_1)}(\tau), \\
&= \left(\frac{35}{53}\bar{r}^{(h_1)}(\tau) + \frac{18}{53}\bar{p}_{+}^{(h_1)}(\tau)\right) \times (-0.053). \\
\Phi_{2r}^{(h_2)}(\tau) &= 0.465\bar{r}^{(h_2)}(\tau) + 0.260\bar{p}_{-}^{(h_2)}(\tau) \\
&= \left(\frac{93}{145}\bar{r}^{(h_2)}(\tau) + \frac{52}{145}\bar{p}_{-}^{(h_2)}(\tau)\right) \times 0.725, \\
\Theta_{2r}^{(h_2)}(\tau) &= -0.035\bar{r}^{(h_2)}(\tau) + (-0.019)\bar{p}_{-}^{(h_2)}(\tau), \\
&= \left(\frac{35}{54}\bar{r}^{(h_2)}(\tau) + \frac{19}{54}\bar{p}_{-}^{(h_2)}(\tau)\right) \times (-0.054),
\end{aligned}$$

The interpretation for republican media is similar to that for democratic media.

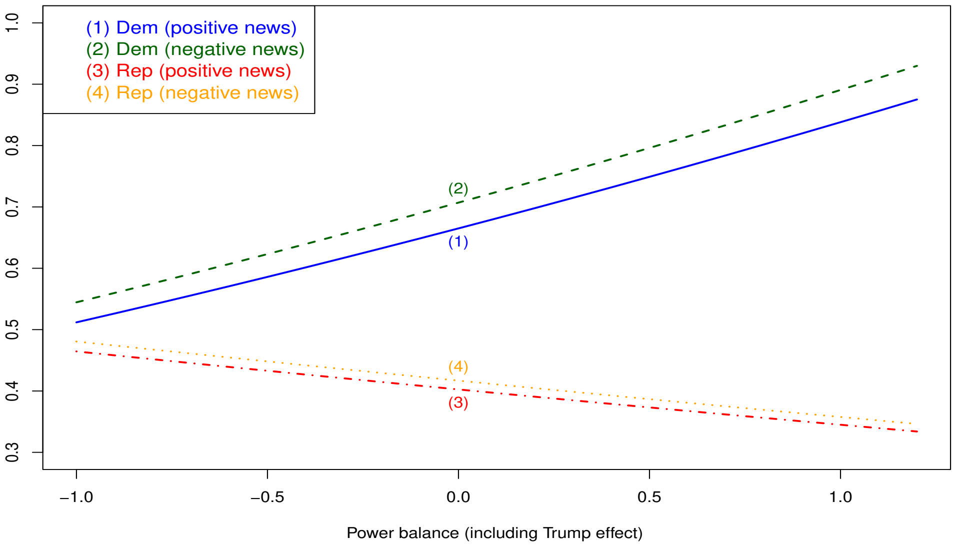

Figure 1: Ratio $\bar{m}_d/\bar{m}$ and $\bar{m}_r/\bar{m}$ of subjective to objective importance by power balance

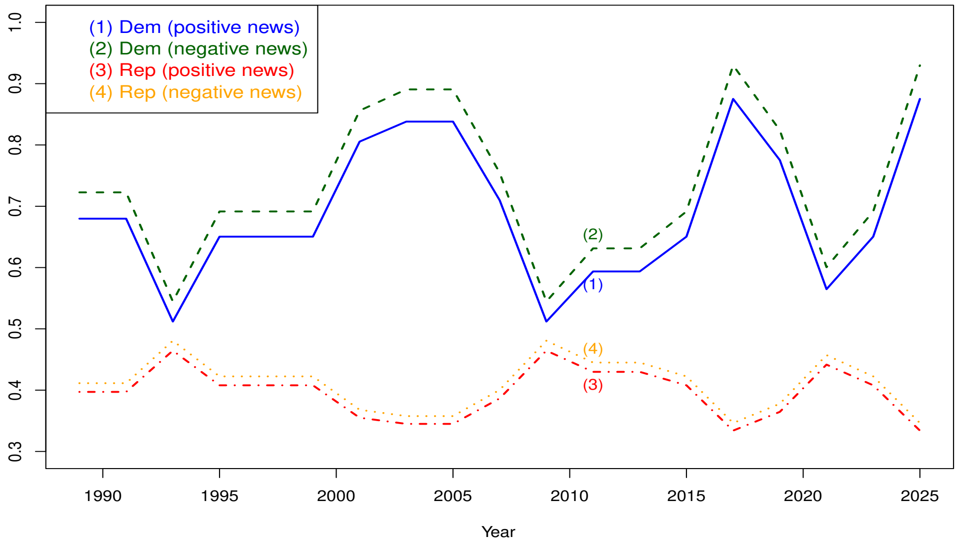

Figure 2: Ratio $\bar{m}_d/\bar{m}$ and $\bar{m}_r/\bar{m}$ of subjective to objective importance by year

Figure 1 shows the trend of subjective importance ratio when power balance increases. For democratic media, the subjective importance of the same news item increases, while for republican media, the subjective importance of the same news item decreases. The trends are all monotonic, and the slope of democratic media is larger than that of republican media. Moreover, as we expect, for a given national TV station, negative news items are always more important than positive ones. Figure 2 shows the subjective importance ratio for the news items with 1 unit reliability and 1 unit positivity/negativity from the perspective of democratic and republican media, using the real power balance at two-year intervals.

2.2.2 Backward process

In this subsection, we begin by setting the ratio of subjective to objective importance for democratic and republican media, corresponding to the bounds of power balance. Then, we calculate the coefficients under different positions of symmetric axis.

We take the news item h_1 with 1 unit of reliability and 1 unit of positivity as an example, and assume that when national power balance is equal to -1, the ratio of subjective to objective importance is 0.5 for democratic media, and 0.5 for republican media. When national power balance is equal to 1.2, the ratio of subjective to objective importance is 0.9 for democratic media, and 0.35 for republican media. Then we have:

$$\text{democratic media:} \qquad \begin{cases} 0.5 = \delta_{0d}^{(h_1)}(\tau) - \delta_{1d}^{(h_1)} + \delta_{2d}^{(h_1)}(\tau), \\ 0.9 = \delta_{0d}^{(h_1)}(\tau) + 1.2\delta_{1d}^{(h_1)} + 1.44\delta_{2d}^{(h_1)}(\tau), \\ -\frac{\delta_{1d}^{(h_1)}(\tau)}{2\delta_{2d}^{(h_1)}(\tau)} = x_d, \end{cases}$$

$$\text{republican media:} \qquad \begin{cases} 0.5 = \delta_{0r}^{(h_1)}(\tau) - \delta_{1r}^{(h_1)} + \delta_{2r}^{(h_1)}(\tau), \\ 0.35 = \delta_{0r}^{(h_1)}(\tau) + 1.2\delta_{1r}^{(h_1)} + 1.44\delta_{2r}^{(h_1)}(\tau), \\ -\frac{\delta_{1r}^{(h_1)}(\tau)}{2\delta_{2r}^{(h_1)}(\tau)} = x_r, \end{cases}$$

where x_d, x_r are the value of symmetric axes needed to be experimented. The solutions of these system of equations are:

$$\text{democratic media:} \qquad \begin{cases} \delta_{2d}^{(h)}(\tau) = -\frac{0.4}{4.4x_d - 0.44}, \\ \delta_{1d}^{(h)}(\tau) = -2x_d\delta_{2d}^{(h)}(\tau), \\ \delta_{0d}^{(h)}(\tau) = 0.5 - (2x_d + 1)\delta_{2d}^{(h)}(\tau), \end{cases}$$

$$\text{republican media:} \qquad \begin{cases} \delta_{2r}^{(h)}(\tau) = -\frac{0.15}{4.4x_r - 0.44}, \\ \delta_{1r}^{(h)}(\tau) = -2x_r\delta_{2r}^{(h)}(\tau), \\ \delta_{0r}^{(h)}(\tau) = 0.5 - (2x_r + 1)\delta_{2r}^{(h)}(\tau). \end{cases}$$

The experiment results are shown in Table 2.

According to the particular equations that determine the ratio of subjective to objective importance given $\bar{r}^{(h_1)}(\tau) = 1$, $\bar{p}_{+}^{(h_1)}(\tau) = 1$, $\bar{p}_{-}^{(h_1)}(\tau) = 0$ from the perspective of democratic and republican TV stations in the forward process:

$$\frac{\bar{m}_d^{(h_1)}(\tau)}{\bar{m}^{(h_1)}(\tau)} = 0.665 + 0.1631B^*(\tau) + 0.01(B^*(\tau))^2,$$

$$\frac{\bar{m}_r^{(h_1)}(\tau)}{\bar{m}^{(h_1)}(\tau)} = 0.403 - 0.0599B^*(\tau) + 0.0022(B^*(\tau))^2,$$

their symmetric axes are equal to -8.2 and 13.6, respectively. The computed coefficient values in the underlined italic rows $x_d = -8$, and $x_r = 14$ approach to the experiment results in the forward process. The consistency between forward and backward processes verifies the mathematical validity of this set of coefficients.

Table 2: Coefficients under different x_d and x_r

democratic media				republican media			
x_d	$\delta_{2d}^{(h)}(\tau)$	$\delta_{1d}^{(h)}(\tau)$	$\delta_{0d}^{(h)}(\tau)$	x_r	$\delta_{2r}^{(h)}(\tau)$	$\delta_{1r}^{(h)}(\tau)$	$\delta_{0r}^{(h)}(\tau)$
−1	0.08264	0.16529	0.58264	1	0.03788	−0.07576	0.38636
−2	0.04329	0.17316	0.62987	2	0.01794	−0.07177	0.41029
−3	0.02933	0.17595	0.64663	3	0.01176	−0.07053	0.41771
−4	0.02217	0.17738	0.65521	4	0.00874	−0.06993	0.42133
−5	0.01783	0.17825	0.66043	5	0.00696	−0.06957	0.42347
−6	0.01490	0.17884	0.66393	6	0.00578	−0.06934	0.42488
−7	0.01280	0.17926	0.66645	7	0.00494	−0.06917	0.42589
<u>−8</u>	<u>0.01122</u>	<u>0.17957</u>	<u>0.66835</u>	8	0.00432	−0.06904	0.42664
−9	0.00999	0.17982	0.66983	9	0.00383	−0.06895	0.42722
−10	0.00900	0.18002	0.67102	10	0.00344	−0.06887	0.42769
−11	0.00819	0.18018	0.67199	11	0.00313	−0.06881	0.42807
−12	0.00751	0.18032	0.67280	12	0.00286	−0.06875	0.42838
−13	0.00694	0.18043	0.67349	13	0.00264	−0.06871	0.42865
−14	0.00645	0.18053	0.67408	<u>14</u>	<u>0.00245</u>	<u>−0.06867</u>	<u>0.42888</u>
−15	0.00602	0.18061	0.67459	15	0.00229	−0.06864	0.42907
−16	0.00565	0.18069	0.67504	16	0.00214	−0.06861	0.42925
−17	0.00532	0.18075	0.67544	17	0.00202	−0.06859	0.42940
−18	0.00502	0.18081	0.67579	18	0.00190	−0.06856	0.42953
−19	0.00476	0.18087	0.67611	19	0.00180	−0.06854	0.42965
−20	0.00452	0.18091	0.67639	20	0.00171	−0.06852	0.42976

3 News number and news objective importance

We relate the quantity and quality of news to major climate-related events, which consists of disasters and policy events.

3.1 Climate-related events

Anderson (2009) summarizes researches on media coverage of climate change, concluding that journalists tend to associate climate change with severe weather events, and that important policy events significantly increase the amount of news coverage. Accordingly, we link the severe U.S. climate disasters, as well as the global and national climate-related public events to the objective importance of news coverage.

3.1.1 The U.S. climate disasters

We obtain information for the U.S. billion-dollar climate disasters from National Centers for Environmental Information (NCEI). Figure 3 illustrates both the number and the overall CPI-adjusted losses attributed to these disasters by year.

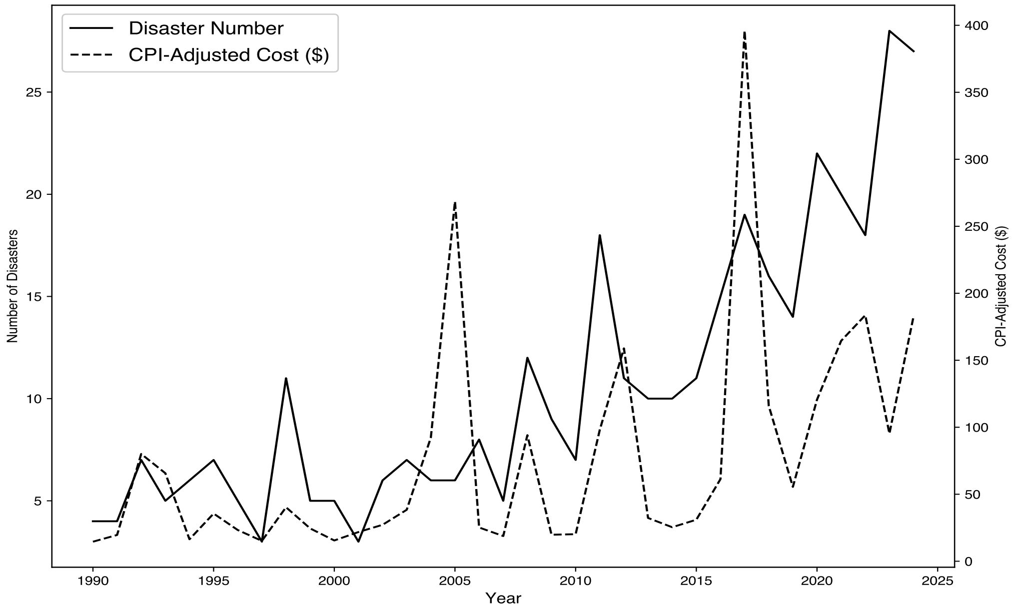

Figure 3: Number and losses of the U.S. billion-dollar disasters

We then create an index $\nu_i^{d-}(\tau)$, namely current intensity of the ith disaster at time τ. This index captures the instantaneous impact of the ith disaster on news coverage. The value of $\nu_i^{d-}(\tau)$ is constructed according to the following assumptions:

- Following Houston JB, et al. (2012), who focus on major natural disasters that occurred in the U.S. from 2000 to 2010, and find that disaster news coverage lasted for 178 days (nearly 6 months) on average when excluding the extremely long news coverage of Hurricane Katrina (occurred in August 2005, causing 1,833 deaths and approximately 201.3 billion dollars losses), we assume that the effects of climate disasters last from 6 to 12 months.

- The impact of a climate disaster on news coverage gradually diminishes over month.

- The initial intensity of a climate disaster increases linearly with its corresponding economic loss $l_i(\tau)$.

Since the effects of climate disasters that occurred in 1989 may have extended into 1990, we also take them into account. Consequently, there were 376 billion-dollar climate disasters in the U.S. from 1989 to 2024, with an average loss of 7.28 billion dollars (CPI-adjusted), while the maximum and minimum losses are 201.3 and 1.1 billion dollars, respectively.

Given the assumptions stated above, we define the initial intensity of the most severe disaster ($l_i = 201.3$) as 12, and that of the least severe disaster ($l_i = 1.1$) as 6. Moreover, the intensity depreciates by 1 unit per month until it reaches 0, so that the duration of impact on news coverage ranges from 6 to 12 months. For example, for the least severe climate disaster occurring at time τ, the affected months and the corresponding current intensities of the disaster are shown as follows:

$\nu_i^{d-}(\tau)$	$\nu_i^{d-}(\tau+1)$	$\nu_i^{d-}(\tau+2)$	$\nu_i^{d-}(\tau+3)$	$\nu_i^{d-}(\tau+4)$	$\nu_i^{d-}(\tau+5)$
6	5	4	3	2	1

We further define the linear equation between initial intensity and economic loss as:

$$\nu_i^{d-}(\tau) = 0.03 l_i(\tau) + 6,$$

where the value of ν_i^{d-} is rounded to the nearest integer. This equation is derived based on two observed points: $(201.3, 12)$ and $(1.1, 6)$. The coefficient 0.03 and the intercept 6 are rounded to two decimal places and the nearest integer, respectively, for simplicity. Finally, the total disaster intensity at time τ is given by the sum of the current diminished intensities of all climate disasters affect that month:

$$\nu^{d-}(\tau) = \sum_i \nu_i^{d-}(\tau).$$

3.1.2 Global and national climate-related public events

Not only domestic climate disasters, but also policy events like international climate conferences or legislative acts may have great impact on news coverage. However, we should notice that these policy events can be either positive or negative.

We use the data provided by Media and Climate Change Observatory (MeCCO) to illustrate the monthly news coverage of climate change on the representative democratic TV station CNN and republican TV station FOX in Figure 4. Apparently, CNN reports much more climate-related news than FOX. We focus on the extremely significant fluctuations and peaks to investigate what influential climate-related policy events occurred around those time points.

As a result, we compile a list of significant climate-related policy events that had great impact on the USA since 1990, and further distinguish them

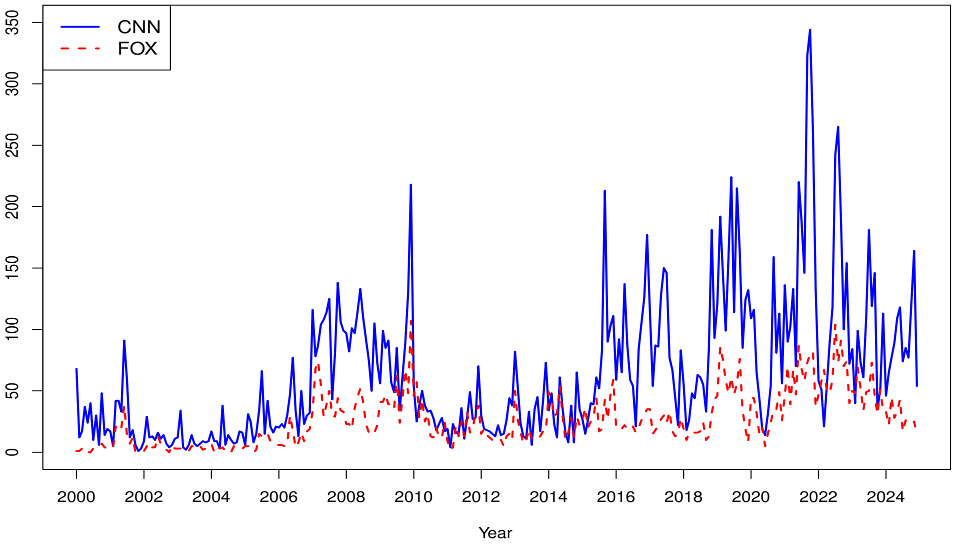

Figure 4: Monthly TV news coverage of climate change in the USA

Table 3: Major climate-related events, 1990–2024

Event	Date	ν_i^{e+}	ν_i^{e-}
UNFCCC Adoption	1992/06	12	0
Kyoto Protocol	1997/12	12	0
Withdraw from Kyoto Protocol	2001/03	0	12
An Inconvenient Truth	2006/05	12	0
American Recovery and Reinvestment Act	2009/02	12	0
American Clean Energy and Security Act	2009/06	12	0
Copenhagen Climate Summit	2009/12	12	0
White House Office of Energy and Climate Change Policy eliminated	2011/04	0	12
Pope Francis emphasized climate change in his speech in Washington	2015/09	12	0
Paris Agreement	2015/12	12	0
Withdraw from Paris Agreement	2017/06	0	12
Global Climate Action Summit	2018/09	12	0
Green New Deal Resolution	2019/02	12	0
Rejoin Paris Agreement	2021/01	12	0
Inflation Reduction Act	2022/08	12	0

as positive or negative in Table 3. Following Houston JB, et al. (2012), who find that news coverage of policy events tends to lasts longer than that of disasters, we assume that the impact of a policy event lasts for 12 months, and contributes an initial intensity which is equal to that of the most severe disaster:

$$\nu_i^{e+}(\tau) = \nu_i^{e-}(\tau) = 12.$$

Similarly, the total policy events intensities for positive and negative events at time τ are given by the sum of the current diminished intensities of all climate-related public events affecting that month:

$$\nu_e^-(\tau) = \sum_i \nu_i^{e-}(\tau), \qquad \nu_e^+(\tau) = \sum_i \nu_i^{e+}(\tau).$$

3.1.3 Total climate events intensity

After aggregating the events intensities contributed by both severe disasters, and policy events, we arrive at the total positive and negative climate events intensities separately:

$$\nu^+(\tau) = \nu_e^+(\tau), \qquad \nu^-(\tau) = \nu_d^-(\tau) + \nu_e^-(\tau).$$

Figure 5 shows the total monthly intensity of climate-related events. It

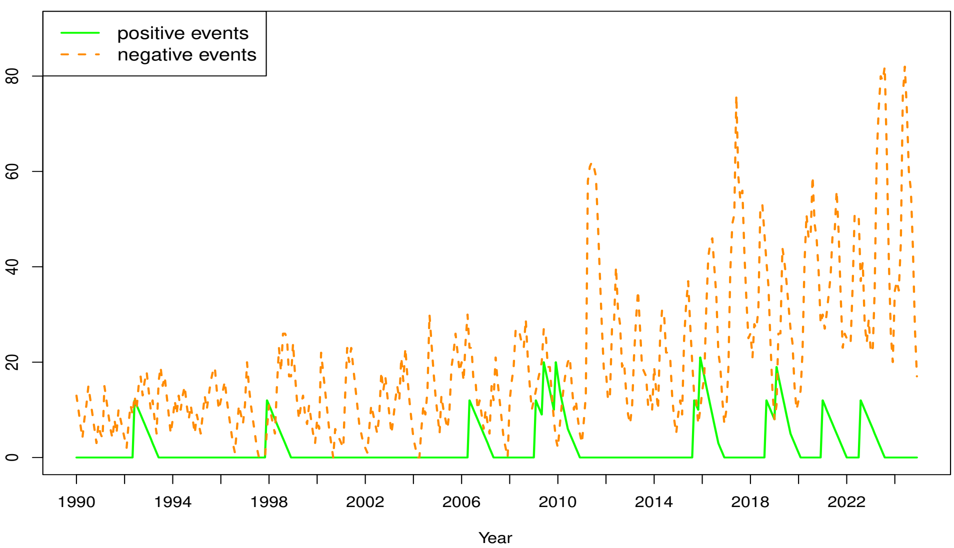

Figure 5: Monthly climate-related events intensity

is obvious that negative climate-related events tend to be more frequent, compared with positive ones.

3.2 Number of news items

In order to transform monthly climate-related events intensity to news blocks, we define the number of positive and negative news items in each month as:

$$n^+(\tau) = \left\lfloor \frac{\nu^+(\tau)}{s} \right\rfloor + 1, \qquad n^-(\tau) = \left\lfloor \frac{\nu^-(\tau)}{s} \right\rfloor + 1.$$

where $\left\lfloor \frac{\nu(\tau)}{s} \right\rfloor$ denotes the floor function, which rounds $\frac{\nu(\tau)}{s}$ down to the nearest integer less than or equal to $\frac{\nu(\tau)}{s}$. The additional of 1 means that apart from severe climate disasters and important climate-related policy events, there are still some other basic climate events with low importance, constituting the baseline climate news block. In other words, there is at least one positive and one negative news block in each month. s is a constant value to adjust the scale of news blocks number. Since $\nu^+_{max} = 21, \nu^-_{max} = 82$, we set $s = 10$ to make

$$n^+_{max} = \lfloor 2.1 \rfloor + 1 = 3, \qquad n^-_{max} = \lfloor 8.2 \rfloor + 1 = 9,$$

and thus $q = n^+_{max} + n^-_{max} = 12$, implying that each month has up to 12 climate-related news blocks overall.

3.3 Objective importance of each news block

We first assume that the objective importance of the most severe disaster and all climate-related policy events is equal to 1, and that of the least severe disaster is equal to 0.4. Furthermore, the objective importance of underlying baseline climate events is set at 0.2. Then similar to the linear equation between initial intensity and economic loss, we assign importance value m_{id} and m_{ie} to each disaster and policy event as follows:

$$m_{id} = 0.003 l_{id} + 0.4, \qquad m_{ie} = 1,$$

where the value of m_{id} is rounded to one decimal place. This equation is also derived based on two observed points: $(201.3, 1)$ and $(1.1, 0.4)$. The coefficient 0.003 and the intercept 0.4 are rounded to three decimal places and one decimal place, respectively, for simplicity. Note that the objective importance of climate-related events is constant, which means it does not decrease over time.

Then, at time τ, the importance of each news block excluding baseline news block is determined by all severe climate disasters and policy events affecting the news coverage of that month, as well as the number of news blocks apart from the underlying baseline block $\left\lfloor \frac{\nu(\tau)}{s} \right\rfloor$. We divide all climate-related events into $\left\lfloor \frac{\nu(\tau)}{s} \right\rfloor$ blocks for positive and negative news items respectively, and the total climate events intensity is evenly allocated to each block:

$$\bar{U}(\tau) = \frac{\nu(\tau)}{\left\lfloor \frac{\nu(\tau)}{s} \right\rfloor},$$

where $\bar{U}(\tau) \in \{\bar{U}^{+}(\tau), \bar{U}^{-}(\tau)\}$, $\nu(\tau) \in \{\nu^{+}(\tau), \nu^{-}(\tau)\}$.

After deriving the intensity of each block, we sort all disasters and policy events in ascending order according to their current intensities and check whether a particular event spans one or two blocks. The share of each event within a given block serves as the weight that it contributes to the objective importance of the news block. The weight of ith event contributes to kth block can be written as:

$$w_{ik}(\tau) = \frac{max\left(0, min\left(V_i(\tau), U_k(\tau)\right) - max\left(U_{k-1}(\tau), V_{i-1}(\tau)\right)\right)}{\bar{U}(\tau)},$$

where $V_i(\tau) = \sum \nu_i(\tau)$, and $U_k(\tau) = \sum k \times \bar{U}(\tau)$. Finally, we derive the objective importance of each news block, which is a weighted average of each climate event:

$$m_k(\tau) = \sum w_{ik}(\tau) \times m_i(\tau),$$

and it is rounded to one decimal place.

3.4 An example

To give an example, we summarize all disasters and policy events that have impact on the news coverage of climate change in September 2017 based on our assumptions:

Disaster and event	Begin date	Loss
Southeast Severe Weather and Tornadoes	2017.04	1.3
South and Southeast Severe Weather	2017.04	1.2
Missouri and Arkansas Flooding	2017.04	2.2
Colorado Hail Storm	2017.05	4.3
North Central Severe Weather and Tornadoes	2017.05	1.2
Minnesota Hail Storm	2017.06	3
Midwest Severe Weather 1	2017.06	1.9
Midwest Severe Weather 2	2017.06	1.8
Withdraw form Paris Agreement	2017.06	/
Western Wildfires	2017.06	23.2
Hurricane Harvey	2017.08	160
Hurricane Irma	2017.09	64
Hurricane Maria	2017.09	115.2

Since there is no positive policy event affecting the news coverage in September 2017, the total positive climate events intensity is $\nu^+(\tau) = 0$, and thus this month only contains one baseline positive news block with 0.2 unit of objective importance. On the other hand, taking the diminishing effect into account, we obtain the total negative climate events intensity for this month $\nu^-(\tau) = 56$. Therefore, there are $n^-(\tau) = \lfloor \frac{56}{10} \rfloor + 1 = 6$ negative news block including the baseline negative news block with 0.2 unit of objective importance in that month.

Figure 6 presents the sorting and division process, and provides the specific calculations of objective importance values for negative news block 1 and 2.

Consequently, we obtain a vector with $q = 12$ elements, representing the objective importance of all news blocks in September 2017:

$$(0 \quad 0 \quad 0.2 \quad 0 \quad 0 \quad 0 \quad 0.2 \quad 0.4 \quad 0.5 \quad 0.6 \quad 0.9 \quad 0.9)$$

The first three elements correspond to positive news, and the subsequent nine elements correspond to negative news. 0 means that the corresponding news block does not exist.

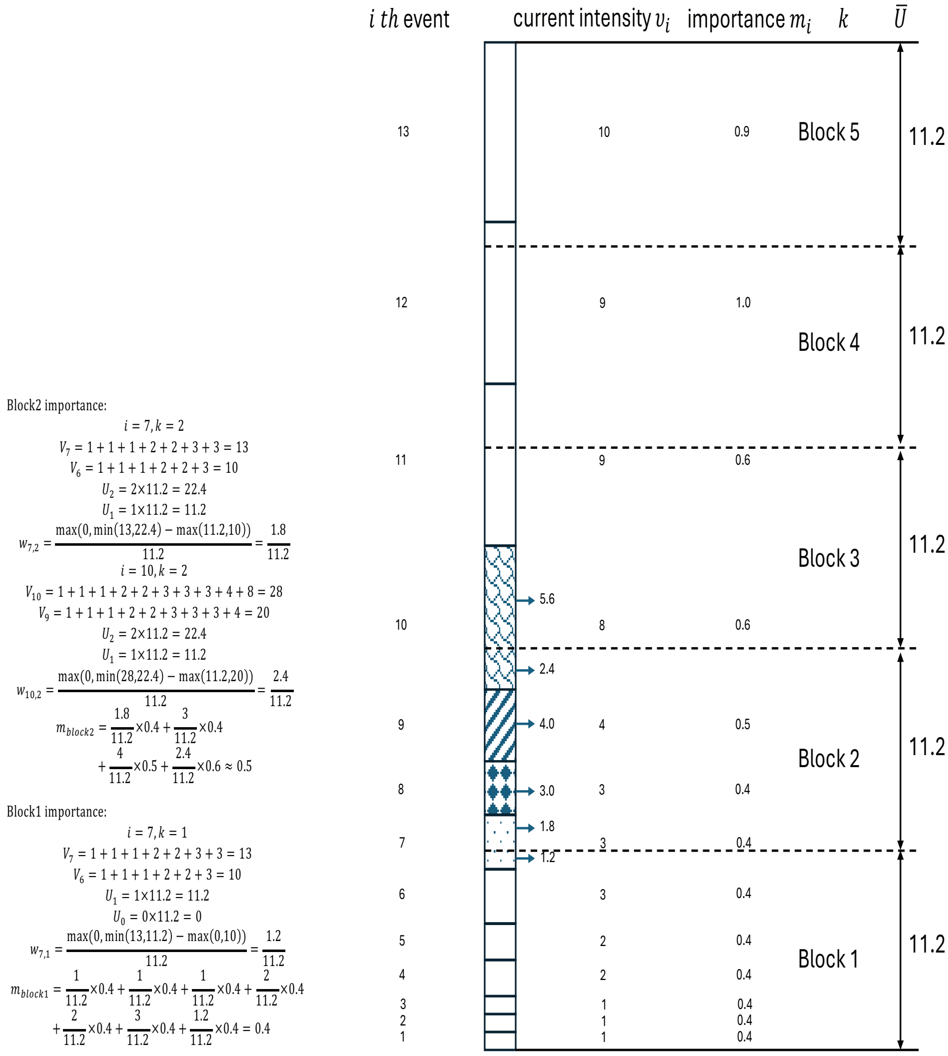

Figure 6: September 2017 negative news blocks and objective importance

4 Baseline model selection

The selection of baseline model is a result of sensitivity test. Table 4 presents the correlation coefficients between pairs of variables when $\gamma_0 = 0.5$. In sum, race diversity, age diversity, political diversity, population density, house median price, and education level are highly correlated (absolute value of coefficient over 0.9). To avoid suffering from multicollinearity, we include only one of these variables each time. In addition to these variables, news importance, news number, voter turnout (%), unemployment (%), and education diversity are always included. We also add education level, political color, and their cross term to explore the interaction effect.

Table 4: Correlation Matrix ($\gamma_0 = 0.5$)

Variable	newsimp	newsnum	racediv	agediv	edudiv	poldiv	turnout	popden	inc	houseprice	unem	edulevel	pc
newsimp	1	0.70	0.33	0.32	−0.32	−0.33	0.25	0.34	−0.06	0.29	0.05	0.30	0.07
newsnum	0.70	1	0.40	0.42	−0.37	−0.38	0.31	0.40	0	0.41	0.04	0.39	−0.14
racediv	0.33	0.40	1	0.98	−0.79	−0.95	0.76	0.99	0.11	0.97	−0.16	0.97	0.21
agediv	0.32	0.42	0.98	1	−0.80	−0.97	0.75	0.97	0.10	0.96	−0.21	0.97	0.15
edudiv	−0.32	−0.37	−0.79	−0.80	1	0.73	−0.45	−0.81	−0.31	−0.77	0.17	−0.85	−0.06
poldiv	−0.33	−0.38	−0.95	−0.97	0.73	1	−0.76	−0.95	−0.03	−0.90	0.24	−0.93	−0.32
turnout	0.25	0.31	0.76	0.75	−0.45	−0.76	1	0.71	−0.01	0.78	−0.12	0.75	0.24
popden	0.34	0.40	0.99	0.97	−0.81	−0.95	0.71	1	0.10	0.94	−0.14	0.96	0.20
inc	−0.06	0	0.11	0.10	−0.31	−0.03	−0.01	0.10	1	0.25	−0.45	0.26	−0.13
houseprice	0.29	0.41	0.97	0.96	−0.77	−0.90	0.78	0.94	0.25	1	−0.21	0.98	0.17
unem	0.05	0.04	−0.16	−0.21	0.17	0.24	−0.12	−0.14	−0.45	−0.21	1	−0.26	−0.22
edulevel	0.30	0.39	0.97	0.97	−0.85	−0.93	0.75	0.96	0.26	0.98	−0.26	1	0.21
pc	0.07	−0.14	0.21	0.15	−0.06	−0.32	0.24	0.20	−0.13	0.17	−0.22	0.21	1

Table 5 presents the empirical results across different models with γ_0 is fixed at 0.5. We find that the estimated coefficients of voter turnout, unemployment, and education diversity appear to be stable in terms of both sign and significance level. The positive effect of news importance is not significantly different from 0 in models (1) – (5), but it turns significant in models (6) and (7) after we include education level and political color. On the other hand, the effect of news number is small but positive in models (1) – (5), however it turns negative in models (6) and (7), although the effect is always statistically insignificant. Income shows statistically significant and positive effect in models (1) – (4), but not in the other models. As for population density and house price, they show strong correlations with the demographic diversities and provide no additional insights. In model (6), where we introduce education level, political color, as well as their cross term, the coefficient estimates of cross term and income are not statistically significant, and thus we delete these two regressors in model (7). Finally, we define model (7) as our baseline model.

Table 6 gives the VIF value for each of variables in our baseline model (7). It shows very low multicollinearity for most variables, with the exception of education level. The VIF value for education level is equal to 10.278, which is a little larger than the conventional threshold of 10, implying the potential risk of higher multicollinearity. But as we attempt to discuss both education level and education diversity simultaneously to reveal the multiple roles of education, we just accept this slightly higher VIF value.

We next introduce a composite variable called social pressure, which is a combination of race diversity, age diversity, education diversity, and political diversity. Table 7, column (2) reports the estimation results of our baseline model, in which diversities are replaced by social pressure. The weights assigned to the four diversity indexes are based on the estimation results of

Table 5: Comparison of seven models for $\gamma_0 = 0.5$

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Focus variables							
constant	-63.6^{***}	-696.5^{***}	-29.6^{***}	-94.1^{***}	-27.4^{***}	-58.4^{***}	-65.3^{***}
	(10.9)	(119.8)	(8.5)	(12.0)	(9.5)	(12.2)	(11.6)
news importance	0.55	0.77	0.36	0.41	0.59	1.49^{**}	1.59^{***}
	(0.55)	(0.56)	(0.56)	(0.53)	(0.57)	(0.56)	(0.56)
news number	0.15	0.07	0.20	0.17	0.18	-0.16	-0.19
	(0.16)	(0.16)	(0.16)	(0.15)	(0.16)	(0.17)	(0.16)
voter turnout	0.18^{***}	0.20^{***}	0.23^{***}	0.18^{***}	0.28^{***}	0.20^{***}	0.23^{***}
	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.05)	(0.04)
median income	0.76^{*}	1.02^{**}	1.12^{***}	1.05^{***}	0.16	-0.50	
	(0.40)	(0.41)	(0.43)	(0.39)	(0.41)	(0.40)	
unemployment	-0.75^{***}	-0.69^{***}	-0.68^{***}	-0.75^{***}	-0.77^{***}	-0.84^{***}	-0.79^{***}
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.05)
pop density				0.01^{***}			
				(0.00)			
house price					0.06^{**}		
					(0.03)		
Auxiliary variables: diversity and social pressure							
race	33.1^{***}						
	(5.3)						
education	139.8^{***}	143.0^{***}	114.3^{***}	170.7^{***}	86.7^{***}	145.4^{***}	149.9^{***}
	(16.7)	(18.2)	(15.8)	(16.9)	(16.1)	(20.3)	(20.2)
age		681.1^{***}					
		(119.8)					
political			-21.1^{***}				
			(4.3)				
Auxiliary variables: levels							
education level						0.37^{***}	0.36^{***}
						(0.07)	(0.07)
political color						-21.4^{***}	-19.6^{***}
						(3.1)	(3.0)
edu level $\times$ political color						-0.62	
						(0.48)	
Observations	420	420	420	420	420	420	420
Res. SE	3.41	3.44	3.48	3.30	3.55	3.34	3.34

Note: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 6: VIF of Model (7) ($\gamma_0 = 0.5$)

Variable	VIF
news importance	2.158
news number	2.399
education diversity	5.353
voter turnout	3.367
unemployment	1.179
education level	10.278
political color	1.288

Table 5, models (1) – (3), indicating that the effect of education diversity is the largest, followed by age, race, and then political diversity. We test for other two sets of weights in columns (3) and (4). The results show that social pressure is significantly and negatively associated with public opinion about climate change, and that changing weights has small effect on coefficient estimates, except for education level. Although the effect of education level turns significantly negative, it is still small enough to be ignored.

Table 7: Introduction of social pressure

race weight	2	2	3
education weight	6	4	7
age weight	5	3	5
political weight	1	1	1
Focus variables			
constant	119.4***	117.8***	130.6***
	(13.1)	(13.6)	(13.0)
news importance	1.40**	1.30**	1.34**
	(0.55)	(0.55)	(0.54)
news number	−0.14	−0.12	−0.15
	(0.16)	(0.16)	(0.16)
voter turnout	0.27***	0.30***	0.26***
	(0.04)	(0.04)	(0.04)
unemployment	−0.90***	−0.92***	−0.93***
	(0.05)	(0.06)	(0.05)
Auxiliary variables: social pressure			
social pressure	−282.2***	−249.7***	−277.3***
	(37.1)	(34.8)	(32.7)
Auxiliary variables: levels			
education level	0.02	−0.08**	−0.11***
	(0.04)	(0.04)	(0.04)
political color	−15.6***	−14.4***	−16.4***
	(2.9)	(2.9)	(2.9)
Observations	420	420	420
Res. SE	3.33	3.36	3.28

Note: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

5 Sensitivity analysis

The baseline model depends on a set of assumptions and specific values of hyperparameters. We deviate from the baseline model in one direction at a time to conduct sensitivity analysis, and see whether the coefficient estimates for our most interested variables are affected.

County interaction.

γ_0 is set to 0.5 in the baseline model. We experiment with values from 0 to 0.9 with a step size of 0.1. According to Table 8, the coefficient estimates of voter turnout, unemployment, education diversity, education level, and political color are always statistically significant at the 1% level. The effect of news importance is always significant, while the level of significance decreases. The effect of news number is significant at 10% level only when $\gamma_0 = 0.0$. So in most cases, we cannot identify any effect of the number of news items. Noticeably, the sign of each coefficient remains unchanged, although the absolute value of all coefficients decreases with γ_0, which is not a surprise, as the effect of each variable is absorbed by spatial interactions.

Table 8: Sensitivity test – γ_0

γ_0	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Focus variables										
constant	−154.6***	−135.8***	−117.4***	−99.4***	−82.1***	−65.3***	−49.3***	−34.1***	−20.0***	−7.7***
	(21.6)	(19.7)	(17.7)	(15.7)	(13.7)	(11.6)	(9.4)	(7.2)	(4.9)	(2.5)
news importance	3.41***	3.05***	2.69***	2.33***	1.96***	1.59***	1.23***	0.87**	0.53**	0.22*
	(1.08)	(0.97)	(0.87)	(0.77)	(0.66)	(0.56)	(0.45)	(0.34)	(0.23)	(0.12)
news number	−0.47*	−0.42	−0.36	−0.30	−0.25	−0.19	−0.13	−0.08	−0.03	−0.00
	(0.28)	(0.26)	(0.24)	(0.22)	(0.19)	(0.16)	(0.14)	(0.10)	(0.07)	(0.04)
voter turnout	0.50***	0.45***	0.39***	0.34***	0.28***	0.23***	0.18***	0.14***	0.09***	0.05***
	(0.08)	(0.07)	(0.07)	(0.06)	(0.05)	(0.04)	(0.04)	(0.03)	(0.02)	(0.01)
unemployment	−1.62***	−1.45***	−1.28***	−1.12***	−0.95***	−0.79***	−0.63***	−0.47***	−0.31***	−0.16***
	(0.11)	(0.10)	(0.09)	(0.08)	(0.07)	(0.05)	(0.04)	(0.03)	(0.02)	(0.01)
Auxiliary variables: diversity										
education	336.8***	298.1***	260.0***	222.6***	185.8***	149.9***	115.1***	81.6***	49.8***	20.9***
	(37.3)	(34.1)	(30.7)	(27.3)	(23.8)	(20.2)	(16.4)	(12.5)	(8.5)	(4.3)
Auxiliary variables: levels										
education level	0.56***	0.53***	0.50***	0.46***	0.41***	0.36***	0.30***	0.23***	0.16***	0.08***
	(0.11)	(0.10)	(0.09)	(0.09)	(0.08)	(0.07)	(0.06)	(0.05)	(0.04)	(0.02)
political color	−43.4***	−38.6***	−33.7***	−28.9***	−24.2***	−19.6***	−15.1***	−10.8***	−6.6***	−2.9***
	(5.6)	(5.1)	(4.6)	(4.1)	(3.5)	(3.0)	(2.4)	(1.8)	(1.2)	(0.6)
Observations	420	420	420	420	420	420	420	420	420	420
Res. SE	3.23	3.25	3.27	3.29	3.32	3.34	3.37	3.41	3.45	3.51

Note: *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

Trump effect.

In our setup, the parameter that captures the effect of Trump administration β_2 is set to 0.2, but we could change the magnitude of it, by raising the value or decreasing the value. As Table 9 shows, the coefficient estimates respond little to changes in Trump effect.

National political color.

Based on our original setting for the political color of two national TV stations, we experiment two deviations.

First, we change the long-term value of national political color, to allow the democratic and republican stations to be more (less) left or more (less) right in Table 10. Second, we have assumed that more right leaning national power balance pushes the democratic station to be more left, and pushes the republican station to be more right, thus reinforces the polarization. We adjust the sensitivity that national TV stations respond to the change in national power balance, and also we change the sign for β_{1d} and β_{1r} to experiment with the opposing assumption that increasing national power balance decreases polarization, as reported in Table 11.

In Table 10, the coefficients of voter turnout, unemployment, education diversity, education level, and political color are always statistically significant at the 1% level, and their values show very small variation. In the case that republican national station becomes more right in column (5), the coefficient of news importance increases a lot, indicating that stronger polarization in media may amplify the impact of news importance. The effect of news number is insignificant and small in most cases.

In Table 11, the coefficient estimates appear to be robust to the changes in the magnitude of β_{1d} and β_{1r}. However, when the signs of β_{1d} and β_{1r} change, the positive effect of news importance decreases a lot, and the significance level also decreases.

Subjective weights of news ingredients.

We specify parameter values that determining how national TV stations assign weights to the three ingredients (objective importance, reliability, positivity) of news, which in turn determine the subjective importance. We experiment with the subjective weights of importance and negativity as examples, and find that the results are very similar, as reported in Table 12 and 13.

National media thresholds.

In the baseline model, national TV stations set changeable thresholds when filtering news items. We either raise or lower these thresholds to test their robustness.

Table 14 shows the estimation robustness when the thresholds of national media change. The coefficient estimates of voter turnout, unemployment, education diversity, education level, and political color are always statistically significant at the 1% level, and their values show very small variation. However, the results show that the effects of news are somewhat sensitive to the changes in national thresholds. Specifically, the magnitude of positive effect of news importance varies a lot across different set of thresholds. On the other hand, the effect of news number remains insignificant in most cases, but it becomes significantly negative when the threshold of republican media is raised in the last column.

Severe events.

The definition of severe events affects the number of non-severe events that enter the filtering process. We change the threshold for defining severe events in Table 15, and find that it makes almost no difference to the results.

News ingredients.

Since we have no information for the objective positivity and reliability, we assign identical, numerically neutral values of positivity and reliability to all news items. We experiment with different values in Table 16. Again, the coefficient estimates of voter turnout, unemployment, education diversity, education level, and political color are quite stable. However, the positive effect of news importance becomes much stronger when positivity or reliability of all news items increases. In addition, the negative effect of news number is estimated more precisely and becomes marginally stronger.

In summary, the parameter estimates of baseline model are very robust across most sensitivity tests, with the exception for news variables. The estimates of news importance and news number are somewhat sensitive to the assumptions and settings. In specific, the magnitude of the effect of news importance may change a lot, while the effect of news number turns significantly negative in some cases.

Table 9: Sensitivity test – Trump effect

β_2	0.1	0.2	0.5	0.9
Focus variables				
constant	-65.3^{***}	-65.3^{***}	-65.6^{***}	-65.9^{***}
	(11.6)	(11.6)	(11.6)	(11.6)
news importance	1.59^{***}	1.59^{***}	1.64^{***}	1.69^{***}
	(0.56)	(0.56)	(0.55)	(0.55)
news number	-0.19	-0.19	-0.21	-0.23
	(0.16)	(0.16)	(0.16)	(0.16)
voter turnout	0.23^{***}	0.23^{***}	0.23^{***}	0.23^{***}
	(0.04)	(0.04)	(0.04)	(0.04)
unemployment	-0.79^{***}	-0.79^{***}	-0.79^{***}	-0.79^{***}
	(0.05)	(0.05)	(0.05)	(0.05)
Auxiliary variables: diversity				
education	149.9^{***}	149.9^{***}	150.3^{***}	150.9^{***}
	(20.2)	(20.2)	(20.2)	(20.2)
Auxiliary variables: levels				
education level	0.36^{***}	0.36^{***}	0.36^{***}	0.36^{***}
	(0.07)	(0.07)	(0.07)	(0.07)
political color	-19.6^{***}	-19.6^{***}	-19.8^{***}	-19.8^{***}
	(3.0)	(3.0)	(3.0)	(2.9)
Observations	420	420	420	420
Res. SE	3.34	3.34	3.34	3.34

Note: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 10: Sensitivity test – level of national political color

β_{0d}	-0.5	-0.6	-0.4	-0.5	-0.5
β_{0r}	0.5	0.5	0.5	0.6	0.4
Focus variables					
constant	-65.3^{***}	-65.7^{***}	-64.8^{***}	-66.0^{***}	-65.2^{***}
	(11.6)	(11.6)	(11.6)	(11.5)	(11.6)
news importance	1.59^{***}	1.59^{***}	1.41^{**}	1.89^{***}	1.58^{***}
	(0.56)	(0.49)	(0.58)	(0.49)	(0.56)
news number	-0.19	-0.23	-0.10	-0.48^{***}	-0.10
	(0.16)	(0.16)	(0.16)	(0.18)	(0.13)
voter turnout	0.23^{***}	0.24^{***}	0.23^{***}	0.24^{***}	0.23^{***}
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
unemployment	-0.79^{***}	-0.79^{***}	-0.79^{***}	-0.79^{***}	-0.80^{***}
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Auxiliary variables: diversity					
education	149.9^{***}	149.9^{***}	149.0^{***}	150.8^{***}	149.9^{***}
	(20.2)	(20.1)	(20.2)	(20.0)	(20.2)
Auxiliary variables: levels					
education level	0.36^{***}	0.36^{***}	0.36^{***}	0.37^{***}	0.35^{***}
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
political color	-19.6^{***}	-19.7^{***}	-19.1^{***}	-21.3^{***}	-19.1^{***}
	(3.0)	(2.9)	(3.0)	(3.0)	(2.9)
Observations	420	420	420	420	420
Res. SE	3.34	3.34	3.35	3.32	3.34

Note: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 11: Sensitivity test – slope of national political color

β_{1d}	-0.07	-0.09	-0.05	0.07
β_{1r}	0.04	0.05	0.03	-0.04
Focus variables				
constant	-65.3^{***}	-65.8^{***}	-65.0^{***}	-64.0^{***}
	(11.6)	(11.6)	(11.6)	(11.5)
news importance	1.59^{***}	1.67^{***}	1.58^{***}	1.03^{*}
	(0.56)	(0.56)	(0.57)	(0.59)
news number	-0.19	-0.22	-0.18	0.06
	(0.16)	(0.16)	(0.17)	(0.17)
voter turnout	0.23^{***}	0.23^{***}	0.23^{***}	0.23^{***}
	(0.04)	(0.04)	(0.04)	(0.04)
unemployment	-0.79^{***}	-0.79^{***}	-0.79^{***}	-0.79^{***}
	(0.05)	(0.05)	(0.05)	(0.06)
Auxiliary variables: diversity				
education	149.9^{***}	150.7^{***}	149.4^{***}	147.9^{***}
	(20.2)	(20.2)	(20.1)	(20.1)
Auxiliary variables: levels				
education level	0.36^{***}	0.36^{***}	0.36^{***}	0.34^{***}
	(0.07)	(0.07)	(0.07)	(0.07)
political color	-19.6^{***}	-19.7^{***}	-19.6^{***}	-18.1^{***}
	(3.0)	(2.9)	(3.0)	(2.8)
Observations	420	420	420	420
Res. SE	3.34	3.34	3.34	3.35

Note: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 12: Sensitivity test – subjective weights of importance

ϕ_{1d}	0.1	0.15	0.08	0.1	0.1
ϕ_{1r}	1.1	1.1	1.1	1.15	1.08
Focus variables					
constant	-65.3^{***}	-66.2^{***}	-65.3^{***}	-66.5^{***}	-65.0^{***}
	(11.6)	(11.6)	(11.6)	(11.5)	(11.6)
news importance	1.59^{***}	1.85^{***}	1.58^{***}	1.93^{***}	1.59^{***}
	(0.56)	(0.56)	(0.56)	(0.57)	(0.56)
news number	-0.19	-0.29^{*}	-0.18	-0.25	-0.24
	(0.16)	(0.17)	(0.16)	(0.16)	(0.16)
voter turnout	0.23^{***}	0.23^{***}	0.23^{***}	0.23^{***}	0.23^{***}
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
unemployment	-0.79^{***}	-0.79^{***}	-0.79^{***}	-0.80^{***}	-0.79^{***}
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Auxiliary variables: diversity					
education	149.9^{***}	151.5^{***}	149.9^{***}	151.9^{***}	149.3^{***}
	(20.2)	(20.1)	(20.2)	(20.1)	(20.2)
Auxiliary variables: levels					
education level	0.36^{***}	0.37^{***}	0.36^{***}	0.36^{***}	0.36^{***}
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
political color	-19.6^{***}	-20.1^{***}	-19.6^{***}	-20.3^{***}	-19.9^{***}
	(3.0)	(2.9)	(3.0)	(3.0)	(3.0)
Observations	420	420	420	420	420
Res. SE	3.34	3.33	3.34	3.33	3.35

Note: ${}^{*}p < 0.10$, ${}^{**}p < 0.05$, ${}^{***}p < 0.01$.

Table 13: Sensitivity test – subjective weights of negativity

ϕ_{4d}	0.04	0.05	0.03	0.04	0.04
ϕ_{4r}	0.50	0.50	0.50	0.51	0.49
Focus variables					
constant	-65.3^{***}	-65.2^{***}	-65.1^{***}	-65.3^{***}	-65.0^{***}
	(11.6)	(11.6)	(11.6)	(11.6)	(11.6)
news importance	1.59^{***}	1.62^{***}	1.55^{***}	1.59^{***}	1.59^{***}
	(0.56)	(0.56)	(0.56)	(0.56)	(0.56)
news number	-0.19	-0.20	-0.17	-0.19	-0.24
	(0.16)	(0.17)	(0.16)	(0.16)	(0.16)
voter turnout	0.23^{***}	0.23^{***}	0.23^{***}	0.23^{***}	0.23^{***}
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
unemployment	-0.79^{***}	-0.79^{***}	-0.79^{***}	-0.79^{***}	-0.79^{***}
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Auxiliary variables: diversity					
education	149.9^{***}	149.8^{***}	149.6^{***}	149.9^{***}	149.3^{***}
	(20.2)	(20.1)	(20.2)	(20.2)	(20.2)
Auxiliary variables: levels					
education level	0.36^{***}	0.36^{***}	0.36^{***}	0.36^{***}	0.36^{***}
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
political color	-19.6^{***}	-19.6^{***}	-19.6^{***}	-19.6^{***}	-19.9^{***}
	(3.0)	(3.0)	(3.0)	(3.0)	(3.0)
Observations	420	420	420	420	420
Res. SE	3.34	3.34	3.34	3.34	3.35

Note: ${}^{*}p < 0.10$, ${}^{**}p < 0.05$, ${}^{***}p < 0.01$.

Table 14: Sensitivity test – national media thresholds

	Deviation from mean				
democratic	− 0.03	−0.04	−0.02	−0.03	−0.03
republican	+ 0.02	+0.02	+0.02	+0.01	+0.03
Focus variables					
constant	-65.3^{***}	-64.2^{***}	-65.4^{***}	-66.3^{***}	-65.9^{***}
	(11.6)	(11.6)	(11.6)	(11.5)	(11.5)
news importance	1.59^{***}	1.25^{**}	1.40^{***}	1.93^{***}	1.91^{***}
	(0.56)	(0.57)	(0.50)	(0.56)	(0.49)
news number	−0.19	−0.05	−0.15	−0.11	-0.48^{***}
	(0.16)	(0.16)	(0.17)	(0.10)	(0.18)
voter turnout	0.23^{***}	0.23^{***}	0.23^{***}	0.23^{***}	0.24^{***}
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
unemployment	-0.79^{***}	-0.79^{***}	-0.79^{***}	-0.79^{***}	-0.79^{***}
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Auxiliary variables: diversity					
education	149.9^{***}	148.1^{***}	149.6^{***}	151.8^{***}	150.7^{***}
	(20.2)	(20.2)	(20.2)	(20.1)	(19.9)
Auxiliary variables: levels					
education level	0.36^{***}	0.35^{***}	0.36^{***}	0.35^{***}	0.37^{***}
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
political color	-19.6^{***}	-18.8^{***}	-19.0^{***}	-18.9^{***}	-21.3^{***}
	(3.0)	(3.0)	(2.9)	(2.8)	(3.0)
Observations	420	420	420	420	420
Res. SE	3.34	3.35	3.34	3.33	3.32

Note: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 15: Sensitivity test – severe events

Objective importance	≥ 0.6	≥ 0.7	≥ 0.8
Focus variables			
constant	-66.4^{***}	-65.3^{***}	-66.2^{***}
	(11.6)	(11.6)	(11.6)
news importance	1.93^{***}	1.59^{***}	1.62^{***}
	(0.57)	(0.56)	(0.51)
news number	-0.29^{*}	-0.19	-0.22
	(0.16)	(0.16)	(0.16)
voter turnout	0.23^{***}	0.23^{***}	0.23^{***}
	(0.04)	(0.04)	(0.04)
unemployment	-0.79^{***}	-0.79^{***}	-0.79^{***}
	(0.05)	(0.05)	(0.05)
Auxiliary variables: diversity			
education	151.5^{***}	149.9^{***}	151.5^{***}
	(20.1)	(20.2)	(20.2)
Auxiliary variables: levels			
education level	0.37^{***}	0.36^{***}	0.36^{***}
	(0.07)	(0.07)	(0.07)
political color	-20.2^{***}	-19.6^{***}	-20.1^{***}
	(2.9)	(3.0)	(3.0)
Observations	420	420	420
Res. SE	3.33	3.34	3.34

Note: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 16: Sensitivity test – positivity and reliability

Positivity	±0.5	±0.3	±0.7	±0.5	±0.5
Reliability	0.5	0.5	0.5	0.3	0.7
Focus variables					
constant	-65.3^{***}	-64.2^{***}	-66.8^{***}	-64.2^{***}	-67.2^{***}
	(11.6)	(11.6)	(11.5)	(11.6)	(11.5)
news importance	1.59^{***}	1.39^{**}	2.05^{***}	1.59^{***}	2.04^{***}
	(0.56)	(0.57)	(0.55)	(0.56)	(0.54)
news number	-0.19	-0.21	-0.33^{**}	-0.34^{*}	-0.34^{**}
	(0.16)	(0.17)	(0.16)	(0.19)	(0.15)
voter turnout	0.23^{***}	0.23^{***}	0.24^{***}	0.23^{***}	0.24^{***}
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
unemployment	-0.79^{***}	-0.78^{***}	-0.80^{***}	-0.78^{***}	-0.80^{***}
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Auxiliary variables: diversity					
education	149.9^{***}	147.9^{***}	151.7^{***}	147.7^{***}	152.4^{***}
	(20.2)	(20.2)	(20.0)	(20.1)	(20.0)
Auxiliary variables: levels					
education level	0.36^{***}	0.36^{***}	0.37^{***}	0.37^{***}	0.38^{***}
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
political color	-19.6^{***}	-19.5^{***}	-20.9^{***}	-20.2^{***}	-20.8^{***}
	(3.0)	(2.9)	(3.0)	(3.0)	(2.9)
Observations	420	420	420	420	420
Res. SE	3.34	3.35	3.32	3.35	3.32

Note: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

6 Policy implications

Although we do not have county-level opinion data in the estimation stage, we can now use the estimated parameters of our baseline model to predict public opinion on climate change for each county.

$$
\begin{aligned}
y(\tau) = A^{-1}(\gamma_0)[&-65.3X_1 + 1.59X_2(\tau-1) + (-0.19)X_3(\tau-1) \\
&+ 0.23X_4(\tau-1) + (-0.79)X_5(\tau-1) + 149.9X_6(\tau-1) \\
&+ 0.36X_7(\tau-1) + (-19.6)X_8(\tau-1)],
\end{aligned}
$$

where X_1, $X_2(\tau-1)$, $X_3(\tau-1)$, $X_4(\tau-1)$, $X_5(\tau-1)$, $X_6(\tau-1)$, $X_7(\tau-1)$, $X_8(\tau-1)$ refer to constant, news importance, news number, voter turnout, unemployment, education diversity, education level, and political color, respectively. We change the input of county-level data to simulate a series of policies. Moreover, since we have the information for the county-level political colors, we can further divide all the counties into two groups, democratic and republican at each time point. This helps us to distinguish different trends in public opinion between democratic and republican counties.

Investment in public education.

We consider that federal government implements a nationwide policy to

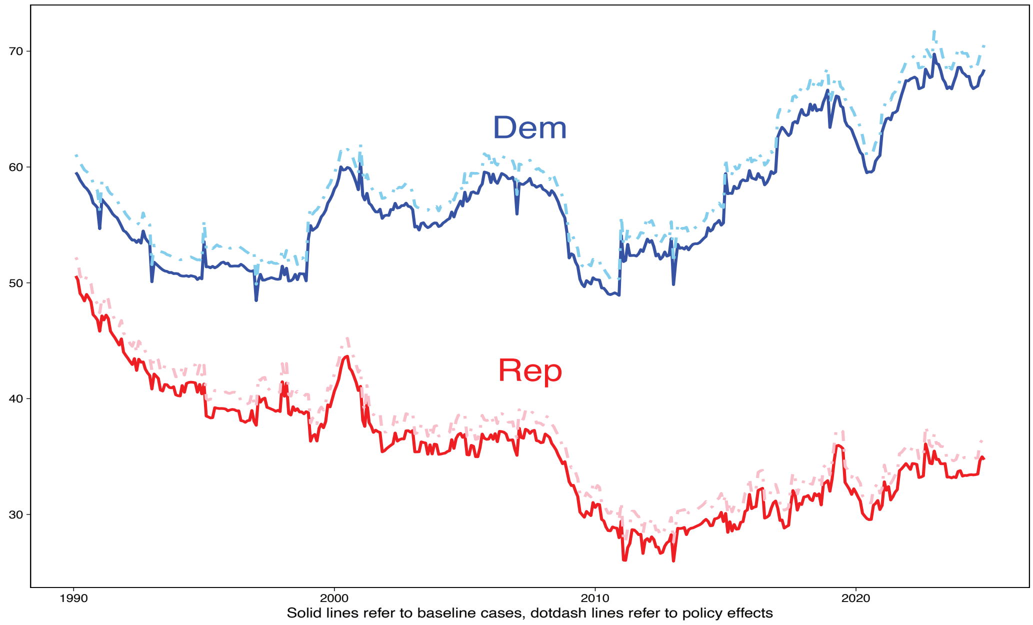

Figure 7: Education level increases by 25% quartile

improve education level of the public. However, the effects on each of the counties are not necessarily the same. Therefore, we compute the 50% and 75% quartiles of education level for each county across all months, and then assume that the nationwide policy succeeds in improving the education level of each county by its own difference between 75% and 50% quartiles. According to Figure 7, a 25% interquartile increase in the education level leads to a 1.6 percentage point (1.5 percentage point) increase in public opinion of democratic (republican) counties. But notice that in this case, the education diversity remains unchanged.

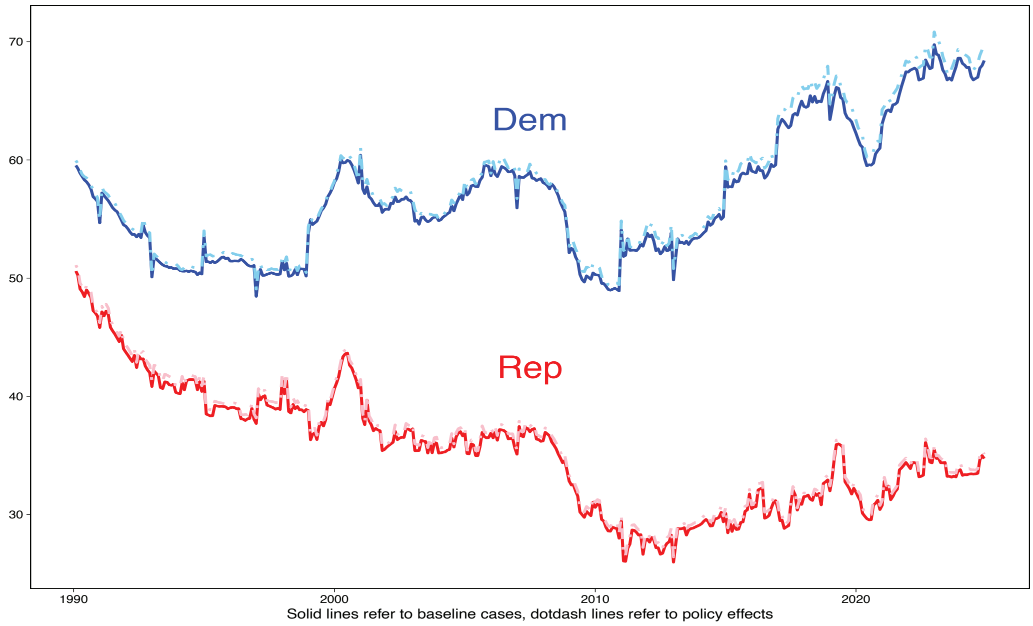

Figure 8: Education level increases by 25% quartile and education diversity decreases by 5% quantile

Next, consider a scenario where there are several levels of education, low, medium low, average, medium high, and high, and the government only invests in the average group to push it to medium high. This will increase the overall level of education, but meanwhile the education diversity declines because more people are concentrated in one group. In Figure 8, we find that even a small decline in education diversity can greatly impede the positive effect of improving education level. When education diversity decreases by the difference between 50% and 45% percentiles, the increase in public opinion declines to 0.6 percentage points (0.4 percentage points) for democratic (republican) counties.

If we further assume that the decrease in education diversity raises to the difference between 50% and 40% percentiles, the positive effect of in-

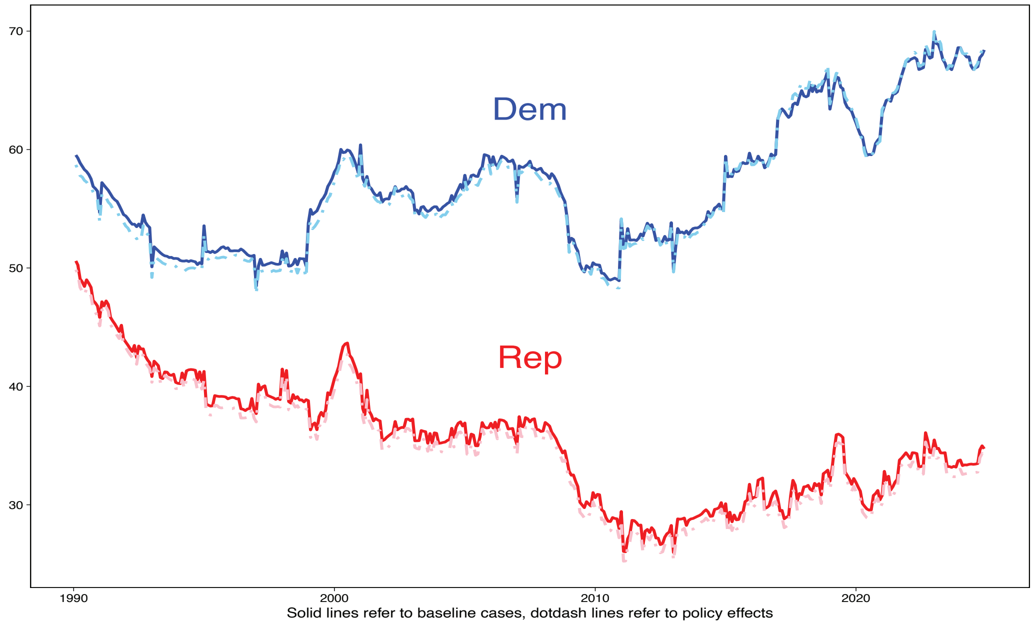

Figure 9: Education level increases by 25% quartile and education diversity decreases by 10% quantile

creasing education level can be even totally offset, as shown in Figure 9. Consequently, the public opinion decreases by 0.34 percentage points (0.73 percentage points) for democratic (republican) counties. This suggests that education investment should be universal, so that the improvement in overall education level is achieved by the development of all education groups. Otherwise, education investment may even backfire and reduce public opinion on climate change.

Existence of only one national TV station.

We experiment with a scenario that there is only one national TV station in Figure 10 and 11. When only democratic TV station is allowed to convey information, the public opinion of republican counties decreases by 0.70 percentage points on average, while that of democratic counties also decreases by 0.21 percentage points. In contrast, when only republican TV station exists, public opinion of democratic counties increases by an average of 0.54 percentage points, and that of republican counties also rises slightly by 0.04 percentage points.

At a first glance, one might wonder why the public opinion of counties that hold the same political stance with the only existing national TV station also slightly deviates, even though the news they broadcast do not change. This is because of the spatial interaction in our model, meaning that a change

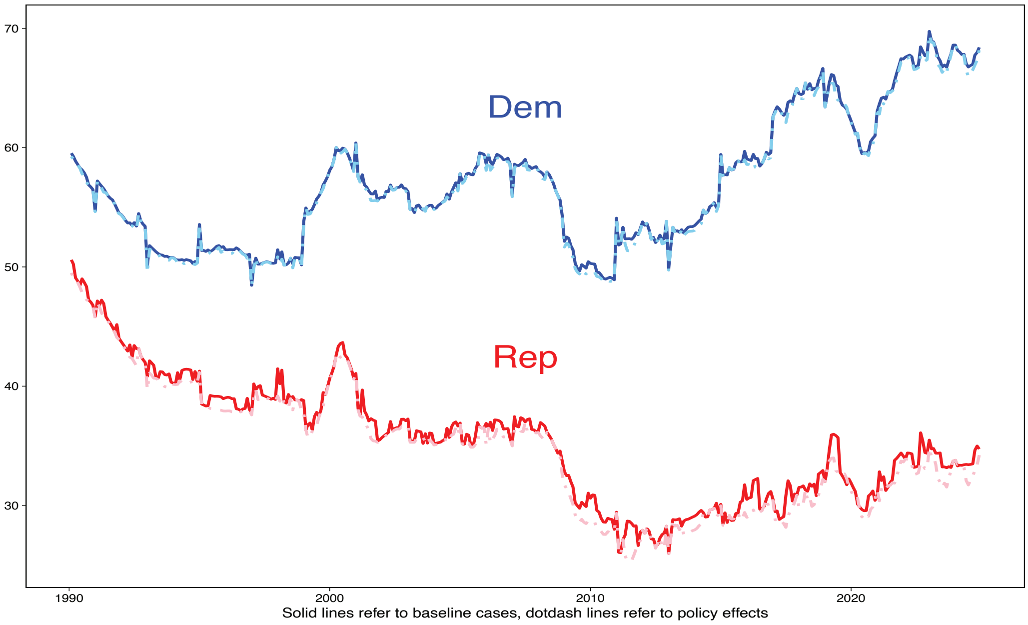

Figure 10: Existence of only democratic TV station

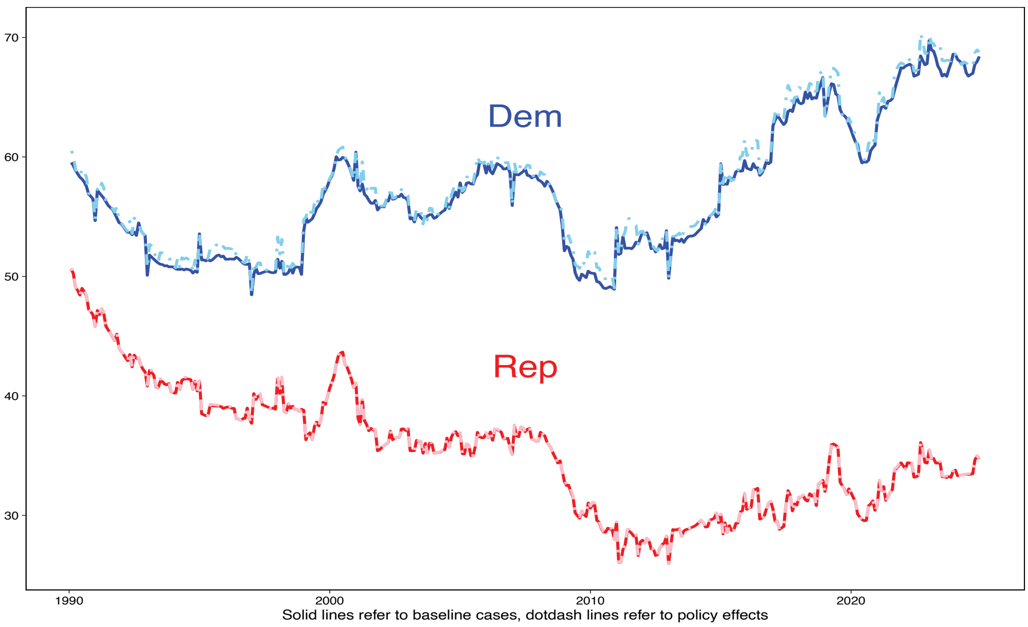

Figure 11: Existence of only republican TV station

in one county affects all neighboring counties.

Also, one might expect that when individuals are exposed to news from a source with opposing political stance, then they should learn something new from it and thus might change their original opinions. This view is in line with one strand of the literature on media effects, which argues that sustained exposure to opposing media enables people to learn alternative information and thus moderate their attitudes (Broockman and Kalla, 2025). However, there is another widely supported branch of research suggests that cross-cutting media may elicit counterarguments, which in turn reinforces prior attitudes due to the theory of motivated reasoning (Taber and Lodge, 2006; Hart and Nisbet, 2012; Levendusky, 2013). Our experiments results correspond to the latter argument.

Reduce unemployment.

We assume that the monthly unemployment decreases by 25 percentage

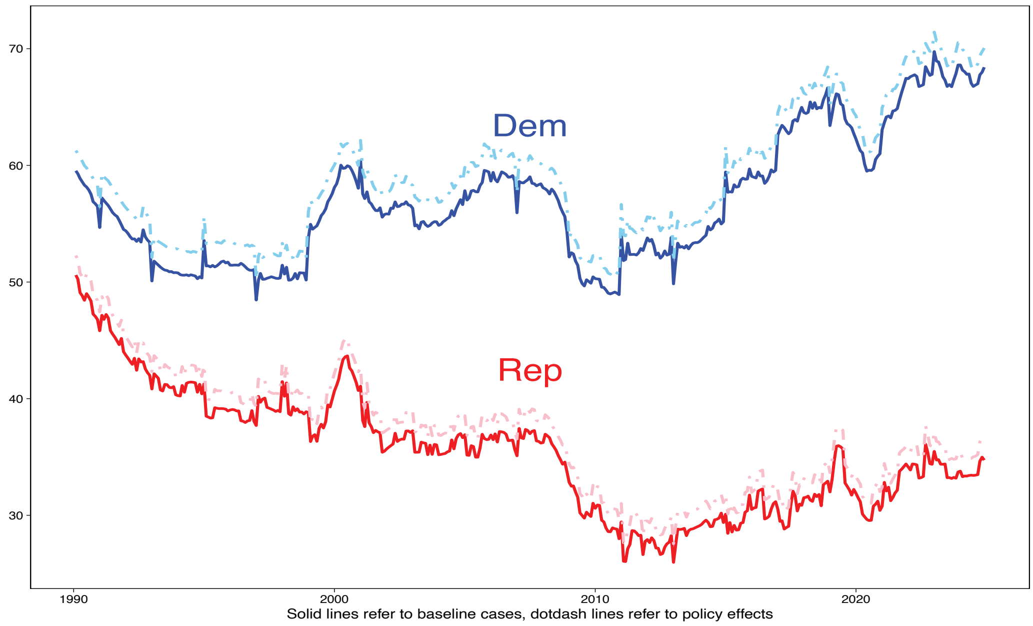

Figure 12: Unemployment decreases by 25% quartile

points (from 50% to 25%). As Figure 12 shows, the public opinion of both democratic and republican counties increase dramatically. Specifically, the opinion of democratic (republican) counties increases by 1.93 percentage point (1.59 percentage point) on average. A reduction in unemployment (economic pressure) allows the public to pay more attention to climate change, and the effect is substantial.

Increase objective positivity and reliability of news items (from

± 0.5 ***and 0.5 to*** ± 0.9 ***and 0.9).***

In Figure 13, we explore the effects of increasing positivity and reliability

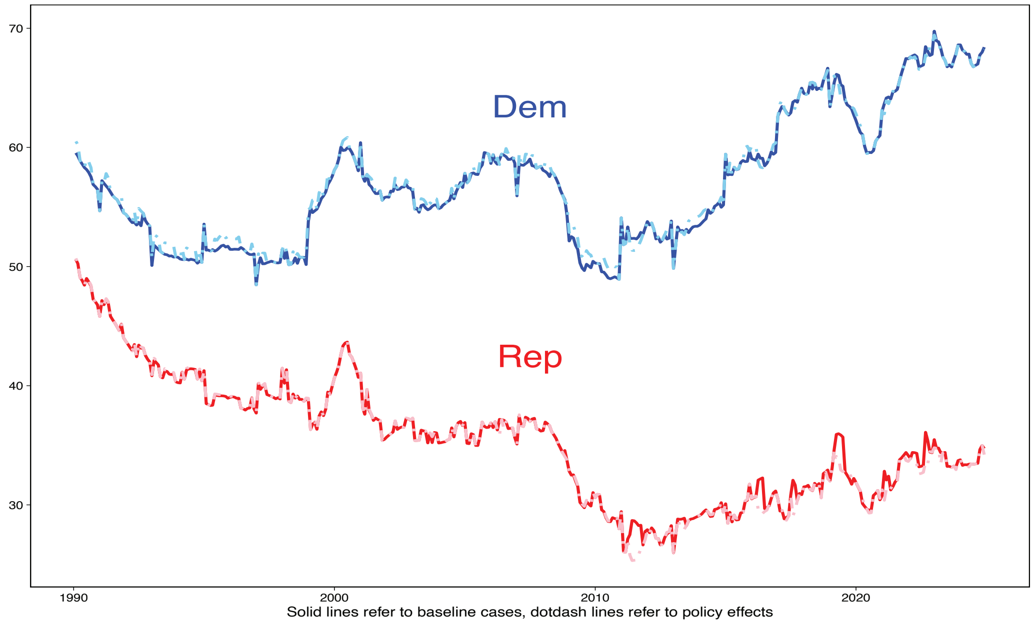

Figure 13: News items with higher positivity and reliability

of news items greatly. According to the figure, the effects vary in direction, sometimes positive and sometimes negative for both groups. However, overall public opinion of democratic counties increases by an average of 0.23 percentage points, and that of republican counties decreases by 0.12 percentage points, which are very small. It implies that news with higher positivity and reliability make democratic counties more concerned about climate change, whereas republican counties become less concerned. Nevertheless, the impacts are extremely limited. The public seems to be indifferent to the positivity and reliability of news.

Adjust news filtering thresholds (Deviation from mean changes from -0.03 ***to*** -0.05 ***for democratic station, from*** $+0.02$ ***to*** -0.02 ***for republican station).***

In Figure 14, we illustrate the effects on public opinion when both national stations lower their thresholds to broadcast more news. It is shown that lower thresholds have relatively large effects on public opinion. The public opinion of democratic (republican) counties decreases by 0.47 percentage points (0.80 percentage points) on average. It seems to be surprise that when more news flow to the public, public concern about climate change actually goes down, for both democratic and republican counties. However, one of the main

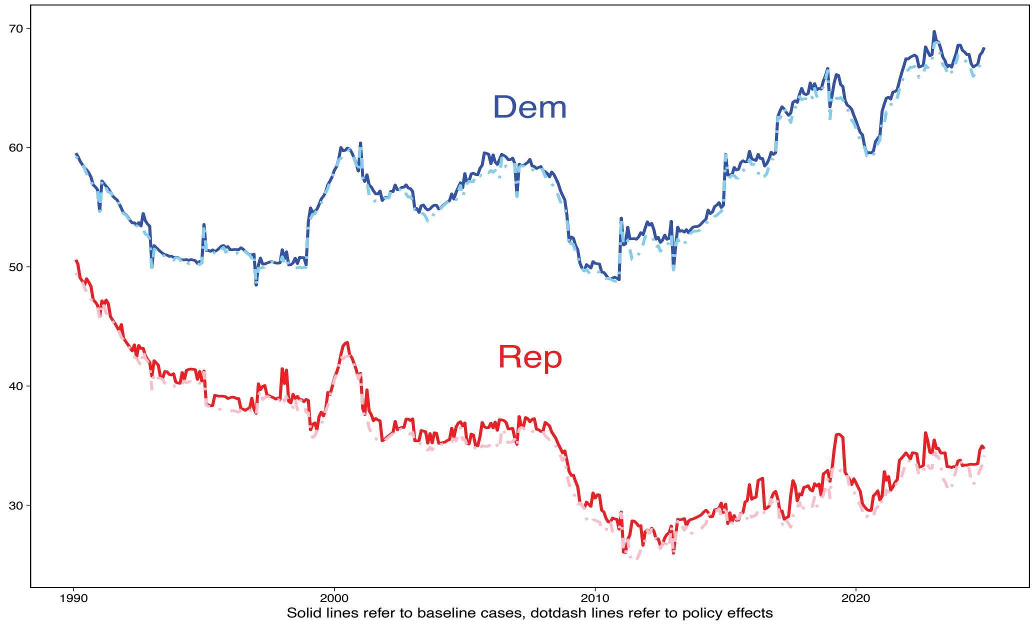

Figure 14: Lower thresholds of national TV stations

distinctions of our study from previous studies is that we quantify the quality of news as well, and include both news importance and news number in the model. Consequently, lower thresholds lead to more news, but at the same time the average importance of news decreases because TV stations select more news with relatively lower objective importance than before. This may make people become accustomed to climate change and lower their worries because of the information dilution effect. In fact, the policy experiments potentially reveal the trade-off between news quality and news quantity. It seems that fewer but more important climate-related news can actually push up public opinion about climate change.

Local TV stations broadcast news from the national TV station holding the opposite political views.

We examine a counterfactual case that individuals are exposed to news from the national station with opposite political stance. Figure 15 indicates that public opinion of democratic counties will slightly increase overall (0.33 percentage points on average), while that of republican counties will decrease moderately (0.66 percentage points on average).

Political distance between national TV stations increases.

We investigate the effect on public opinion when national TV stations become more extreme in their political stances in Figure 16. As expected, the larger political distance between national TV stations intensifies the polariza-

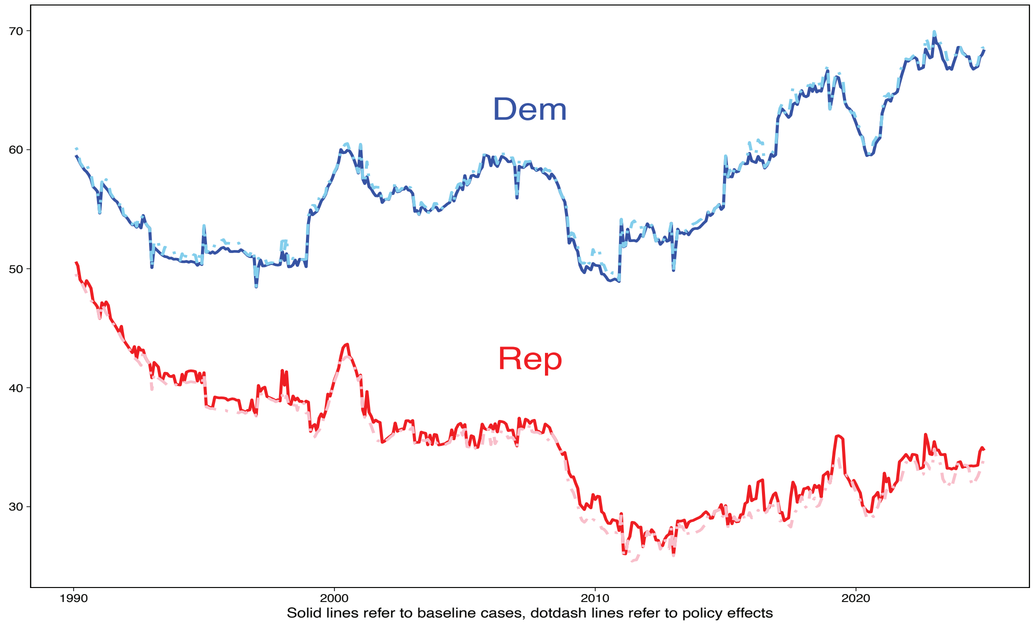

Figure 15: Contrarian behavior of local TV stations

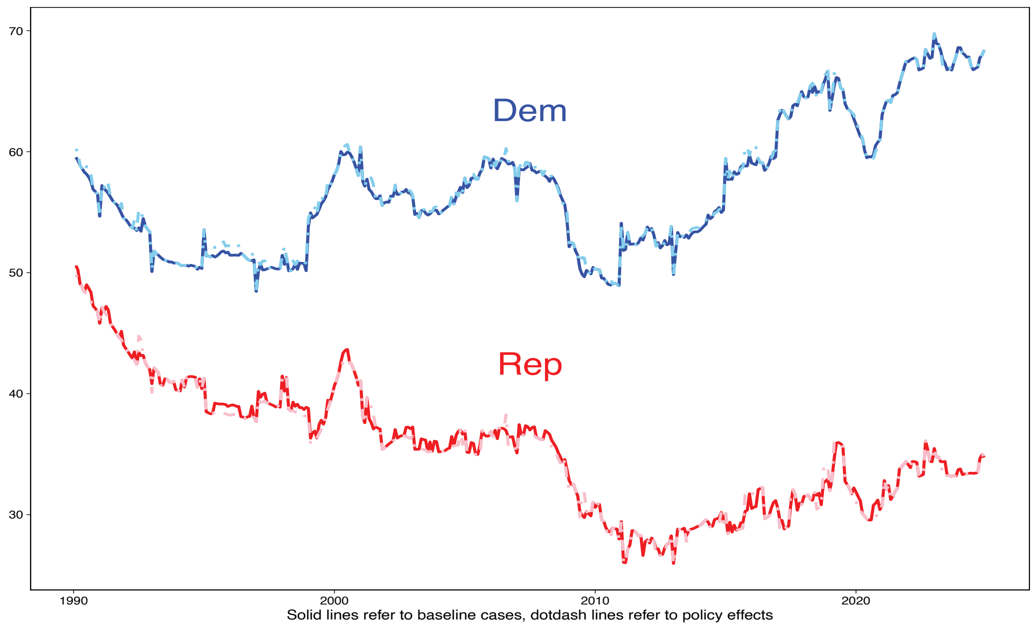

Figure 16: Polarization of two national TV stations

tion in public opinion between two groups of counties (democratic increases by 0.15 percentage points, republican decreases by 0.13 percentage points on average), although the effects are so small that they can be almost neglected.

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