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Polarisation of Climate and Environmental Attitudes in the United States, 1973-2022

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Since the early 1990s, increasing political polarisation is among the greatest determinants of individual-level environmental and climate change attitudes in the United States. But several patterns remain unclear: are historical patterns of polarisation largely symmetrical (equal) or is rather asymmetrical (where one set of partisans shifts more than others)? How have polarisation patterns have changed over time? How generalizable are polarization patterns across different environmental and climate change attitudes? We harmonised four unique sets of historical, pooled cross-sectional survey data from the past 50 years to investigate shifts across seven distinct measures of citizen environmental and climate change attitudes. We find that contemporary attitudes are polarised symmetrically, with Democrats (higher) and Republicans (lower) attitudes are equidistant from the median. But the historical trends in polarisation differ by attitudes and beliefs. In particular, we find evidence of two distinct historical patterns of asymmetric polarisation within environmental and climate change attitudes: first, with Republicans becoming less pro-environmental, beginning in the early 1990s, and second, a more recent greening of Democratic environmental attitudes since the mid-2010s. Notably, recent increases in pro-environmental attitudes within Democrats is a potentially optimistic finding, providing opportunities towards overcoming decades-long inertia in climate action. These findings provide a foundation for further research avenues into the factors shaping increased pro-environmental attitudes within Democrats.

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INTRODUCTION

Addressing global environmental problems requires collective action at multiple levels of governance. Citizen preferences can play an influential role for policymakers. Public acceptability strongly influences governmental actors and regulatory implementation frameworks within democratic states[1]. As policymakers aim to align actions with the preferences of their constituents[2,3], citizen demands can mitigate barriers to addressing environmental problems, especially if the pressure for policy solutions comes from a diversified set of party adherents.

Yet, over recent decades, environmental attitudes and policy preferences have become increasingly polarised in the United States[4,5]. Currently, Republicans are less likely to be concerned about the environment or to support environmental policies[6,7]. However, several open questions remain regarding the polarisation of citizen environmental attitudes. Have increases in polarisation been largely symmetrical[8], where the environmental attitudes and policy support of Democrats and Republicans have been similarly moving away from the median? Or rather, asymmetrical, where the attitudes of one partisan group have moved away from the others[9–11]?

In this paper, we present findings from harmonized environmental attitudes survey data across four distinct sets of pooled, historical cross-sectional datasets ranging from 1973-2022, accounting for a combined 83 unique survey years and n=110,237 individual respondents, to explore 7 dimensions of environmental and climate change attitudes. We adopt cross-classified random effect modelling (CCREM) techniques and substantive calculations of predicted probabilities to address three primary areas of inquiry: (i) what is the pattern of polarisation, is the polarisation of environmental attitudes symmetrical, occurring on both sides of the spectrum, or is it asymmetrical? (ii) Have these polarisation patterns changed over recent years? (iii) Does polarisation differ with regard to the type of environmental and climate change attitudes and behaviours?

Theoretical expectations

Over recent decades, the ideologies and policy positions of the Democratic and Republican Party in the United States have increasingly diverged. At the elite level, party differences are likely greater now than at any other time in the last fifty years[12,13]. Further, there is growing evidence of increased political polarisation amongst the American public[14,15]. From 1972 and 2012, the proportion of voters indicating 'no' or 'weak' party preferences has declined starkly, with the corollary increase in the proportion of voters with a 'very' or 'fairly strong' preference for a specific party[14]. Additionally, partisan polarisation has increased substantially across a range of political issues, such as employment, living standards, and health insurance[16].

Yet, there is further debate regarding the form such polarisation takes among citizens, namely whether polarisation is symmetrical (where parties and adherents move equidistantly away from each other) or asymmetric (where one party or adherents moves away from the others). Recent studies note a symmetric distribution of Americans, where the attitudes of Republicans and Democrats are diverging, and moving toward the poles, resulting in a shrinking 'middle'. Notably, the median Republican in 2014 is more conservative than 94% of Democrats (up from 70% in 1994) and the median Democrat is more liberal than 92% of Republicans (up from 64% in 1994)[17]. Alternatively, there is growing evidence that polarisation is rather asymmetrical[9–11]. Over recent decades,

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Republicans have shifted further from the median than Democrats across a broad range of attitudes: ideology, social welfare, and presidential feelings thermometer. Much of the increasingly polarised attitudes can be attributed to the politically rightward movement of Republican voters[15,18].

Polarisation of environmental attitudes. Since the beginning of sociopolitical inquiries into human-environmental systems, political polarisation has been a core driver patterning environmental attitudes[19], a phenomenon that appears to be increasing over recent decades[4,20]. Political preferences are among the strongest and most consistent predictors of citizen-level environmental attitudes and policy support in the United States[6,21].

The mechanisms driving environmental partisan polarisation among citizens can be separated into group- and individual-level factors. Group-level political differences in environmental attitudes are often shaped by elite member cues. Individuals do not have entirely internally consistent preferences, but respond to messaging from elite in-group members[22–24]. Oft-remarked is the role elites have played in the politicisation of climate change —the behaviour of lobbyists, NGOs, scientists, legislators, and public policymakers[25,26]. This shift is often attributed to an increasingly hostile conservative movement against environmental legislation[27].

Over time, Republican elites have increasingly challenged the legitimacy of climate change science and have consistently prevented regulatory action. In the 1970s, Republican elites only tended to be slightly less pro-environmental than Democrats, while differences have escalated in recent years with Republicans elites holding ever stronger anti-environmental stances[20], a shift that has often been attributed to intense lobbying from the fossil fuels industry[28,29]. For example, groups supporting transportation, electrical utilities and fossil fuel industry have outspent those supporting renewable energy and environmental protection by a ratio of more than 10:1[30].

The growing anti-environmental ideology among conservatives has been called a "counter-movement"[20], consisting of 'Astroturf' campaigns against climate change legislation, supported by corporations (especially those in the oil, coal, and natural gas sectors), conservative think tanks and their funders, and contrarian scientists[4,31,32]. These movements have been particularly successful in public messaging, which has amplified via conservative-friendly media outlets[33,34], as well as via conservative Christian elites[35]. Additionally, the parties have steadily shifted in terms of race, age, education, and ideology, such that the constituencies of the two main parties are more heterogeneous in the past, likely contributing to polarisation[36–39]. The literature on party sorting notably demonstrates that the Republican constituency is more consistently conservative than in the past, and the Democratic constituency is more consistently liberal.

At the individual level, political beliefs are often rooted in social identities, where people adopt a party affiliation, setting boundaries for who is 'in' and 'out' of their group[40,41]. People develop a sense of belonging to their 'in-group'[42], and this emotional attachment drives them to adopt the norms and attitudes common to those of the group[43]. That is, partisans are likely to adjust their attitudes to conform with those of the party, especially for salient issues[44], resulting in a smoothing-over process, harmonising attitudes within a partisan group. This consolidation process leads to further polarisation between different groups of partisans, as individuals are less likely to adopt the attitudes of 'out' groups[45,46]. Accordingly, environmental polarisation could be a result of Democrats becoming increasingly likely to view environmental and climate change issues as core components of their partisan 'in-group' identity. Or, on the other hand, Republicans could also increasingly view environmental and climate change issues as a salient feature of the adversarial 'out-group', and are mobilized against this perceived threat[47].

There is substantial evidence suggesting increased environmental partisan polarisation amongst people in the United States over recent decades. Previous studies have used pooled cross-sectional data from the General Social Survey to assess changes in preferences for national spending on the environment as a result of political polarisation[5,28,48–50], while other sets of studies have also explored climate change attitudes using the Gallup Poll Social Series[20,51,52], and climate and environmental attitudes using data from Pew[53,54] and the Cooperative Congressional Election Study[55]. Similarly, recent studies have also adopted multiple sources of survey data, exploring historical trends in the aggregate US population[56,57]. However, to date, no studies have compared longitudinal shifts within partisan groups with multiple historical sets of survey data, nor across such a wide range of environmental and climate change attitudinal measures.

Although the extant literature notes that Republicans are increasingly less likely to have pro-environmental attitudes, it is less clear whether polarisation is the product of symmetrical or asymmetric processes. That is, are Republicans alone driving these attitudinal differences via asymmetric polarisation and moving away from the political median, or have the attitudes of both parties shifted [at least somewhat] equally?

Accordingly, here we explore several empirical questions regarding polarisation of citizen environmental attitudes in the United States over recent decades:

(i) Is the polarisation of environmental attitudes similar within both Republicans and Democrats, or are these trends asymmetric?
(ii) How have these patterns of polarisation within parties changed over recent years?
(iii) Are there differences in polarisation patterns based upon the type of environmental and climate change attitudes and behaviours (e.g. broad environmental attitudes versus those specifically related to climate change, or between climate change scepticism and concern)?

RESULTS

Research design

We use pooled cross-sectional survey data from four unique sets of historical data. First, we utilise survey data from the cumulative General Social Survey 1973-2021 (GSS)[58] to identify shifts in support for federal environmental spending and confidence in the scientific community. Next, we utilise two distinct series of surveys conducted by the Pew Research Center focusing on climate change attitudes in the United States. First, Pew has collected data from 2001 to 2020 at 16 separate time points, focusing on perceptions of the priority of climate change as an issue for Americans. Second, Pew has also asked Americans about their perceptions about the threat of climate change, collected at 8 separate time points from 2009 to 2019. Lastly, we use data from the Gallup Poll Social Series (GPSS), 1989–2021, to identify patterns in three separate indicators: climate change worry, beliefs about when climate change will happen and the seriousness of climate change. In sum, these data comprise nearly five decades of historical environmental attitudes and beliefs (1973–2021), across seven separate measures, pooled across $n =$ 110,237 respondents.

We group results for these seven measures of environmental attitudes into three conceptualizations: environmental attitudes (environmental spending, confidence in scientific community), climate change beliefs (climate change worry, when climate change will happen, the seriousness of climate change), and climate change attitudes (major threat, and top priority) (see Fig. 6).

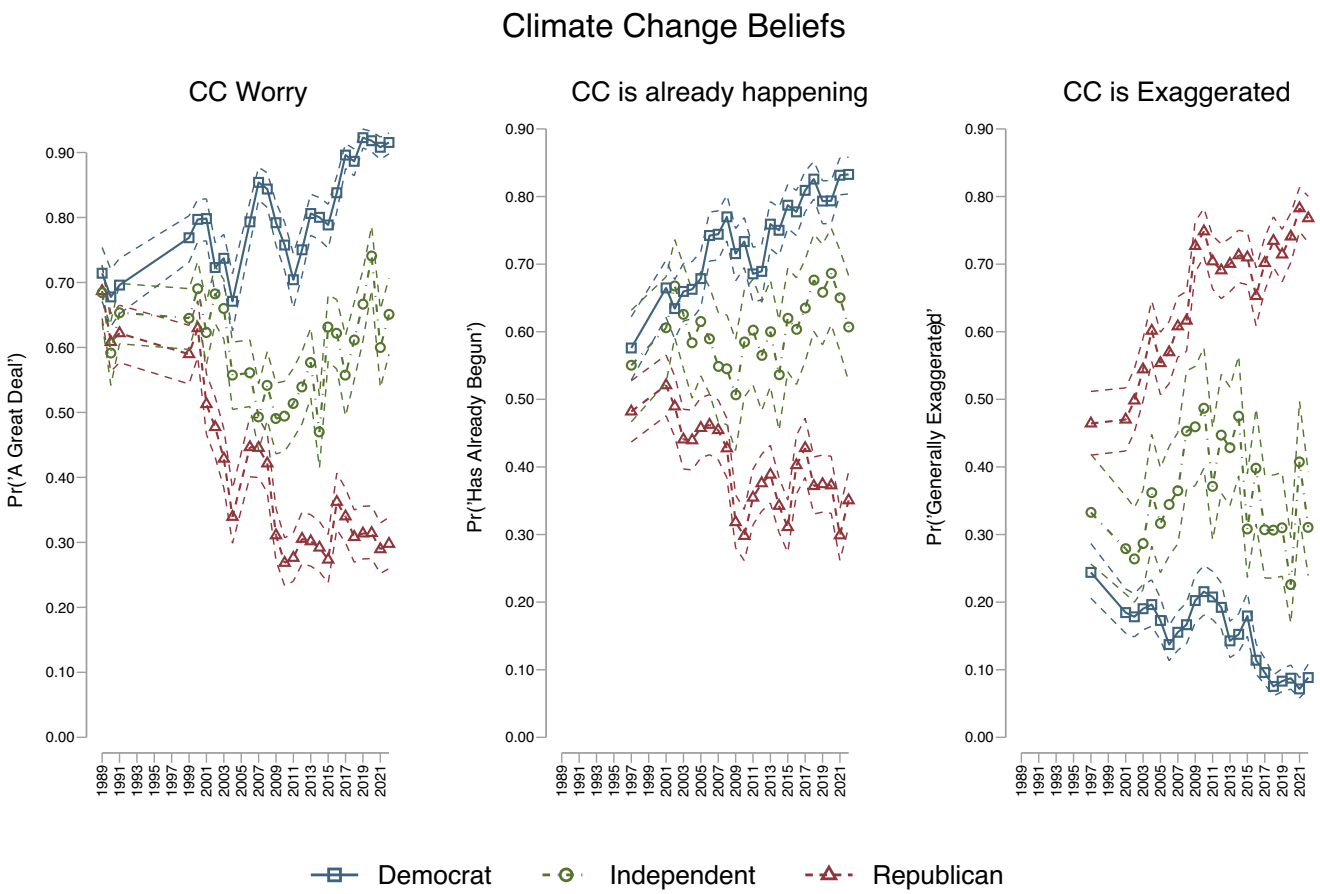

Fig. 1 Environmental attitudes, 1973–2021. Average predicted probabilities of United States residents responding that spending on the environment is 'too little' (n = 60,700) and confidence in the scientific community is 'a great deal' (n = 42,050) by party affiliation per year. Probabilities are calculated using results from Supplementary Table 1, Models 1 and 2, using the combined fixed and random effects of party identification, holding all other variables at their means. 95% confidence intervals are plotted in dashed lines. Data is from the General Social Survey.

To explore polarisation trends, we employ a three-item indicator of party identification (GOP/ Independent/Democrat), estimating the effect of partisanship over time using cross-classified random effect models (CCREM)[59,60], controlling for age, gender identification, education and racial identification. This modelling approach allows for the interpretation of historical trends, independent of demographic cohort and subgroup factors, as well as broader temporal trends. Full CCREM pooled regression estimates are available in Supplementary Table 1, along with cumulative descriptive statistics (Supplementary Table 2), as well as descriptive statistics for by survey year (Supplementary Tables 3–7). Furthermore, the raw means of responses by party are plotted in Supplementary Figures 1–3.

To facilitate substantive interpretation, we draw upon the CCREM estimates to calculate predicted probabilities in each year of available data at the three levels of party identification (GOP/ Independent/Democrat) for environmental attitudes in Fig. 1, climate change beliefs in Fig. 2 and climate change attitudes in Fig. 3. The 95% confidence intervals are also plotted in Figs. 1–3, where non-overlapping bars for predicted probabilities can be interpreted as statistically significant differences. Polarisation patterns can be interpreted as first, when the predicted probabilities for Democrats and Republicans branch equally apart over time, polarisation can be presumed to be symmetrical. Second, when the trajectory of predicted probabilities for party affiliations diverge (e.g. one party moves further away from the median than the other), this implies that polarisation has been asymmetrical. Accordingly, this data design allows for the interpretation of historical trends among party affiliations across time.

Environmental attitudes

First, we explore historical patterns in environmental attitudes from 1973-2021 in Fig. 1, finding that beginning in the early 1990s, support for environmental spending decreased quite substantively for Republicans (denoting a pattern of asymmetric polarisation). Yet, beginning in the mid-2010s, support has markedly increased among Democrats. For example, the predicted probability of a Democrat believing environmental spending is 'too little' has increased from ~ 0.70 in 2015 to 0.85 in 2021. For Republicans, the downward trend in support for environmental spending appeared to have stabilized in between the mid-2000s and late-2010s, yet in the most recent survey data wave in 2021, the predicted probability has dropped substantively to from ~0.45 to 0.34. Given these results are from a single party-year data point, additional data is required to determine if 2021 is the beginning of a second negative shift among Republicans, or rather just an outlier.

Turning to confidence in the scientific community, there appears to be minimal differences based upon party affiliation across most of the past 50 years. But the most recent data in 2021 suggest a substantial shift in polarisation, where Democrats have become some 0.20 more likely to express 'a great deal' of confidence in the scientific community and Republicans are slightly less likely (~0.05). Again, this trend would need to be confirmed with future historical data.

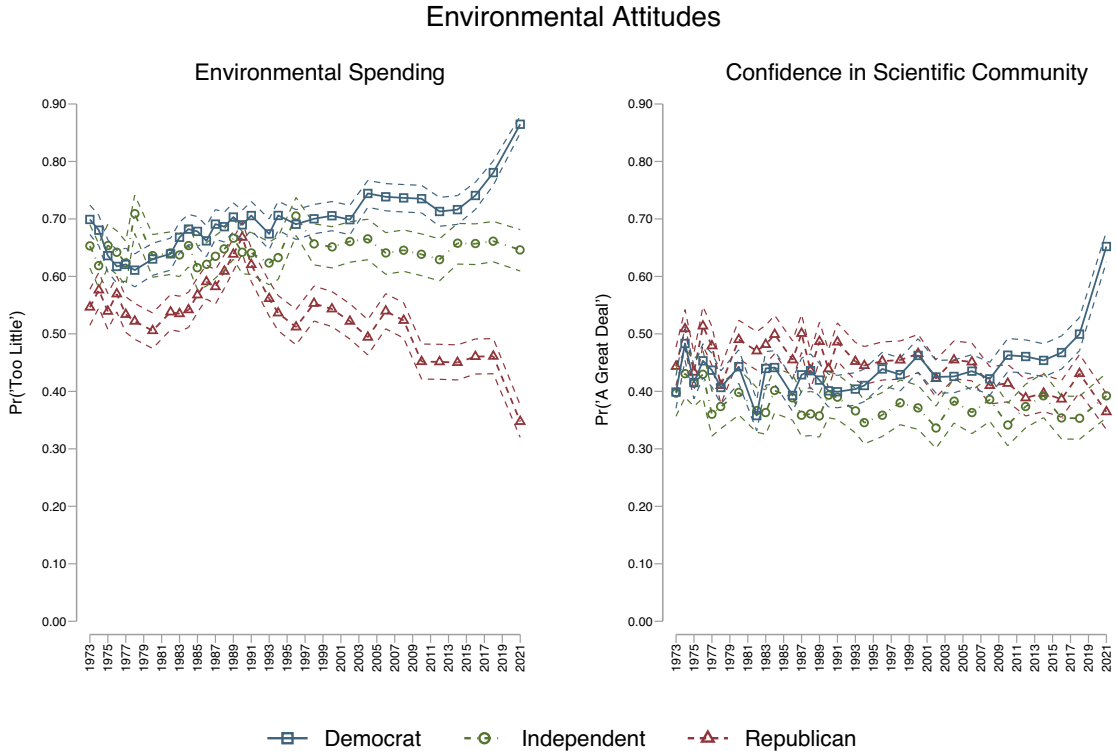

Fig. 2 Climate change beliefs, 1989–2021. Average predicted probabilities of United States residents responding that they are worried about climate change 'a great deal', (n = 25,797) climate change has 'already begun' (n = 21,736) and that the seriousness of climate change is 'generally exaggerated' (n = 21,729) by party affiliation per year. Probabilities are calculated using results from Supplementary Table 1, Models 3-5, using the combined fixed and random effects of party identification, holding all other variables at their means. 95% confidence intervals are plotted in dashed lines. Data is from the Gallup Poll Social Series.

Climate change beliefs

For historical patterns of polarisation in climate change beliefs, we adopt data for three separate measures in Fig. 2. First, for the likelihood to respond that they are worried 'a great deal' about climate change, we find very minimal differences based upon partisan affiliation in 1989. Yet, beginning in the mid-1990s, we find a substantive decrease in worry among Republicans, dropping some 30% towards a predicted probability of ~0.30, a trend which has remained relatively stable since the mid-2000s. For Democrats, we find a substantial increase in having a 'great deal' of worry beginning in 2011, where the predicted probability has increased from 0.70 to 0.91 in 2021.

Second, for beliefs that climate change has already begun, we initially find comparatively minimal differences between the likelihood of Republicans and Democrats in 1997—both sets of partisans are found to have a predicted probability around 0.50. However, in the most recent data in 2021, Democrats have a predicted probability of 0.83 and Republicans have 0.30, indicating substantial polarisation.

Lastly, for beliefs that climate change has been 'generally exaggerated', we already find substantial differences between Democrats and Republicans at the initiation of our historical data in 1997, suggesting that polarisation has already occurred prior to data availability (likely sometime in the early 1990s). Republicans had a predicted probability of 0.46 in 1997 of responding that climate change is exaggerated, which has steadily increased to 0.79 in 2021. Alternatively, the probability that a Democrat reports believing that climate change is exaggerated is approaching the lower bound of 0 by 2021. Among independents, beliefs have largely remained within a range between 0.30-0.40 over this time period.

In sum, we largely find evidence of symmetrical polarisation across these three forms of climate change beliefs, where Republicans and Democrats are both continually shifting their attitudes further away from the median.

Climate change attitudes

Lastly, we explore two measures of climate change attitudes in Fig. 3. First, for responding that climate change is a 'top priority', we find evidence of substantial polarisation at the beginning of our historical survey data in 1999. Republicans have remained largely stable over the past 20 years (~0.15) but the likelihood for Democrats to state that climate change is a top priority has increased substantially from (~0.45) in the mid-2000s to 0.69 in the most recent data point in 2020.

Second, for responding that climate change is a 'major threat', we again find evidence of significant polarisation at the beginning of our historical data in 2007—a difference in predicted probability of (~0.45) between Republicans and Democrats. But again, over recent years, Republicans have remained largely stable, yet the probability that Democrats believe climate change is a major threat has increased from (~0.70) to 0.83 in 2020.

In sum, we find evidence of two patterns of asymmetric polarisation in climate change attitudes, first among Republicans in the mid-1990s, and now more recently among Democrats beginning in the mid-2010s.

Robustness checks

Here we perform two sets of robustness checks. First, we explore how environmental and climate change attitudes vary by survey year period birth cohort. Beyond the estimates of party affiliation by year, the CCREM models (see Supplementary Supplementary

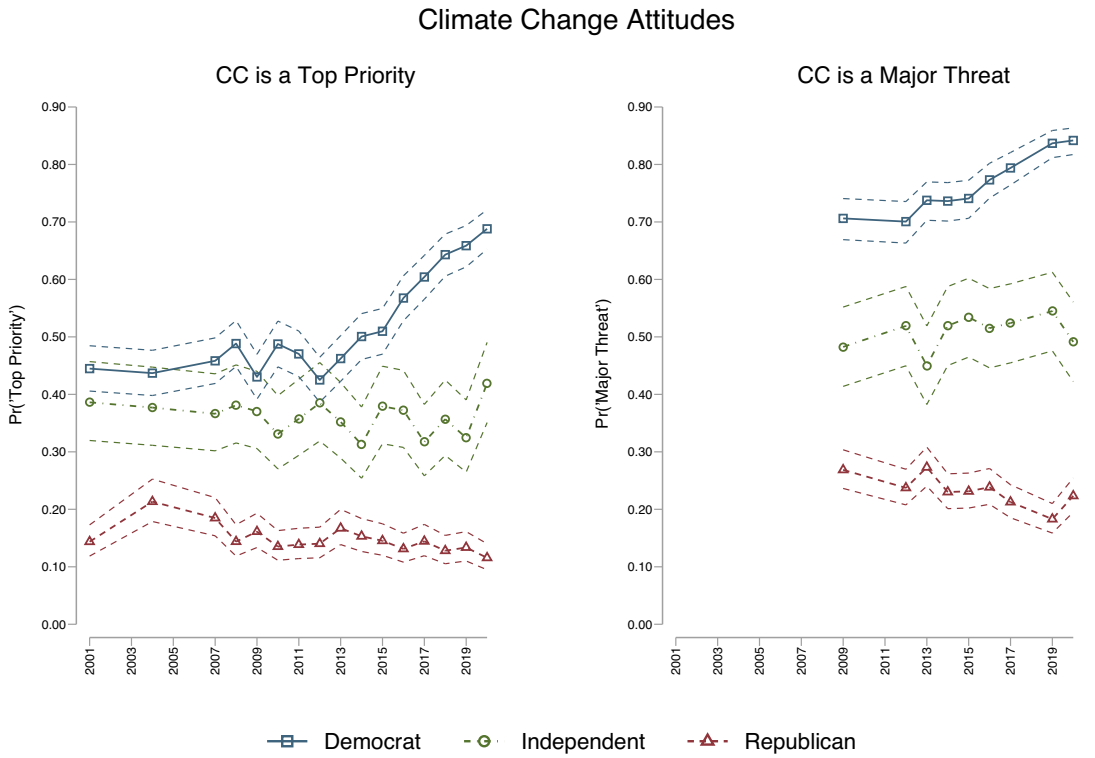

Fig. 3 Climate change attitudes, 2001–2021. Average predicted probabilities of United States residents responding that climate change is a 'top priority' for the government ($n = 12{,}464$) and that climate change is a 'major threat' ($n = 11{,}276$) by party affiliation per year. Probabilities are calculated using results from Supplementary Table 1, Models 6 and 7, using the combined fixed and random effects of party identification, holding all other variables at their means. 95% confidence intervals are plotted in dashed lines. Data is from the Pew Research Center.

Table 1) estimate the random effects of the survey year period and birth year cohort (5-year 'generation' intervals). The period variance components are significant for spending on the environment (0.04), climate change priority (0.09) and climate change threat (0.06), indicating a general pattern of "greening" attitudes among US residents during these time periods. At the same time, the variance component for the survey year period is also significant for responding that the seriousness of climate change is generally exaggerated (0.02), indicating that climate scepticism has also increased over these historical data. Yet, for all of these significant effects of the survey year period, none explain much more variance than the changes in party affiliation over time.

Further, we also explore the effect of potential birth-year cohort characteristics, plotting the predicted probabilities in Fig. 4 for each 5-year cohort from 1904 to 1995. Although we find statistically significant variance over these historical data for each dependent variable in Supplementary Table 1, we do not find evidence of large differences between demographic cohorts. That is, this data provides little evidence in support of a 'rising green generation', and rather, environmental and climate change attitudes are broadly evenly dispersed across cohorts, consistent with other recent findings[5,48,49].

In sum, these findings both suggest that although there are certainly evidence for some greening of attitudes over time, these do not appear to strongly affiliated with any demographic shifts, providing further evidence for the enduring effect of party affiliation dynamics over time.

Second, we further evaluate the sensitivity of our findings to model estimation techniques. We estimate the effect of partisan affiliation over time using four common techniques—(1) the CCREM models presented in the main text, (2) fixed-effect logistic regression models where the survey year period is interacted by party identification, (3) random intercepts logistic regression models for survey year period, (4) random effects logistic regression models for party identification nested in each survey year period—adopting the data for climate change as a top priority as an example. For each of these models, we include the same operationalization of the data and control variables as for the results presented in the main text. In order to allow for comparisons to be made across estimation techniques, we calculate average predicted probabilities across these models for the likelihood to respond that climate change is a 'top priority' for both Republicans and Democrats in Fig. 5. We find that the same pattern emerges for all four estimation techniques. Notably, the effect of Democratic Party affiliation appears to be comparatively smallest for the CCREM technique adopted in this analysis. This may be due to the more explicit incorporation of period and cohort effects within the CCREM approach, moderating the effects of party affiliation. Further, given that our analyses focuses on the role of party affiliation over time, and not on identifying the distinct role of age, period, and cohort effects, our findings are likely less susceptible to concerns of mis-attenuation of demographic effects. In sum, these comparative analyses suggest minimal differences across estimation techniques, where the CCREM approach has comparatively more conservative estimates of the varying effect of party affiliation over time.

DISCUSSION

Drawing upon historical survey data, we analyse trends in environmental and climate change attitudes, by party affiliation, over time, across multiple measurement dimensions. We find that within the contemporary citizenry, the environmental and climate change beliefs and attitudes of Americans broadly exhibit symmetric patterns of polarisation. Across seven distinct measures, Democrats are currently more likely to have heightened environmental and climate change beliefs and attitudes (in

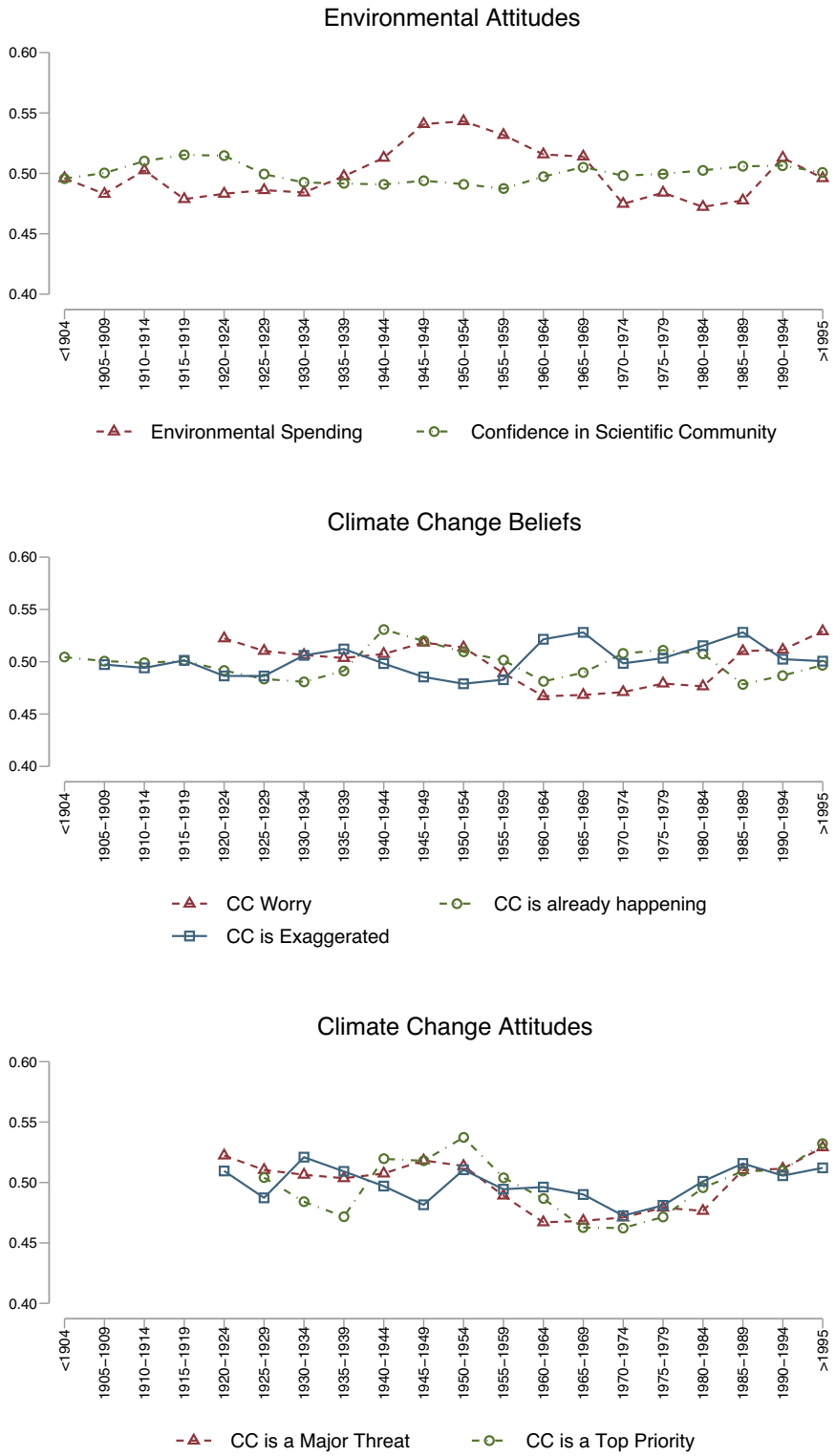

Fig. 4 Cohort effects. Predicted probabilities of survey year period and birth year cohort at five-year intervals. Calculated utilising random effects of period and cohort estimated in Supplementary Table 1, Models 1 and 7.

comparison to the average American), which is mirrored by decreased likelihood to have environmental and climate change beliefs and attitudes within Republicans.

Yet, the historical patterning of how these attitudes and beliefs have become polarised differs by environmental and climate change constructs. For both sets of environmental and climate change attitudes, we find two distinct historical patterns of asymmetric polarisation: first substantial decreases in environmental and climate change attitudes within Republicans largely beginning in the early 1990s, and second, a more recent trend of heightened environmental and climate change within Democrats initiating in the mid-2010s. While, for climate change beliefs, we

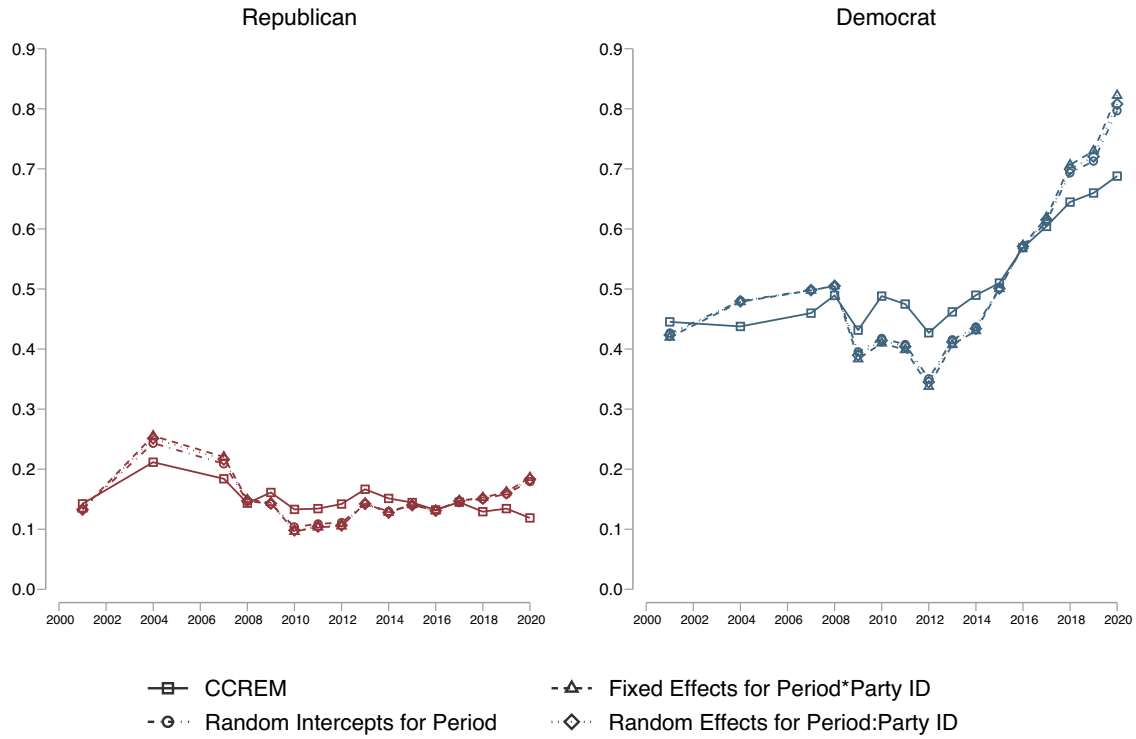

Fig. 5 Comparison of modelling approaches for climate change priority. Average predicted probabilities of responding that climate change is a 'top priority' by party identification per year for 4 different regression modelling approaches: (1) CCREM models presented in the main text, (2) fixed-effect logistic regression models where survey year period is interacted by party identification, (3) random intercepts logistic regression models for survey year period, (4) random effects logistic regression models for party identification nested in each survey year period.

find evidence of symmetrical polarisation of attitudes, with partisans diverging in relatively equidistant historical patterns from the median beginning in the mid-1990s.

These findings support previous research[5,20,21,28,48,49,61] further demonstrating that, beginning in the 1990s, Republicans became far less likely to believe in anthropogenic change, less likely to be concerned about climate change, and are less likely to support mitigating policies[6,62]. Drawing upon related findings[29,34,63], we suggest that the hyper-polarisation amongst Republicans can, in some ways, be attributed to the aggressive and concerted efforts from conservative think tanks and sympathetic media figures[21,31–35]. For example, in recent decades over $2 billion has been spent on climate change lobbying in the US, of which, the groups supporting renewable energy and environmental protection have been outspent by a ratio of more than 10:1 by those supporting transportation, electrical utilities and the fossil fuel industry[30].

Further, we most notably observe a more recent upward recent shift within Democrats, which have become more likely to support increased spending on the environment, and to state that climate change is a top priority or a major threat. These shifting attitudes among Democrats have affected a prominent recent increase in the aggregated US population, resulting 10-20% increase in the mean of pro-environmental and climate change attitudes. This observation illuminates a foundational trend, one that calls for further research to engage in the causes of heightened attitudes within Democrats, similar to the extant literature examining the diverse factors driving polarisation within Republicans. Accordingly, we draw upon extant findings to develop an agenda for potential factors shaping environmental and climate change attitudes within Democrats below.

First, Democrats could be increasingly willing to accept the scientific consensus of anthropogenic climate change. Climate change scientific knowledge transfer activities are more likely to influence Democratic voters, either via processes of Bayesian updating[64] or motivated reasoning[65,66]. For example, Democrats that have heard about climate change from news weather-casters are more likely to report changing their beliefs[67]. Furthermore, experiencing extreme weather events[68,69], e.g. floods and heat waves[70], have been found to reduce the psychological distance to potential climate-related impacts[71], and thereby act as potential mechanisms instigating larger-scale changes in climate change attitudes and behaviours. However, possibly due to motivated reasoning, Republicans may be less likely to recognize changes in weather[72], such as increased flooding[73–75]. That is, intensifying impacts from climate change will not, by itself, shift climate change attitudes (or environmental concern) among conservatives, but might do so for Democrats[76].

Next, increased environmental attitudes could also be attributed to shifting political coalitions—for example, women, and particularly highly educated women[77], have become increasingly likely to be affiliated with the Democratic Party, a constituency that is commonly found to have higher pro-environmental attitudes[78–81]. Heightened environmental attitudes could also be reflective of norm-shifts within the Democratic constituency. People are motivated to conform beliefs with what they perceive group members believe[82], or also importantly, don't believe[83]. For example, partisans are far more supportive of climate change policies in the United States if they believe other members of their party support them as well[84].

Further, Democrats could also be responding to shifting elite-cues regarding climate change[85]. Such shifts would be substantively similar, but in the opposite direction, of the recent attitude and behavioural shifts observed among Republicans in response to elite cues regarding COVID-19[86,87]. Notably, the frequency of Democratic policymakers discussing climate change in congressional speeches

increased greatly beginning in the late 2000s, often focusing on impact-related issues (such as extreme weather and the effects on public health)[88].

Lastly, the increased pro-environmental attitudes could result from demographic shifts, For example, recent evidence from Western Europe suggests that younger generations are becoming more likely to support green parties[89]. While we find that environmental attitudes are not affiliated with age and period demographic shifts among all respondents in Fig. 4 (echoing other similar findings from the United States[5,48,49]) it is possible that more recent shifts are driven by younger, Democratic partisans. In an exploratory, descriptive analysis, we find that young Democrats (under 30 years old) have becoming increasingly likely to have pro-environmental attitudes since the mid-2010 (Supplementary Figs. 4–6). While environmental attitudes among young Republicans have remained more stable during this time. But, we also find that the increase in environmental attitudes among Democrats is similar across age ranges (Supplementary Figs. 7–9). Accordingly, these findings suggest that in comparison to Republicans, environmental attitudes are increasing within all Democrats, regardless of their age. Yet, these exploratory findings require more robust statistical evaluation to validate recent demographic shifts by party affiliation.

The patterns of asymmetric polarisation have implications for collective action and coalition-building to address environmental problems in the U.S. While political actors are reactive to changing voter preferences, either via longer-term thermostatic mechanisms[90,91] or more ephemeral updating of political behaviours[92,93], environmental governance regimes remain particularly sticky institutions. Institutionalist perspectives suggest that a substantial shift in public opinion dynamics[94], or the development of new voter coalitions[95], would be required to implement meaningful climate actions.

Such a shift could occur via asymmetric polarisation processes, where, for example, Democratic partisans rapidly shifts demands towards increased climate action. Yet, Democratic coalitions tend to be much more ideologically and socio-demographically diverse than the Republican base[96], and accordingly, policies to mitigate and adapt to climate change must appeal to this broad Democratic coalition if Republicans remain opposed. Indeed, this appears to be the case with the recent passage of the Inflation Reduction Act (2022). Democrats were able to consolidate the entirety of a very thin majority in the House in the Senate to unanimously vote in favour of the budget reconciliation package, with no support from opposing party legislators.

Further, drawing upon a longer historical lens, the recent asymmetric shift in Democratic climate change attitudes and policy preferences could be seen as countering the decades-long anti-environmental trend among Republicans. In this way, this shift would enact the culmination of symmetrical polarisation surrounding climate change, where the attitudes and preferences of both sets of partisans now appear to be equally spread.

However, the current Democratic single-party control is historically infrequent, as divided government is the much more likely norm than a unified government[97,98]. In the future case of divided government, if the U.S. is to enact further change policies at the federal level, at least some support from Republican Party members is likely required as part of an emergent environmental policy coalition. This is potentially problematic for the climate change policies—recent survey evidence suggests that the climate and environmental have the greatest partisan gap in support among an array of policy preferences (e.g. health care, defence, immigration, social programs)[99]. Indeed, climate change and the environment likely remains one of the more sticky arenas for further policy development.

There are some caveats and limitations of this study that point to future research needs. First, our dependent variables are comparatively broad measures of environmental and climate change attitudes, and may be sensitive to partisan responding[100]. Other areas of environmental policy, such as energy efficiency and renewable energy[101–103], are typically less polarised and as such, further future research should explore potential forms of polarisation in these areas when data becomes available, to understand whether these patterns or mirrored, or if there are certain areas of public policy that are less sensitive to polarising dynamics. Further, as noted above, future research and data collection can confirm evidence of recent trends among Democrats, in particular those in response to measures of environmental spending and trust in the scientific community.

METHODS

Data sources

For this analysis, we draw upon four separate data sources. First, the General Social Survey (GSS), a nationally representative, probability sample of English-speaking persons eighteen years of age or older. The GSS began in 1972, and has been conducting surveys annually or biannually up to the most recent release, in 2021. We utilise the cumulative GSS data from 1973-2021[58] to identify shifts in support for federal environmental spending and confidence in the scientific community based upon party affiliation.

Next, we utilise two historical series of surveys conducted by the Pew Research Center (Pew) focusing on climate change attitudes in the United States. First, Pew has collected data from 2001-2020 at 16 separate time points, focusing on assessing the priority of climate change as an issue for Americans. Further, in a separate set of surveys, Pew has also asked Americans about their perceptions about the treat of climate change at collected at 8 separate time points from 2009-2019. While both collected by Pew, these data on climate change priority and threat perception were collected independently, in different surveys at time periods, and as such, are adopted as distinct sources for our subsequent analyses.

Lastly, we use data from the Gallup Poll Social Series (GPSS), a longitudinal, monthly data collection project conducted by Gallup, Inc. Within the GPSS, items regarding American attitudes and behaviours towards climate change have been asked between 1989-2021, for a total of 27 separate time points. Drawing upon these data, we use three separate indicators: climate change worry, beliefs about when climate change will happen and those regarding the seriousness of climate change.

Several previous studies have used pooled cross-sectional data from the GSS to evaluate changes in preferences for national spending on the environment as a result of political polarisation[5,28,48,49], while a further set of studies has also explored climate change attitudes using the GPSS[20,51,52] and data from Pew[53,54]. But, as of current, no studies have compared these longitudinal partisan shifts between multiple historical sets of data, nor across such a wide range of environmental and climate change measures.

For each of these seven measures, we employ a common indicator for party identification (GOP/ Independent/Democrat) and control variables (age, gender identification, education and racial identification) across all analyses. Below, we describe the coding methodology for each of the seven dependent variables, party affiliation and control variables.

Dependent variables

Support for environmental spending. The GSS has included a battery of questions measuring support for federal spending on the environment in every round of data collection between 1973 and 2021. *Support for environmental spending* is operationalized through the question "I'd like you to tell me whether you think we're spending too much money on it, too little money, or about the right amount on improving and protecting the environment",

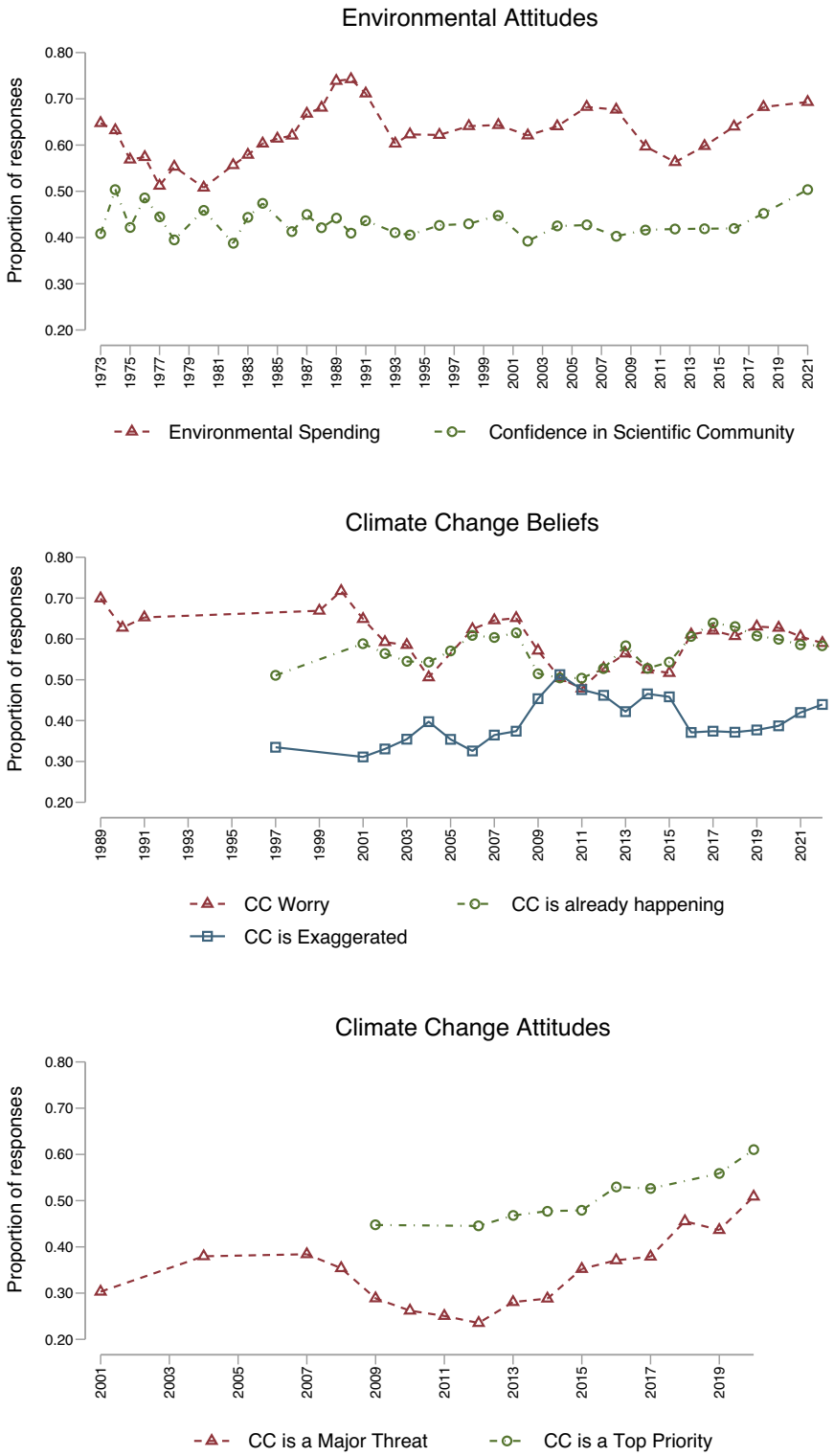

Fig. 6 Environmental and climate change attitudes. The proportion of respondents who respond that spending is 'too little', 'a great deal' of confidence in the scientific community, having 'a great deal' of worry about climate change, climate change 'has already begun', the seriousness of climate change is 'generally exaggerated', climate change is a 'top priority', and climate change is a 'major threat' over the historical time period covered by each of these data. The dotted gray line represents the cumulative average per year.

where respondents are grouped by whether they selected spending is 'too little' or not. Throughout the duration of the GSS data, a majority of respondents have selected that the US spends 'too little' on the environment (62% see Fig. 6), where this proportion has varied greatly over this time period, ranging from roughly 0.50 in the early 1980s to around 0.70 in the most recent survey (2021).

Confidence in scientific community. Furthermore, the GSS has asked respondents about their *Confidence in Scientific Community*

every wave from 1973-2021 (with the exception of 1985). This measure is captured as part of a battery, where respondents are prompted with the statement, "I am going to name some institutions in this country. As far as the people running these institutions are concerned, would you say you have a great deal of confidence, only some confidence, or hardly any confidence at all in them?: Scientific Community". Potential responses range from (1) a great deal, (2) only some, (3) hardly any. We transform this item into a binary variable, where (0) 'only some/hardly' and (1) 'a great deal' are used for our subsequent analyses.

Climate change is a top priority. Similar to the GSS, Pew Research Center has included a battery measuring how much priority respondents believe should be given to national political issues. *Climate change prioritization* is operationalized using the prompt "Please tell me how much priority you think each should be given. Should [global warming (2001-2015)/ climate change (2016-2020] have a top priority, important but lower priority, not too important, or should it not be done"? Responses are grouped into whether (1) 'top priority' was selected or (0) not. Cumulatively, 32% of respondents selected climate change as a 'top priority' from 2001-2020, where the proportion of responses has increased steadily over time, ranging from roughly 0.40 in the mid-2000s to 0.50 in the most recent survey (2020), see Fig. 6.

Climate change is a major threat. More recently, Pew Research Center asked respondents about their perception of the threat posed by climate change. *Climate change threat* uses the item "Do you think that climate change is a major threat, a minor threat or not a threat to the well-being of the United States?". Responses are grouped into those that selected (1) 'major threat' or (0) not. Cumulatively from 2009-2019, roughly 50% responded that climate change is a major threat, which has increased substantially in recent waves (see Fig. 6).

Climate change worry. For the last three measures, we use historical data from the GPSS, ranging from 1989-2021. *Climate Change Worry* is operationalized via asking respondents "How much do you personally worry about [The "greenhouse effect" or global warming / Global warming / Global warming or Climate Change]?", with responses ranging from (1) a great deal, (2) a fair amount, (3) only a little, to (4) not at all. This item was asked between 1989-1991, 1997, 1999-2004, and 2006-2021. Similar to other items, we also transform this variable in a binary indicator, where (0) 'only a little/not at all' and (1) 'a fair amount/a great deal'.

Climate change is already happening. Next, we adopt a second measure from the GPSS, *Climate change is already happening*. For this measure, the data ranges from between 1997-2021, where it is asked in 1997 and then every year between 2001-2021. We operationalize beliefs towards when climate change will happen via an item prompting the respondents "which of the following statements reflects your view of when the effects of global warming will begin to happen?" with responses ranging from (1) they have already begun to happen, (2) they will start happening within a few years, (3) they will start happening within your lifetime, (4) they will not happen within your lifetime, but they will affect future generations, and (5) they will never happen. Fitting with other measures, we transform this measure into a binary variable (0) 'not yet begun to happen' to (1) 'already begun to happen'.

Climate change is exaggerated. Lastly, we include a measure of American perceptions towards the seriousness of climate change. This item *Climate change is exaggerated* is operationalized with the statement "In your view is the seriousness of climate change: (1) generally exaggerated, (2) generally correct, or (3) it generally underestimated?". We further transform this item into a binary variable, (0) 'not exaggerated' and (1) 'exaggerated' to identify those hold more climate sceptical beliefs. For this measure, the data again range from between 1997-2021, where it is asked in 1997 and then every year between 2001-2021.

Predictors

Party affiliation. We capture individual *party affiliation* by using the questions related to the party with which the respondent most closely identifies. For the GSS, this question is worded as: "generally speaking, do you usually think of yourself as a Republican, Democrat, Independent, or what?", where seven ordered responses range from 'strong Republican' to 'Independent' to 'strong Democrat'. In order to simplify the analyses, we have collapsed these responses into three party affiliations 1 'Republican' 2 'Independent' 3 'Democrat'. Specifically, 'strong' and 'somewhat' Democrats/Republicans are coded into either Democrat or Republican, respectively. Independent, independent-lean Democrat/Republican are all coded as Independents. While for the Pew data sources, we adopt a similar item for *party affiliation*, "In politics today, do you consider yourself a Republican, Democrat, or independent?". Lastly, within the GPSS, respondents are asked "In politics, as of today, do you consider yourself a Republican, a Democrat, or an Independent?", where we again code those that respond either 'lean Republican'/'Republican' as 'Republican' (similarly for Democrats as well).

We display how the proportion of respondents identifying as 'Republican', 'Independent' and 'Democrat' varies over time for each of the four datasets in Fig. 7.

Control variables. Informed by prior literature, we control for a number of covariates. *Education* is often found to be related to greater environmental concern and likelihood to support environmental collective actions[104,105],– we use a categorical variable for highest obtained educational degree, ranging from 'less than high school degree' to 'college degree'. Gender also plays a role, where women are more likely to be concerned about the environment[78,79,106], and as such, we use a dummy code for *female*. Given the CCREM modelling approach (see below), we include an indicator for age and age[2][59,60]. Lastly, we control for *race/ethnicity* identification, coded as (1) 'white' and (0) 'not white'.

The pooled descriptive statistics for each data source are available in Supplementary Table 2, while the descriptive statistics per year are presented in Supplementary Table 3–7.

Estimation

Our datasets have a complex structure. Individual respondents are nested within their respective survey year, but also with their birth cohort. Accordingly, a fixed-effects approach is inappropriate, as the effects of political polarisation vary by individuals across survey year and birth cohort. To accommodate this structure, we rely upon a hierarchical age period cohort models-based approach, using cross-classified random effect models (CCREM),[59,60]. In our application, individual responses (level-1) are nested within 5-year birth cohort and survey-year periods (level-2). The multi-level mixed random effects analytical approach[107] estimates fixed effects (which are consistent across all individual responses), as well as allowing for random effects to vary across period and cohort. Further, to identify changes in polarisation across time, we estimate a random coefficient for party affiliation within each survey year.

This approach has also been adopted within several recent analyses using historical pooled cross-sectional GSS data to explore environmental attitudes[5,48,49]. Specifically, the CCREM

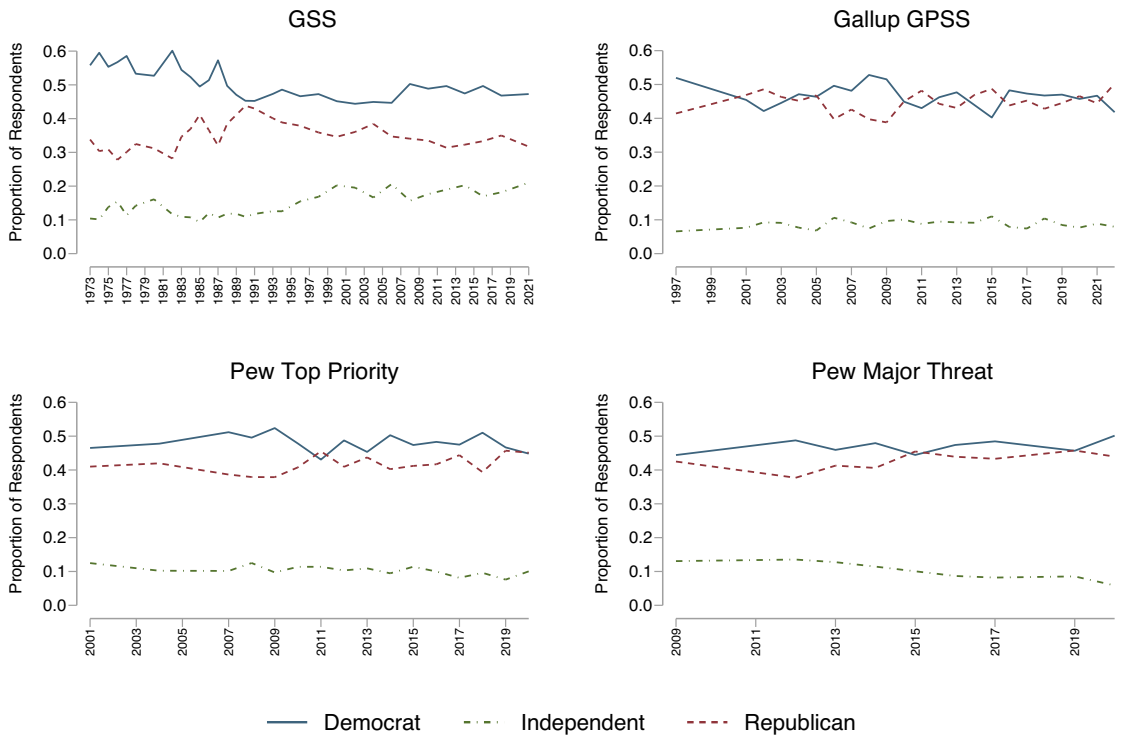

Fig. 7 Party affiliation. The proportion of respondents who identify with the Democratic Party, the Republican Party or as an Independent for each survey wave in the GSS (1973-2018), GPSS (1989-2022), Pew 'Top Priority' (2001-2020) and Pew 'Major Threat' (2009-2020).

approach estimates the equations on two levels: Level one "within wave":

$$\text{Environmental Spending}_{ijk} = \beta_{0jk} + \beta_1 \textit{Party Affiliation}_{ijk} + \beta_2 Age_{ijk} + \sum_{p=31}^{p} \beta_p X_p + e_{ijk} \quad (1)$$

For $(i = 1, 2, \ldots . n_{jk})$ respondents are nested within a five-year interval birth cohort (j) and time period or survey wave (k), where within each cohort and period, the respondent's preference for environmental spending is estimated as a function of party affiliation, age, gender identification, educational attainment, and race/ethnicity. In such a model, the intercept β_{0jk} varies by nesting in the j_{th} cohort and k_{th} period. β_1 and β_2 are the individual-level fixed effects for party affiliation and age and the remaining covariates are represented by β_p and e_{ijk} is the random individual effect (i.e. error term). This individual-level equation can also be generalized to all seven dependent variables included in these analyses.

Level-two "between wave":

$$\beta_{0jk} = \gamma_o + \mu_{0j} + \nu_{0k} \quad (2)$$

In the level-2 portion of the model, the intercept is again represented by β_{0jk} and γ_o is the model intercept (e.g. grand mean for environmental spending preferences across all respondents). As individuals are nested in two components, each of these also has a residual random effect for cohort μ_{0j} and period ν_{0k}. As such, the preference for environmental spending averaged across all cohorts would be $\beta_{0j} = \gamma_0 + \mu_{0j}$, and when averaged across all periods $\beta_{0k} = \gamma_0 + \nu_{0k}$.

As with many emerging methodological approaches, there is great diversity in the empirical literature on the best solution to resolve the identification problem associated with pooled cross-sectional survey data[108–110], namely regarding how each approach resolves the long-standing identification problem of classic age-period-cohort models[111,112]. As we adopt CCREM approaches to correct for demographics effects in the estimation of party affiliation dynamics, our primary focal results are less sensitive to concerns of misattenuation as these are largely relegated to disentangling age, period, and cohort effects, and not those of other modelled covariates.

Still, as a robustness check, we implement several plausible alternatives to this analytical approach, to test for variability in the estimation of the key variables of interest, party affiliation, using *climate change priority* as an example (see Fig. 5). Given the diversity of these approaches, the estimated slopes are not directly comparable. Accordingly, the predicted probabilities of responding that climate change is a priority are plotted for party identification (GOP and Democrat) using each selected alternative estimation technique. Broadly, we find very minimal differences across these models. Accordingly, we adopt the CCREM model, as well as a means to control for time-variant and cohort based effects within pooled cross-sectional data.

Postestimation analyses. Coefficients on a logistic scale are notoriously difficult to interpret. Furthermore, analyses focusing solely on their statistical significance can lead to false conclusions or misinterpretation of results[113]. Motivated by these concerns, we estimate predicted probabilities to aid in intuitive understanding of our results[114,115]. Predicted probabilities were calculated by holding control variables at their mean values and averaging the probabilities of responding to the dependent variable for each level of party affiliation (Republican, Democrat and Independent) nested within each year. All probabilities are estimated for the higher outcome of the dependent variable (e.g. spending is 'too little' for *support for environmental policies* and 'top priority' for *climate change priority*), and is labelled on the y-axis of each figure.

As a robustness check, we also calculate the predicted probabilities for birth cohort (see Fig. 4). These probabilities are separately calculated using the random effects (i.e. intercepts) for cohort, holding other effects at their means.

Adopting a focus on predicted probabilities offers a "best of both worlds" solution in this case, as substantive comparisons can

be made between the estimated effects of partisanship, both within year and over time, while still controlling for the effects of substantial covariates.

All analyses were performed using Stata 16.1.

Reporting summary

Further information on research design is available in the Nature Research Reporting Summary linked to this article.

DATA AVAILABILITY

Cumulative general social survey data is available at https://gss.norc.org/. All individual Pew Research Center datasets are available for download at the Roper Center for Public Opinion. Gallup Poll Social Series (GPSS) survey data is made available by subscription to Gallup Analytics.
Data harmonisation code and analytical replication materials are available on the Harvard Dataverse with the identifier https://doi.org/10.7910/DVN/DWXVIE.

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K.S. and J.B. designed the research. K.S. harmonised the data and analysed the results. All authors co-wrote and revised the manuscript.

COMPETING INTERESTS

The authors declare no competing interests.

ETHICS

The authors declare they have adhered to all ethical regulations. Secondary survey data were exclusively used in these analyses, and therefore this research did not directly involve human subjects.

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