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The effects of climate change and environmental regulation analysing U.S. citizens' typology

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ABSTRACT

This study analyses the relationship between the effects of climate change and environmental regulation for the first time, considering how some individuals' socioeconomic characteristics affect the different types of Americans' perceptions. A panoply of fuzzy set methods, including Fuzzy Hybrid TOPSIS, Fuzzy Clustering and Fuzzy Clustering ECO-Extended Apostle, are applied to a dataset of 10,156 respondents representing the USA. The latent variables are measured by two scales using an answer format based on how likely different effects of climate change and environmental regulation will happen within the next 30 years. The study determines the following respondents' categories: neither convinced of climate change and environmental regulation effects, convinced only of climate change, convinced only of environmental regulation, and convinced of both effects. The results indicate that Americans are more prone to be more convinced of both (73.8 %) than only environmental regulation effects (13.6 %), climate change effects (10.1 %) or none (2.5 %). Some socioeconomic, demographic, and other segmentation variables will be studied to analyse their impact on Americans' categorisation. The segmentation variables are mainly based on environmental attitudes, societal and political views, and political ideology. The implications and limitations of our results will be further discussed.

1. Introduction

In the past two decades, global warming, climate change (CC), and environmental regulations (ERs) have been subjects of extensive media coverage. In this context, our study's findings are of utmost importance. Adelle et al. (2018) identify ways to mitigate the impact of climate change while fostering economic growth and individual well-being, a crucial task to support the efforts of the world's most developed countries. Environmental regulations have raised concerns and criticisms among citizens, notably religious Americans. The Pew Research Center (2022) has reported that many religious Americans are apprehensive "about the potential consequences of environmental regulations, such as a loss of individual freedoms, fewer jobs, or higher energy prices (p.7)".

The issue of climate change gained significant attention since the Intergovernmental Panel on Climate Change (IPCC) and the United Nations Framework Convention on Climate Change were established in 1988 and 1992, respectively. These institutions are responsible for establishing a global framework for cooperation to address climate change and to guide policymakers. They are also responsible for leading various climate treaties, conferences and summits, such as the Kyoto Protocol 1997 and the Paris Agreement 2015. The last conference was held in Dubai, the United Arab Emirates, and joined around some 85,000 participants, including more than 150 Heads of State and Government. It marked momentum for the first 'global stocktake' of the world's efforts to address climate change under the Paris Agreement (COP28, 2024).

Pew Research Center (2022) conducted a survey that explored to what extent Americans' religious beliefs affect their position on different societal features, such as climate change effects (CCE) and environmental regulation effects (ERE). The survey was administered to 10,156 U.S. adults who form part of a representative American panel from April 11–17, 2022. The microdata of the survey is employed in the current study to analyse these two latent variables and their relationship to find four citizens' categories that range from unconvinced with both LVs to convinced with both LVs.

To analyse the categorisation effects, we include the following sixteen variables divided into five dimensions: (1) environmental attitudes (perception of climate change (earth getting warmer), personal attitude towards energy conservation, moral acceptability of energy-

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intensive food production, moral acceptability of low gas mileage vehicles, and relationship between humans and other living things); (2) societal and political views (agreement with potential unnecessary environmental regulations; belief in humanity's ability to slow climate change); (3) demographics (age, gender); (4) socioeconomic variables (education level, ethnic group affiliation, religion, and income level); and (5) political ideology.

This study aims to fill a fundamental gap, analysing U.S. citizens' combined attitudes towards climate change effects (CCE) and environmental regulation (ERE), using a novel methodological approach that reflects the uncertainty and complexity of public understanding, such as Fuzzy-Hybrid TOPSIS and Fuzzy Clustering ECO-Extended Apostle Model (Indelicato & Martín, 2022). To this end, the following paper has four specific aims.

1. To measure U.S. citizens' CCE and ERE using a fuzzy hybrid TOPSIS technique.
2. To classify respondents into four main categories (convinced of none, more convinced of CCE than ERE, more convinced of ERE than CCE, and convinced of both) using a Classic Apostle Model.
3. To refine this classification, a fuzzy cluster ECO-Extended Apostle model will be applied, allowing for a more precise segmentation of U.S. citizens' attitudes toward CCE and ERE.
4. To examine the influence of 16 socio-demographic, ideological and attitudinal environmental variables on the likelihood of belonging to each of the four groups.

The remainder of the paper is organised as follows: Section 2 offers some insights from the literature, Section 3 describes the data and the methodology, Sections 4 and 5 present and discuss the results, and Section 6 offers some concluding remarks.

2. Literature review

2.1. Framing climate and regulation attitudes: the role of norms, cognition, and political identity

Understanding the diversity of attitudes towards climate change and environmental regulations benefits from grounding the analysis in established theoretical frameworks in environmental psychology and political sociology. First, the Value-Belief-Norm (VBN) theory describes how values shape environmental beliefs, influencing personal norms and behaviours towards pro-environmental actions (Han, 2021). Recent studies show that environmental knowledge as a primary external factor influences the VBN structure (Jansson et al., 2011; Liobikienė & Poškus, 2019). Increased environmental knowledge builds an ecological worldview and activates private and public environmental actions. These findings suggest that efforts to make people ecologically aware are more likely to instil sustainable behaviour, leading to climate change mitigation and acceptance of green legislation. Liobikienė and Poškus (2019) take the VBN theory further by using social norms to predict pro-environmental behaviour. Their study explains how cultural environments are involved, suggesting that different ethnic groups behave differently towards green legislation and messages. For example, according to the study, social norms are most likely to evoke Pro-Environmental behaviours among multicultural masses, requiring culturally specific approaches to environmental education and advertising.

Also, the relationship between cultural cognition and political ideology significantly impacts public attitudes and responses to climate change and environmental regulation. Cultural cognition provides an important theoretical framework for considering the political polarisation of climate change beliefs. There is evidence that individuals' assessments of the risks of climate change are not necessarily based on science but are strongly linked to their cultural and political values (Kahan et al., 2011). For example, McCright and Dunlap (2011) found in a study that Democrats and liberals are more likely to believe in the scientific consensus on climate change, while Republicans and conservatives are more doubtful. These polarisations have significant implications for climate policy. Research shows that communication frames must be reshaped to bridge these ideological divides and build a greater consensus for climate action (McCright et al., 2016). In this context, Gromet et al. (2013) found that conservatives oppose energy-saving technologies when they are framed as environmentalists and, therefore, need to be framed differently in a way that resonates with conservative interests.

Individual experiences of climatic events significantly influence beliefs about climate change. Lujala et al. (2015) illustrate how immediate experiences of climatic impacts either validate or invalidate political beliefs, suggesting that risk perception is not a fixed but a fluid concept and varies with individual experiences. Similarly, the most recent factors influencing perceptions of climate change again highlight the role of psychological distance and personal experience in shaping public beliefs. (Weber, 2016).

As in Hamilton and Stampone (2013), citizens' political ideology also influences the level of trust they place in environmental organisations and scientists in ways that make climate science acceptance complex. The anti-reflexivity thesis also describes how conservatives selectively trust scientific research that supports their ideological position and reject that which indicates negative environmental impacts (You et al., 2019). Fielding et al. (2012) propose a two-channel approach to science communication that integrates scientifically accurate information with culturally appropriate messages to address these challenges. This approach aims to reverse polarisation and increase public concern about climate threats, building more significant support for environmental policies.

2.2. Intersections of climate change perceptions and environmental regulation responses

Climate change effects or climate emergency is mainly caused by the existing interdependence of climate with ecosystems, biodiversity, and human societies (IPCC, 2023). National Academies of Sciences, Engineering, and Medicine (2021) recognised that climate change already affects many communities and that the impacts and challenges will spread worldwide shortly. Carbon dioxide contributes to climate change and presents significant environmental damage (Wang et al., 2024; Wei et al., 2024).

However, the lack of consensus regarding the action plan seems evident in two dimensions: territory or space and time horizon. The climate adaptation or environmental regulation action plan must be strategically developed considering data needs, knowledge formation and understanding. In addition, Khan et al. (2023) contended that geopolitical risks highly affect environmental regulation, undermining or postponing the implementation of adequate environmental regulation that mitigates the effects of climate change.

Climate change is the leading cause of the recurrence of extreme weather events such as floods, forest fires, droughts and tornadoes (Phung et al., 2015). Extreme weather events also affect the number of migrants and provoke many people's displacement from insecure environmental places to more stable locations (Rigaud et al., 2018), and the trend will be more persistent in the following years, affecting mainly three regions, Sub-Saharan Africa, South Asia, and Latin America. Environmental regulatory measures are necessary to address this issue.

According to the National Academies of Sciences, Engineering, and Medicine (2023), environmental regulation to mitigate climate change should concentrate first on efforts to decarbonise electric power and eliminate fossil-fuel combustion sources, particularly emphasising the transport and heating industry. Lee (2022) contended that electricity prices would likely increase in the short term as the new technology is relatively more expensive than traditional sources. Additional cost inefficiencies are based on the intermittency of the latest generation

sources like sun and wind, and that the electricity cannot be stored very quickly, and storage facilities are still expensive and inefficient (Panda et al., 2023; Pracheil et al., 2022).

In addition to the increase in electric prices, ERE can also affect the perception of human freedom. As in other areas of personal choice, it is usually tricky to find a proper balance between our actions and their environmental effects. Questions about whether humans are ready to fly or use their private combustion car less remain unanswered. There are many examples in which ER restricts our choices. For example, land use restrictions or access permissions are usually in effect to protect endangered species or sensitive ecosystems (Baloch et al., 2023; Weiskopf et al., 2020). The ideological position also affects how EREs are perceived. Some people may prefer making their own environmental decisions rather than having them mandated by the government (de la Porte & Jensen, 2021; Spadaro, 2020).

EREs also pose difficulties to some incumbent and well-established industries, such as aviation, oil, and car, which are experiencing similar turbulences seen before by the coal industry. EREs usually cause a decline in critical activity and job losses in the affected sectors worldwide (Brauers & Oei, 2020; Kalt, 2021). In academic terms, it is easy to mention short-run adjustment costs or the rigidity of labour mobility. However, workers have their lives in their hometowns, have specific skills, and experience massive anxiety if they need to find a job in a different city and industry. It is not simply a job loss, as it affects their mental health and subjective well-being (Fullerton & Muehlegger, 2019).

Despite these concerns, in the long run, ER is essential to limit harmful emissions that could mitigate the climate emergency. Worldwide, governments are introducing climate campaigns, educating and encouraging citizens to take mitigation actions that could stop or reduce the destructive and apparent existing impacts (Pickering & Dale, 2023). Besides these campaigns, it is still striking that many citizens still believe that CC is not critical or essential and are reluctant to take actions that mitigate CC's impact. In this respect, it is crucial to analyse what factors might influence whether citizens are ready to take mitigation actions or support ER to reduce the effects of CC.

The EREs vary considerably throughout different industries. We have already analysed how their effects on some sectors, like coal or oil, produce short-term losses in terms of job destruction or market value falls. However, in other industries, ER also fosters economic growth and innovation. For example, Adelle et al. (2018) contended that the new EU green deal could be an opportunity to invest in green infrastructure and job creation, guaranteeing economic growth under a low-carbon economy. Policy packages and roadmaps were envisaged as masterpieces to achieve smart, sustainable and inclusive growth. Similarly, Khurshid et al. (2024a) also contended that ER could incentivise producers to adopt greener technologies, fostering innovation processes. The authors examined how ER might impact green innovation in twenty-five European countries.

Shahzad (2020) analysed the relationship between ER, energy consumption and environmental quality, focusing on three distinct classifications: (i) environmental taxes, energy consumption, and energy efficiency; (ii) environmental taxes and environmental quality; (iii) energy consumption (renewables, non-renewable, and fossil fuels) and environment deterioration. The author concluded that ER in the form of taxes does not provide enough clear evidence, so a more in-depth investigation is needed. Nevertheless, in general, environmental taxes are designed to reduce greenhouse gas emissions by discouraging the use of fossil fuels. They do this by taxing activities that contribute to environmental damage.

ER is usually needed to control the severe environmental externalities that, unfortunately, are not internalised by the market forces. Nevertheless, the local environmental problems are not evenly spatially distributed as some communities bear the most significant burden. ER measures should address multidisciplinary complex issues of global relevance (National Academies of Sciences, Engineering, and Medicine, 2022). Cheng et al. (2017) and Yu and Wang (2021) classified ER measures into four different categories: (1) command and control or administrative supervision; (2) market or economic incentives (Pigouvian taxes); (3) public participation or public legislation; and (4) voluntary action.

De Pryck (2023) claimed that command and control measures are needed because voluntary action based on informing or educating society is not enough. Abbass et al. (2022) also realised that CC concerns are a multifaceted issue with different prisms and layers, such as a lack of environmental education and knowledge, unsustainable consumer behaviour and lifestyle, a lack of incentives for environmental regulation and legislation, and insufficient governmental commitment to developing an honest international climate change policy that can help mitigate the real threat of climate change. Duan et al. (2024) studied how Industry 4.0 technologies can help the automotive manufacturing industry in China to minimise the adverse production impact on the environment and society, finding that "augmented virtual reality appears to have broad applicability when considering the social sustainability of products, and big data has the highest application rate for producing sustainable goods when both environmental and economic factors are considered, whereas cloud applications have the lowest relevance (p.8)".

Kurshid et al. (2024b) analysed the relationship among energy access, green technology adoption, institutional quality, and environmental sustainability in 26 African nations from 2001 to 2021. Environmental sustainability is proxied by using clean fuels and technologies for energy provision at the household level. The authors contributed significantly to the literature "by analysing how household energy access, green technology adoption, and institutional factors affect ecological sustainability, GHG and CO2 mitigation, and clean fuel technology adoption in Africa (p. 89)", recommending that policymakers prioritise more green energy access through fostering research and innovation.

3. Data and methods

3.1. Survey and respondents

A recent survey conducted by the Pew Research Center aimed to investigate the correlation between Americans' religious beliefs and their views on climate change and the environment. The survey was conducted from April 11 to April 17, 2022, and included a sample of 10,156 adults aged 18 years and older from across the United States, including Alaska and Hawaii. The participants were selected randomly through a national residential address sampling and were part of the American Trends Panel (ATP), an online survey panel. The interviews were conducted in English and Spanish, and the Pew Research Centre developed the questionnaire in consultation with Ipsos. The margin of sampling error for the total sample is plus or minus 1.6 percentage points. To encourage participation, all respondents received an incentive of $5 to $20 based on their traditional response propensities. For further data collection information, refer to the study's technical report (Pew Research Center, 2022).

3.2. Variables

The survey included four questions that can be used to measure the climate change latent variable. These questions were included in the CLMWRRY variable, and respondents were asked to rate their likelihood of occurrence within the next 30 years due to global climate change. The four questions correspond to the following items (Pew Research Center, 2022): (1) Lower quality of life; (2) More extreme weather events such as tornadoes, flooding, and droughts; (3) An increase in refugees and displaced people; and (4) Food and water shortages.

The survey included three questions that will be used to measure the latent variable ERE. These three questions were included in a variable

called GOVWRRY. Respondents were asked to rate the likelihood of the following events happening within the next 30 years due to environmental regulations (Pew Research Center, 2022): (1) Much higher prices for fuel and electricity; (2) Gradual loss of individual freedoms; and (3) Fewer jobs and declining pay in industries that depend on fossil fuels.

All the items were randomly assigned to prevent biased responses. Each item had a full 5-point semantic scale according to: 1 Extremely likely, 2 Very likely, 3 Somewhat likely, 4 Not too likely, and 5 Not at all likely. The answers were reverse-coded to ensure that higher figures indicated a response more aligned with the most likely events.

The analysis includes sixteen variables related to socioeconomic, demographic, and segmentation. These variables consist of personal perception of life in ten years, attitude towards energy conservation, energy saving personal position, the relationship between humans and other living things, moral acceptability of eating food that requires a lot of production energy or driving a car that gets low gas mileage, level of agreement with the assertion that the United States will create many unnecessary environmental regulations, belief in human's ability to slow the pace of climate change, age, gender, education, ethnicity, religion, income, and ideology.

We have included as segmentation variables to analyse environmental attitudes (perception of climate change (earth getting warmer), personal attitude towards energy conservation, moral acceptability of energy-intensive food production, moral acceptability of low gas mileage vehicles, and relationship between humans and other living things); (2) societal and political views (agreement with potential unnecessary environmental regulations; belief in humanity's ability to slow climate change); (3) demographics (age, gender); (4) socioeconomic variables (education level, ethnic group affiliation, religion, and income level); and (5) political ideology.

We decided to include segmentation variables proxying environmental attitudes, societal and political views, and belief in the human ability to slow climate change when studying the relationship between CCE and ERE for the following reasons: (1) ERE public support can be better understood; (2) policy effectiveness can be predicted with more information; (3) communication strategies can be better tailored; and (4) key drivers beyond basic demographics, socioeconomic and political ideology can be identified.

People with solid pro-environmental views are more likely to support stricter regulations. Analysing these attitudes helps researchers understand the public's receptiveness to environmental regulations. Societal and political values can influence how people perceive climate change and the need for regulation. For that, the analysis helps identify potential roadblocks or areas of solid support for specific policies. Americans who believe humans can slow climate change are more likely to support regulations and potentially comply with them. Studying this belief can assist in forecasting the effectiveness of regulations, depending on the trust the public holds in them.

By segmenting the population based on these variables, researchers can identify groups with specific beliefs and tailor communication strategies to better resonate with them for building public support and promoting policy change. The variables can act as proxies for underlying factors like ecological risks still in human hands or God's will. The analysis of how these segments differ in positioning CCE and ERE can shed light on why some people are more or less accepting than others. Segmenting the population based on these variables provides a more nuanced picture of the relationship between climate change and environmental regulation. It helps researchers understand the public's views, predict policy effectiveness, and develop targeted communication strategies for promoting environmental action beyond other more classical variables previously studied.

3.3. Methods

The extensive literature on the Fuzzy Hybrid TOPSIS method calculates synthetic indicators that capture latent variables. For the sake of brevity, we will not delve into the specifics of the underlying mechanisms, such as triangular fuzzy numbers (TFNs) (Martín, Moreira, & Román, 2020; Saayman et al., 2016), their membership functions (Cantillo et al., 2020; Martín & Indelicato, 2023), the algebra used to manipulate TFNs (Buckley, 1985; Sharma & Kumar, 2023), the defuzzification method used to convert fuzzy values to crisp values (Kumar, 2017; Martín & Indelicato, 2023), the concept of ideal solutions in the fuzzy context (D'Urso et al., 2016; Martín et al., 2019) or the specific calculus used to arrive at the synthetic indicators (Cantillo et al., 2020; Hwang & Yoon, 1981; Zeleny, 1982). The conversion of the semantic scale into TFNs follows Leon and Martín (2020) as in Table 1.

While latent variable modelling often uses other statistical techniques such as latent class analysis (LCA) or structural equation modelling (SEM), this study uses fuzzy set methods because of their inherent ability to deal with always present ambiguity using surveys. In contrast to LCA, which restricts individuals to mutually exclusive groups, fuzzy clustering allows for overlapping memberships and thus the real-world complexity in which individuals can simultaneously hold contradictory or ambiguous opinions. Similarly, while SEM is perfect for testing theory-driven causal relationships between latent constructs, it is based on linearity and precise variable measurement, which is not necessarily required for the probabilistic and vague nature of the survey data used here (Indelicato & Martín, 2022). Additionally, fuzzy logic facilitates the estimation of synthetic indicators from linguistic opinions using membership functions and can withstand intense segmentation by distance-based clustering without insisting on rigorous parametric assumptions (Biasetton et al., 2023; D'Urso, 2007; Lin & Yeh, 2013; Zadeh; 1965, 1975).

3.3.1. Fuzzy clustering

We provide more details on the fuzzy clustering method, assuming the three-cluster solution that D'Urso et al. (2016) considered. Three representative respondent profiles are obtained for each LV: (1) extremely convinced, extremely unconvinced, and intermediate convinced respondents. Respondent profiles are selected based on the synthetic indicators' maximum, minimum, and median obtained through a fuzzy hybrid approach.

A three-component vector is obtained for each respondent, representing to what extent the sample's individuals are more or less similar to the representative profile of each cluster. The hybrid fuzzy cluster algorithm is presented in equation (1). The method extends the Bagged Cluster algorithm (Leisch, 1999) for fuzzy data, as follows (Martín, Román, et al., 2020):

$$min: \sum_{i=1}^{n}\sum_{c=1}^{C} u_{ic}^{m} d_F^2(\widetilde{x}_i, \widetilde{p}_c) = \sum_{i=1}^{n} \times \sum_{c=1}^{C} u_{ic}^{m}\left[w_2^2 \left\|a_2^i - p_2^c\right\|^2 + w_1^2\left(\left\|a_1^i - p_1^c\right\|^2 + \left\|a_3^i - p_3^c\right\|^2\right)\right] \quad (1)$$

$$s.t. \quad m > 1, u_{ic} \geq 0. \sum_{c=1}^{C} u_{ic} = 1$$
$$w_1 \geq w_2 \geq 0. w_1 + w_2 = 1$$

Table 1
Conversion of likert-point scale into triangular fuzzy numbers (TFNs).

Likert Response	Triangular Fuzzy Number (TFN)
Not at all likely	(0, 0, 30)
Not too likely	(20, 30, 40)
Somewhat likely	(30, 50, 70)
Very likely	(60, 70, 80)
Extremely likely	(70, 100, 100)

Note: These TFNs were used to fuzzify the ordinal response data and compute individual and segment-level synthetic indicators for the latent variables (CCE and ERE). Segment-level aggregation was performed for 377 population subgroups based on 79 segmentation variables.

Where, $d_F^2(\widetilde{x}_i, \widetilde{p}_c)$ represents the squared fuzzy distance between the *ith* respondent and the representative profile of the *cth* cluster; the $\widetilde{x}_i \equiv \{\widetilde{x}_{ik} = (a_{1ik}, a_{2ik}, a_{3ik}) : k = 1 \ldots K\}$ denotes the TFN vector for the *ith* respondent obtained from each individual observation for the latent variables analysed in the study, 4 and 3 in our case; $\widetilde{p}_c \equiv \{\widetilde{p}_{ck} = (p_{1ck}, p_{2ck}, p_{3ck}) : k = 1 \ldots K\}$ represents the fuzzy profile of the *cth* cluster; $\left\|a_2^i - p_2^c\right\|^2$ is the squared Euclidian distances between the centres of the TFN vectors of the *ith* respondent and the representative profile of the *cth* cluster; $\left\|a_1^i - p_1^c\right\|^2$ and $\left\|a_3^i - p_3^c\right\|^2$ are the squared Euclidian distances between the left and right extreme components of the TFN vectors of the *ith* respondent and the representative profile of the *cth* cluster, respectively; $w_1 \geq w_2 \geq 0$ are suitable weights for the center and extreme components for the fuzzy distance considered; $m > 1$ is a weighted exponent that controls the fuzziness of the obtained partition, directly increasing with m (m equals 1.5, as in D'Urso et al. (2016); u_{ic} is a vector that provides the similarity degree of the *ith* respondent in each cluster *c*. Interested readers can deep more on how to select the best number of clusters and the best representative cluster profiles in D'Urso et al. (2013, 2015, 2016). The fuzzy clustering method segments individuals into homogeneous clusters by calculating their membership degree in each cluster (Coppi et al., 2012; Kruse et al., 2007). In the current study, the 3-cluster solutions are named extremely convinced, extremely unconvinced, and intermediates.

3.3.2. The fuzzy clustering eco-extended apostle model

Jones and Sasser (2009) introduced the apostle model to analyse the relationship between loyalty and satisfaction to improve the survival of organisations. We will follow the same approach as Schaefer (2013), Martín et al. (2023) and Christidis et al. (2024) to transfer the analysis of satisfaction and loyalty latent variables to any pair of latent variables that could be of interest to researchers. Thus, the classical four quadrants, originally named defectors, mercenaries, hostages and apostles, are adequately renamed in the current study as: (1) None (being unconvinced of CCE and ERE) - defectors; (2) Climate (convinced of CCE and unconvinced of ERE) - mercenaries; (3) Environment (unconvinced of CCE and convinced of ERE) - hostages; and (4) Both (being convinced of both CCE and ERE) – apostles.

Indelicato and Martín (2022) explain that one limitation of the classical apostle method is its inability to accurately distinguish citizens whose responses fall close to both average LV values. Ideal quadrant distinction is impossible due to low distances between observed data points. The authors propose the fuzzy-clustering ECO extended apostle model to reduce blurriness surrounding average values, choosing an alpha value (equal to 0.5) to find these "pure" categories of the four quadrants defined in the Classical Apostle Model.

Thus, consider two vectors, θ_{CCE} and δ_{ERE} representing the two vectors containing the membership of each individual to the three clusters respectively of the CCE and ERE, and following these functions for each vector θ_{CCE} and δ_{ERE}:

$$f(\theta_{CCE}) = \begin{cases} 1 \; if \theta_{CCE2} > \alpha \\ 3 \; if \theta_{CCE3} > \alpha \\ 4 \; if \theta_{CCE1} > \alpha \\ 2 \; otherwise \end{cases} \tag{2a}$$

$$f(\delta_{ERE}) = \begin{cases} 1 \; if \delta_{ERE2} > \alpha \\ 3 \; if \delta_{ERE3} > \alpha \\ 4 \; if \delta_{ERE1} > \alpha \\ 2 \; otherwise \end{cases} \tag{2b}$$

By combining these functions, the extended model introduces 16 possible clusters, expanding upon the original Classic Apostle Model, where now the "Pure None" are characterized by the pair $f^* = (f(\varepsilon), f(\delta)) = (1,1)$. Similarly, the "Pure Both" are clustered by $f^* = (4,4)$, $f^* = (4,4)$ for the "Pure Climate", and $f^* = (1,4)$ for the "Pure Environment".

3.3.3. Relative conditional probability ratios

The methodology section concludes by presenting an approach using relative conditional probability ratios. The independence of two events could be empirically tested by estimating the confidence intervals of these ratios to see if, for example, environmental attitudes or personal attitudes towards energy conservation, societal and political views on environmental regulation or the belief in humanity's ability to slow climate change, age, gender, political ideology or other socioeconomic variables have a positive (driver) or negative (barrier) effect on the probability of belonging to each of the quadrants mentioned above.

Two events, A and B, are independent if and only if the outcome of one event does not provide any new information about the likelihood of the other event. Mathematically, the definition is based on:

$$P(A \cap B) = P(A)P(B) \Leftrightarrow P(A/B) = P(A) \Leftrightarrow P(B/A) = P(B) \tag{3}$$

Thus, for each quadrant category and covariate of interest, it is possible to calculate the conditional probability ratios as follows:

$$R_{AB} = \frac{P(A \cap B)}{P(A)P(B)} \tag{4}$$

Where A and B denote a category and a covariate, respectively. For example, A can denote to be in the both quadrant and B can be whether citizens think energy conservation is a serious problem. A and B are not independent and positively or negatively associated if the ratio is significantly greater or lower than one. The ratios in Equation (4) are calculated based on 1000 bootstrap subsamples taken with replacement Bootstrap is a valuable statistical tool used for statistical inference. The method skips the assumptions to get the answers, being a powerful statistical technique that provides accurate estimates of standard errors, confidence intervals, and hypothesis tests without relying on complex assumptions about the underlying population (Davison et al., 2003). This makes it ideal for situations where traditional methods might be unreliable. By mimicking the sampling process from the data itself, bootstrapping lets researchers directly estimate the sampling distribution of a statistic, providing a robust assessment of its accuracy (Hesterberg, 2011).

4. Results

Table 2 shows the basic descriptive statistics of the sixteen socioeconomic, demographic, and segmentation selected variables used in the study. It can be seen that almost one-fourth of the sample considered that life would be worse in ten years. More than half per cent of the sample considered that the earth is getting warmer because of human activity. About twelve per cent considered energy conservation not a serious or too serious problem. Fifty-seven per cent saved energy to save money and protect the environment. The sample is almost equally distributed among those who consider that humans are (not) more important than all other living things, with a slight tendency to consider other living things as important as human beings. Three-quarters of the sample considered eating food that requires much energy and driving cars with low gas mileage as not moral issues. Forty per cent of the sample considered that the USA will create many unnecessary environmental regulations extremely or very likely. Almost sixty-six per cent of the sample considered that humans can only slow the pace of climate change by making difficult or smart choices. Interestingly, this is one of the questions with more missing values, as twenty-one per cent of the sample did not answer it by acknowledging they did not know. The demographic makeup of the United States indicates a growing older population, with a majority (59 %) of individuals in the sample being over 50. Furthermore, the sample consists of 54 % females. The religious landscape of the U.S. is dominated by Protestantism, with 42 % of the population identifying with this faith, followed by Roman Catholicism at 21 %. The agnostic and atheist segments comprise more than 11 % of the sample. The education level in the USA is significantly high, with nearly

Table 2
Descriptive statistics of the socioeconomic, demographic and segmentation variables[a].

Variable	Category	N	Percentage*
Life in ten years	Better	4259	41.94
	Worse	2380	23.43
	About the same	3484	34.30
The earth is getting warmer	Human activity	5377	52.94
	Natural patterns	2679	26.38
	No solid evidence	968	9.53
	Not sure	1095	10.78
Energy conservation	EC is an extremely serious problem	1792	17.64
	EC is a serious problem	3329	32.78
	EC is a somewhat serious problem	3734	36.77
	EC is not too serious a problem	1018	10.02
	EC is not a problem	266	2.62
Energy saving	To save money	2295	22.60
	To protect the environment	623	6.13
	To save money and protect the environment	5839	57.49
	I do not save energy	1301	12.81
Humans and other living things	Humans are more important	4557	44.87
	Humans are not more important	5502	54.17
Eating food that requires a lot of production energy	Morally acceptable	1060	10.44
	Morally wrong	1196	11.78
	Not a moral issue	7781	76.61
Driving a car that gets low gas mileage	Morally acceptable	1259	12.40
	Morally wrong	969	9.54
	Not a moral issue	7842	77.22
The United States will create many unnecessary environmental regulations.	Extremely likely	2170	21.37
	Very likely	1897	18.68
	Somewhat likely	2159	21.26
	Not too likely	2559	25.20
	Not at all likely	1261	12.42
Humans can slow the pace of climate change.	Making difficult changes	3056	30.09
	Making smart choices	3647	35.91
	No, they cannot slow the pace of CC	1304	12.84
Age	Age. 18-29	886	8.72
	Age. 30-49	3225	31.75
	Age. 50-64	2950	29.05
	Age. 65+	3052	30.05
Gender	Male	4532	44.62
	Female	5541	54.56
	Another gender	59	0.58
Education	Less than high school	310	3.05
	Highschool graduate	1445	14.23
	Some college, no degree	2143	21.10
	Associate's degree	1114	10.97
	College graduate/ some post-grad	2779	27.36
	Postgraduate	2336	23.00
Ethnic group	White-Non Hispanic	7108	69.99
	Black-Non Hispanic	795	7.83
	Hispanic	1411	13.89
	Other ethnic	330	3.25
	Asian non-Hispanic	365	3.59
Religion	Protestant	4261	41.96
	Roman Catholic	2173	21.40
	Mormon (Church of Jesus Christ	198	1.95
	Orthodox	54	0.53
	Jewish	203	2.00
	Muslim	60	0.59
	Buddhist	68	0.67
	Hindu	50	0.49
	Atheist	573	5.64
	Agnostic	602	5.93
	Other religion	246	2.42
	Religion. Nothing in particular	1612	15.87
Income	Less than $30,000	1613	15.88
	$30,000 to less than $40,000	932	9.18
	$40,000 to less than $50,000	836	8.23
	$50,000 to less than $60,000	862	8.49
	$60,000 to less than $70,000	699	6.88
	$70,000 to less than $80,000	732	7.21
	$80,000 to less than $90,000	540	5.32
	$90,000 to less than $100,000	641	6.31
	$100,000 or more	2843	27.99
Ideology	Very conservative	1011	9.95
	Conservative	2748	27.06
	Moderate	3648	35.92
	Liberal	1764	17.37
	Very liberal	819	8.06

[a] The table was obtained from PEW Research Center (2022). *Some categories do not add 100 because some values are missing.

half the population having completed some form of college or post-graduate studies. Regarding the ethnic breakdown, 70 % of the population identifies as White non-Hispanic, followed by 14 % Hispanic. The income distribution is characterised by being more represented by the two extremes: less than $30,000 (15.9 %) and $100,000 or more (28 %). Moreover, the most representative ideologies are Moderate (36 %) and Conservative (27 %).

Table 3 shows the TFNs and defuzzified values corresponding to both latent variables CCE and ERE for the total sample of respondents. The values examination makes it evident that all the TFNs overlap. It is not surprising at all, as the majority of the items were specifically chosen to represent the underlying latent variables, CCE and ERE, being studied, clearly indicating a strong correlation between them. The analysis of the crisp defuzzified values shows that respondents perceived as more likely events that the environmental regulation effects will provoke much higher prices for fuel and electricity, and the least likely event is also in ERE for the gradual loss of individual freedom.

In Table 4, the ideal solutions for both latent variables are displayed, along with the percentage variation between them. The items included in the CCE, except the gradual loss of freedom included in ERE, have a

Table 3
TFNs and defuzzified values of CCE and ERE of the sample.

LV	Item	TFN	Crisp
CCE	Lower quality of life	(41.65, 58.10, 70.49)	57.08
	More extreme weather events	(49.50, 68.44, 77.94)	66.08
	An increase in refugees and displaced people	(47.87, 65.72, 76.13)	63.86
	Food and water shortages	(45.79, 63.14, 74.20)	61.57
ERE	Much higher prices for fuel and electricity	(55.18, 75.38, 83.36)	72.33
	Gradual loss of individual freedom	(40.74, 57.23, 69.27)	56.12
	Fewer jobs and declining pay in industries that depend on fossil fuels	(49.58, 68.04, 78.44)	66.03

LV: Latent variable. CCE: Climate Change Effects. ERE: Environmental Regulation Effects.

Table 4
Fuzzy hybrid TOPSIS ideal solutions.

LV	Item	A^+	A^-	Perc. Var.
CCE	Lower quality of life	77.83	38.01	104.8
	More extreme weather events, such as tornadoes, flooding and droughts	85.42	30.72	178.1
	An increase in refugees and displaced people	82.34	38.73	112.6
	Food and water shortages	81.73	36.08	126.5
ERE	Much higher prices for fuel and electricity	86.00	59.68	44.1
	Gradual loss of individual freedom	81.00	34.34	135.9
	Fewer jobs and declining pay in industries that depend on fossil fuels	77.54	55.11	40.7

LV: Latent variable. CCE: Climate Change Effects. ERE: Environmental Regulation Effects.

higher variation. This suggests a higher societal polarisation and a likelihood of events associated with the CCE.

The fuzzy hybrid TOPSIS method was used to identify three representative profiles for each cluster in both LVs. The convinced representative respondent rated all items in each LV with a 5, the unconvinced representative respondent rated all items with a 1, and the intermediate respondent provided values between 3 and 4, except for the third item in CCE, "an increase in refugees and displaced people" (Table 5).

Fig. 1 displays the ternary plot for the entire sample for both LVs – Climate Change Effects (Fig. 1a) and Environmental Regulation Effects (Fig. 1b). The ternary plots visually represent the distribution of respondents based on the membership function obtained using the fuzzy clustering method. Upon analysis of the graph, it is evident that there is significantly more heterogeneity in the group of respondents who are more similar to the intermediate profile compared to the other two clusters for both LVs.

The average probability of belonging to each cluster indicates that the "positive," "negative," and "intermediate" clusters are represented by 35.4 %, 16.4 %, and 48.1 %, respectively, for CCE and by 30.8 %, 7.5 %, and 61.7 %, respectively, for ERE. This suggests that most citizens agree that CCE and ERE will likely trigger all the items included in the scales.

4.1. The classical vs. the fuzzy clustering ECO extended apostle model

As discussed above, only a minority of Americans report being unconvinced about CCE and ERE, with a small proportion of less than eight per cent in the case of the likelihood of events caused by ERE. The subjacent hypothesis that can be assessed is whether (un)convinced CCE citizens are also (un)convinced ERE citizens. The models will also permit the analysis of those Americans who are CCE convinced but ERE unconvinced, and vice versa: they are CCE unconvinced but ERE convinced.

Table 5
Fuzzy clustering profiles.

LV	Item	Positive	Negative	Intermediate
CCE	Lower quality of life	5	1	3
	More extreme weather events, such as tornadoes, flooding and droughts	5	1	4
	An increase in refugees and displaced people	5	1	5
	Food and water shortages	5	1	3
ERE	Much higher prices for fuel and electricity	5	1	4
	Gradual loss of individual freedom	5	1	3
	Fewer jobs and declining pay in industries that depend on fossil fuels	5	1	4

LV: Latent variable. CCE: Climate Change Effects. ERE: Environmental Regulation Effects.

After applying the classical Apostle model using the fuzzy TOPSIS hybrid method, we have determined that there exists almost an equal distribution between the four quadrants: none or CCE and ERE unconvinced (28.3 %); CCE convinced, and ERE unconvinced (28.4 %), CCE unconvinced and ERE convinced (19.9 %); and both CCE and ERE convinced (23.4 %). As discussed in the methodological section, the results are mainly caused by using the average figures of the method. Nevertheless, results will change dramatically when the fuzzy clustering ECO extended apostle model is applied.

After applying the new method, the most represented group is now the quadrant convinced by both CCE and ERE (73.8 %), followed by the environmental group (13.6 %), the climate group (10.1 %) and the unconvinced about both LV effects (2.5 %). More than sixty per cent of the sample changed the category when the ECO extended apostle model was applied. Using the correspondence function, it can be seen that a large group of Americans classified by the classical apostle model as only climate change-convinced citizens (25.2 %) are now better classified by the ECO extended apostle model as being convinced by both LVs. Regarding the pure categories, the ECO extended model shows that the most represented group is the purely convinced citizen by both effects, with 9.2 per cent of the sample.

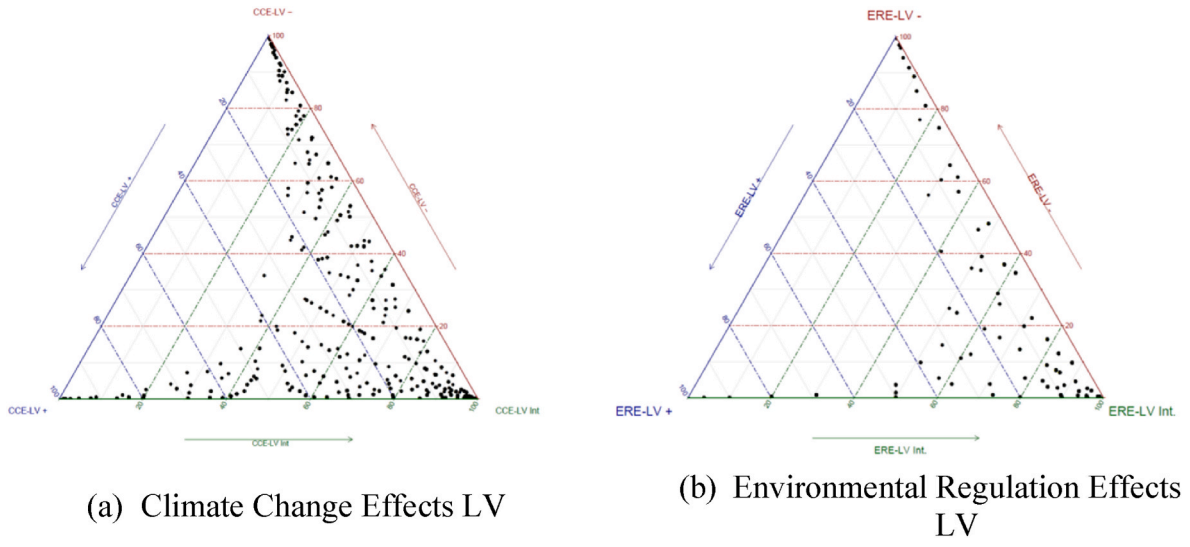
4.2. The analysis of the relative probability ratios

The results of the relative conditional probability ratios of each category –under the fuzzy clustering ECO extended apostle model and the covariates studied are shown in Table 6. The ninety-five per cent confidence interval can be calculated using the two adjacent figures of the columns for each pair of events. For example, between there being no solid evidence regarding the earth getting warmer and being in the first quadrant (unconvinced of the effects of climate change and environmental regulation), it can be seen that the bootstrap method that dropped 50 respondents in each draw of the one thousand subsamples, the confidence interval of the ratio is (2.71, 2.77). Thus, it can be deduced that these two events have a strong positive association. In other words, those who think there is no solid evidence that the earth is getting warmer belong to the first quadrant characterised by being unconvinced of CC and ER effects with a higher probability. The same row analysis helps to conclude that they also belong with more probability to the third quadrant, and belong less likely to the second and fourth quadrant.

The interpretation of the table is straightforward, following a similar reasoning to the one expressed above. When one is included in the interval, the two events are independent. Otherwise, there is a positive or negative association which is statistically significant. The significance level is determined by the higher values of the percentile 2.5 for the case of positive associations and the lower values of the percentile 97.5 for the case of negative associations.

Table 5 shows that the following segmentation variables produce less significant effects on the probability of belonging to each quadrant: how life is going to be in ten years, opinions on whether humans are (not) more important than other living things, age, gender, education, ethnic group, majority religions in the USA, and income. These results indicate that the other segmentation variables used in the analysis can better explain the American CCE and ERE perceptions. In other words, for example, low-income and high-income Americans are not very different regarding whether they belong to each of the four clusters, namely none, climate, environment or both.

On the other hand, the segmentation variables that have significant effects are based on the answers given to: whether the earth is getting warmer or not due to human activity or they think there is no solid evidence on this; those who considered that energy conservation is not a problem or a too serious problem; whether they saved energy for other reasons or did not save energy at all; those who considered morally wrong to eat food that requires a lot of energy or to drive a car with a low



(a) Climate Change Effects LV

(b) Environmental Regulation Effects LV

Fig. 1. Fuzzy clustering ternary graphs.

gas mileage; those who expressed extreme opinions (not at all likely or extremely likely) to whether the USA will create many unnecessary environmental regulations; whether humans can slow the pace of climate change; minority religions; and being very conservative, liberal or very liberal.

A quadrant analysis shows that for being unconvinced of CCE and ERE, there is a strong positive association with the following segments: there is no solid evidence that the earth is getting warmer, energy conservation is not too serious problem or not a problem, citizens save energy for other reasons or do not save energy at all, and process the Hindu religion. On the other hand, there is a strong negative association with those who think the earth is getting warmer by human activity, save energy to protect the environment, think that eating food that requires a lot of production energy is morally wrong, think that driving a car that gets low gas mileage is morally wrong, are Muslims or Atheist, and have a very liberal ideology.

Regarding the quadrant of those who are convinced of CCE and unconvinced of ERE, the results show that a positive association exists with those who do not think at all likely that the USA will create many unnecessary environmental regulations, think the earth is getting warmer by human activity, do not save energy, are Orthodox, Buddhist or Muslim, have a liberal or very liberal ideology. The association is very negative for those who think it extremely likely that the United States will create many unnecessary environmental regulations, think humans cannot slow the pace of climate change, think there is no solid evidence the earth is getting warmer, think energy conservation is not a problem, save energy for other reasons or do not save energy, and have a very conservative ideology.

The third quadrant of those being unconvinced of CCE and convinced of ERE shows a very positive association with those who think that energy conservation is not a too serious problem or a problem, think it is extremely likely that the USA will create many unnecessary environmental regulations, think humans cannot slow the pace of climate change, think there is no solid evidence the earth is getting warmer, do not save energy, and have a very conservative ideology. Meanwhile, the negative association is observed for those who think the earth is getting warmer by human activity, who save energy to protect the environment, who think that driving a car that gets low gas mileage is morally wrong, who think that it is not at all likely that the USA will create many unnecessary environmental regulations, who process the Hindu religion and are liberal or very liberal.

Finally, for the fourth quadrant of those who are convinced of both CCE and ERE, it can be seen that there exists a very strong positive association with those who think that humans can slow the pace of climate change by making complex changes, who think it is morally wrong to eat food that requires a lot of production energy and to drive a car that gets low gas mileage, who save energy to protect the environment, who think that the earth is getting warmer by human activity, and those who have a liberal or very liberal ideology. A strong negative association is found among those who think energy conservation is not a problem or a too serious problem, who think it is extremely likely that the USA will create many unnecessary environmental regulations, who think humans cannot slow the pace of climate change, who think there is no solid evidence that the earth is getting warmer, who do not save energy and are very conservative.

It is interesting to highlight that from the five dimensions included in the analysis, environmental attitudes, societal and political views, and political ideology play a more determinant role in explaining the different categorisations of American citizens regarding whether they are more or less convinced of the effects of climate change and environmental regulation. This is not surprising, in contrast with the low relevance obtained for other demographics or socioeconomic variables, in which the only relevant role is found in minority religions. Segments based on age, gender, education, ethnic group or income play a less significant role than the other commented characteristics.

5. Discussion

The analysis of the crisp defuzzified values shows that respondents perceived as more likely events that the environmental regulation effects will provoke much higher prices for fuel and electricity, and the least likely event is also in ERE for the gradual loss of individual freedom. Regarding the first result, Lee (2022) already contended that environmental regulations to reduce greenhouse gas emissions, such as increasing the mix of electricity power in favour of more renewable green sources substituting fuel and coal sources, will increase electricity prices. The fossil energy reduction required, especially in industry and transport, will require innovation in developing electrification processes, but the higher electricity demand will lead to higher electricity prices.

It is unclear why some Americans respond that environmental regulation does not affect their choices and individual freedom. It is more than evident that some environmental regulation affects the decisions drastically like restricting activities in certain areas that protect habitats and species (Baloch et al., 2023; Weiskopf et al., 2020), limiting water consumption during droughts (California Water Boards, 2022;

Table 6
Conditional probability ratios (95 per cent confidence intervals).

Name	Q1 (2.5)	Q1 (97.5)	Q2 (2.5)	Q2 (97.5)	Q3 (2.5)	Q3 (97.5)	Q4 (2.5)	Q4 (97.5)
Life in 10 years better	1.03	1.04	1.08	1.09	0.76	0.77	1.03	1.03
Life in 10 years worse	0.95	0.97	0.82	0.83	1.43	1.44	0.94	0.95
Life in 10 years about the same	0.98	1.00	1.01	1.02	0.99	0.99	1.00	1.00
The earth is getting warmer (Human activity)	0.27	0.28	1.29	1.29	0.14	0.14	1.14	1.14
The earth is getting warmer (natural patterns)	1.69	1.72	0.72	0.73	1.99	2.00	0.83	0.83
The earth is getting warmer (No solid evidence)	2.71	2.77	0.45	0.46	3.20	3.22	0.61	0.61
The earth is getting warmer (Not sure)	1.27	1.32	0.74	0.75	0.84	0.85	1.05	1.05
Energy conservation is a extremely serious problem	0.60	0.63	1.18	1.20	0.31	0.31	1.11	1.11
Energy conservation is a very serious problem	0.53	0.54	1.08	1.09	0.48	0.48	1.10	1.10
Energy conservation is somewhat serious problem	1.04	1.06	0.94	0.95	1.22	1.23	0.96	0.97
Energy conservation is not too serious problem	2.23	2.28	0.72	0.73	2.39	2.41	0.73	0.74
Energy conservation is not a problem	3.76	3.91	0.41	0.45	3.61	3.65	0.49	0.50
I do save energy to save money	1.39	1.41	0.76	0.77	1.54	1.55	0.92	0.92
I do save energy to protect the environment	0.32	0.32	1.19	1.21	0.18	0.19	1.14	1.15
I do save energy to save money and protect the environment	0.52	0.53	1.15	1.15	0.50	0.50	1.09	1.09
I do save energy for other reasons	3.96	4.04	0.49	0.50	1.59	1.68	0.84	0.86
I do not save energy	2.54	2.58	0.67	0.68	2.61	2.63	0.69	0.69
Humans are more important than all other living things (Y)	1.39	1.40	0.84	0.84	1.60	1.60	0.90	0.90
Humans are more important than all other living things (N)	0.69	0.70	1.14	1.14	0.50	0.51	1.08	1.08
Eating food that requires a lot of production energy: Morally acceptable	0.79	0.83	0.89	0.90	1.10	1.11	1.00	1.00
Eating food that requires a lot of production energy: Morally wrong	0.13	0.13	1.21	1.23	0.19	0.20	1.15	1.15
Eating food that requires a lot of production energy: Not a moral issue	1.16	1.17	0.97	0.97	1.12	1.12	0.98	0.98
Driving a car that gets low gas mileage: Morally acceptable	0.70	0.73	1.06	1.07	0.82	0.84	1.03	1.03
Driving a car that gets low gas mileage: Morally wrong	0.29	0.29	1.22	1.24	0.16	0.17	1.14	1.15
Driving a car that gets low gas mileage: Not a moral issue	1.13	1.14	0.96	0.96	1.14	1.14	0.98	0.98
The United States will create many unnecessary environmental regulations. Extremely likely	1.58	1.60	0.62	0.63	2.54	2.55	0.75	0.75
The United States will create many unnecessary environmental regulations. Very likely	1.22	1.24	0.86	0.87	1.26	1.28	0.96	0.96
The United States will create many unnecessary environmental regulations. Somewhat likely	0.72	0.74	0.81	0.82	0.66	0.67	1.09	1.10
The United States will create many unnecessary environmental regulations. Not too likely	0.68	0.70	1.25	1.26	0.21	0.22	1.12	1.12
The United States will create many unnecessary environmental regulations. Not at all likely	0.70	0.73	1.65	1.67	0.15	0.15	1.07	1.08
Humans can slow the pace of climate change. Making difficult changes	0.33	0.34	1.12	1.13	0.24	0.24	1.14	1.15
Humans can slow the pace of climate change. Making smart choices	0.60	0.61	1.27	1.28	0.42	0.43	1.08	1.08
Humans cannot slow the pace of climate change	2.04	2.09	0.58	0.59	2.83	2.85	0.68	0.68
Age. 18-29	0.99	1.04	1.03	1.04	0.40	0.41	1.10	1.10
Age. 30-49	0.97	0.99	1.04	1.05	0.78	0.78	1.03	1.04
Age. 50-64	1.07	1.08	0.96	0.97	1.26	1.26	0.95	0.96
Age. 65+	0.94	0.96	0.97	0.98	1.16	1.17	0.97	0.98
Male	1.19	1.21	1.04	1.04	1.22	1.23	0.95	0.95
Female	0.84	0.85	0.97	0.97	0.81	0.81	1.04	1.04
Less than high school	0.77	0.78	1.18	1.22	0.45	0.48	1.07	1.08
Highschool graduate	1.13	1.16	0.84	0.85	0.94	0.95	1.02	1.03
Some college, no degree	0.87	0.90	0.92	0.93	1.04	1.05	1.01	1.01
Associates degree	1.36	1.40	0.95	0.96	1.10	1.11	0.97	0.98
College graduate/some post grad	0.96	0.98	0.98	0.99	1.09	1.10	0.98	0.99
Postgraduate	0.89	0.91	1.17	1.18	0.90	0.91	1.00	1.00
White-Non Hispanic	1.05	1.06	0.98	0.98	1.15	1.15	0.97	0.97
Black-Non Hispanic	1.05	1.11	1.16	1.19	0.44	0.45	1.07	1.08
Hispanic	0.76	0.79	0.96	0.98	0.52	0.53	1.10	1.10
Other ethnicity	0.36	0.36	0.93	0.97	1.21	1.24	0.98	0.99
Asian non-Hispanic	0.98	0.99	1.17	1.20	0.47	0.49	1.07	1.07
Protestant	1.12	1.14	0.85	0.86	1.36	1.36	0.95	0.95
Roman Catholic	1.10	1.12	1.01	1.02	0.95	0.96	1.00	1.00
Mormon (Church of Jesus Christ	0.40	0.41	0.75	0.81	1.68	1.73	0.91	0.92
Orthodox	1.47	1.50	1.28	1.31	0.95	0.97	0.95	0.97
Jewish	1.17	1.19	1.22	1.28	0.88	0.92	0.97	0.98
Muslim	–	–	2.35	2.51	0.61	0.63	0.90	0.92
Buddhist	0.58	0.59	2.21	2.36	0.22	0.22	0.97	0.99
Hindu	3.96	4.05	1.24	1.41	0.15	0.15	1.00	1.02
Atheist	0.14	0.14	1.26	1.28	0.26	0.27	1.12	1.13
Agnostic	0.39	0.40	0.94	0.96	0.53	0.54	1.11	1.11
Other religion	0.64	0.65	1.17	1.22	0.36	0.39	1.09	1.10
Religion. Nothing in particular	1.06	1.09	1.11	1.12	0.63	0.64	1.05	1.05
Less than $30,000	0.94	0.97	1.02	1.03	0.62	0.63	1.06	1.07
$30,000 to less than $40,000	1.07	1.12	1.02	1.03	0.85	0.86	1.02	1.02
$40,000 to less than $50,000	0.62	0.67	0.79	0.81	0.88	0.90	1.06	1.06
$50,000 to less than $60,000	0.83	0.88	1.19	1.21	0.96	0.97	0.98	0.98
$60,000 to less than $70,000	0.86	0.92	0.98	1.00	0.97	0.99	1.01	1.01
$70,000 to less than $80,000	0.93	0.98	0.85	0.87	1.05	1.06	1.01	1.01

(*continued on next page*)

Table 6 (*continued*)

Name	Q1 (2.5)	Q1 (97.5)	Q2 (2.5)	Q2 (97.5)	Q3 (2.5)	Q3 (97.5)	Q4 (2.5)	Q4 (97.5)
$80,000 to less than $90,000	1.12	1.19	0.95	0.98	1.03	1.04	0.99	0.99
$90,000 to less than $100,000	0.88	0.94	0.99	1.01	1.12	1.13	0.98	0.98
$100,000 or more	1.12	1.14	1.02	1.03	1.17	1.18	0.96	0.96
Very conservative	2.24	2.30	0.54	0.55	2.59	2.61	0.72	0.73
Conservative	1.58	1.60	0.74	0.75	1.90	1.91	0.85	0.85
Moderate	0.69	0.70	1.05	1.06	0.51	0.51	1.09	1.09
Liberal	0.36	0.39	1.35	1.36	0.15	0.16	1.13	1.13
Very liberal	0.14	0.15	1.40	1.42	0.08	0.08	1.14	1.14

Q1. None (being unconvinced of CCE and ERE; Q2. Climate (being convinced of CCE and unconvinced of ERE; Q3. Environment (being unconvinced of CCE and convinced of ERE); Q4. Both (being convinced of both CCE and ERE).

Quesnel & Ajami, 2017), banning the use of plastic bags (Kish, 2018; Wang et al., 2022), or recycling plastic, paper and glass waste (Wang et al., 2020; Zhu et al., 2023). We will return to the topic with education and awareness campaigns that affect the choices on meat consumption and car demand (Laestadius et al., 2013; Lane & Potter, 2007).

The ideal solutions showed that CCE items, jointly with ERE's gradual loss of freedom, presented the highest dispersion. The answers' variability is mainly due to the polarisation that exists in the USA regarding CCE and ERE and, in our view, to the own information and understanding of respondents. Leiserowitz (2005) identified several distinct American groups interpreting how climate change affects their lives, highlighting the 'naysayers' who were quite sceptical about climate change existence. More recently, Cakanlar (2024) analysed the increasing polarisation in the USA and worldwide that divides society regarding CCE and ERE. The author proposed a framework to develop strategies to reduce the existing polarisation.

Regarding the information and understanding of respondents, it is clear that the lack of scientific consensus and the existing noise on the political agenda polarise the societal views on CCE and ERE. It is frequent to read that scientists who support the consensus on anthropogenic global warming do it for having the guarantee of receiving enough funds in the form of grants. At the same time, there are also scientists denying climate change or criticising current environmental policies because of their political agenda. In both cases, the same sanctorum claim is made in the name of relevant scientists or experts (Cloud, 2020).

Our results showed that the average probability of belonging to the negative cluster of "unconvinced citizens –the Leiserowitz naysayers" is more represented in the case of CCE (16.4 %) vs. only less than eight per cent in the case of ERE. Falkenberg et al. (2022) found that "a prominent opposition to the dominant pro-climate discourse has established itself since late 2019, resulting in a highly polarised online climate debate (p. 1114)". It would be unsurprising that environmental regulation dissensus would not also be the norm soon as in CCE, especially because it is undeniable that some groups with vested interests are acting in favour of changing current energy production without carrying out the real cost-benefit analysis of such new green policies. In Heyvaert's (2019) words, "the study of environmental law and regulation is a rewarding but emotionally draining enterprise (p. xi)".

The classical Apostle determined that the four quadrants contain almost the same number of respondents. The classical Apostle model, while valuable, presents a limitation in its tendency to distribute respondents fairly evenly across the four quadrants. This can be problematic because it overlooks the subtle variations within the respondents' views on CCE and ERE. Thus, the fuzzy clustering ECO extended apostle model is needed to clarify the valuable insights that lie in these subtle differences, breaking the oversimplification obtained by the classical apostle model by a more subtle range of opinions within American society. When citizen groupings are too broad, it becomes difficult to extract valid conclusions about the real range of CCE and ERE opinions of specific segments of the population. The new proposal is a more nuanced approach, allowing for targeted interventions that better address up-to-now hidden differentiation.

Applying the ECO Extended Apostle Model led to significant changes in category assignments for over 60 % of the sample. The analysis highlights a key shift: a large portion (25.2 %) previously classified by the classical model as solely convinced by climate change are now identified by the ECO model as convinced by both latent variables. Interestingly, the ECO model also reveals a remarkably distinct group – the "purely convinced" citizens – comprising 9.2 % of the sample demonstrating strong conviction in both LVs.

The results of the confidence intervals showed that the following segmentation variables produced less significant effects on the probability of belonging to each quadrant: how life is going to be in ten years, opinions on whether humans are (not) more important than other living things, age, gender, education, ethnic group, majority religions in the USA, and income. These results indicate that the American CCE and ERE perceptions can be better explained by the other segmentation variables used in the analysis. In other words, for example, low-income and high-income Americans are not very different regarding whether they belong to each of the four clusters, namely none, climate, environment or both.

On the other hand, the segmentation variables that have significant effects are based on the answers given to: whether the earth is getting warmer or not due to human activity or they think there is no solid evidence on this; those who considered that energy conservation is not a problem or a too serious problem; whether they saved energy for other reasons or did not save energy at all; those who considered morally wrong to eat food that requires a lot of energy or to drive a car with a low gas mileage; those who expressed extreme opinions (not at all likely or extremely likely) to whether the USA will create many unnecessary environmental regulations; whether humans can slow the pace of climate change; minority religions; and being very conservative, liberal or very liberal.

The results of global warming or energy conservation are aligned with previous studies that have analysed individual attitudes and behaviour concerning the acceptance of technologies, environmental regulation, or pro-environmental action (Chen et al., 2022; Gkargkavouzi et al., 2019; Markle, 2013). Gkargkavouzi et al. (2019) found that within the field of Environmental Behaviour (EB), numerous scholars have proposed typologies that categorise individuals based on their engagement in environmentally significant behaviours. One of the prominent categories is that of environmental activists who are highly committed to participating in public demonstrations and environmental organisations. Unfortunately, it is impossible to find a correspondence between the former categorisations and the one proposed in the study.

The results on whether humans can slow the pace of climate change are likely related to religiosity. For example, environmental devastation for very religious people is commonly attributed to God, with natural disasters seen as tests or punishments for sin and out of human control. These beliefs can challenge environmental action, as these communities often focus on religious interventions like prayer, and other actions are seen as futile if God's will is believed to be unchangeable. The link between religious belief and environmental action showcases the complexity of the issue. Thus, religious affiliation was a muted factor:

religious minorities such as Buddhists and Muslims were more pro-climate action, but differed on regulation, possibly due to different theological or cultural conceptions of management (Shah & Asghar, 2024). For others with conservative religious beliefs, distrust may arise from a world where environmental issues are divine providence rather than human agency. These ideological and religious tendencies highlight the importance of placing quantitative segmentation in the context of theories such as value-belief-norm theory (Canlas et al., 2022), political identity theory (Gubitz, 2022), and cultural cognition (Dressler, 2020).

These group-level differences reflect underlying cultural and socio-political "ideologies". Individuals who identified as very conservative were significantly more likely to be sceptical about climate change and opposed to environmental regulation (more convinced of CCE than ERE), a finding consistent with previous research documenting the association between conservative ideology and resistance to government intervention or environmental risk framing (Linde, 2020). In comparison, very liberal respondents were over-represented among those who believed in ERE and CCE effects (convinced of both) and are most likely to be more open to pro-environmental orientations, acceptance of scientific consensus, and sanctioning of structural change.

6. Conclusions

This research analysed an under researched topic, the relationship between CCE and ERE, using a very detailed dataset for the occasion from the Pew Research Center (2022). The study contributes to the scarce literature that exists on the analysis of this relationship. To that aim, different fuzzy logic methods are used with the objective of comparing the results of the fuzzy clustering ECO extended apostle model with the results of the classical Apostle model applied with the synthetic indicators obtained for each LV. The relative conditional probabilities are used to analyse the positive and negative associations between sixteen different covariates and the four obtained categories. Thus, it was possible to determine that being convinced of the effects of CC and ER was the most representative category and that most of the covariates under analysis affected the degree of belonging of each category.

From the sixteen covariates included in the analysis, results showed that how life is going to be in ten years, opinions on whether humans are (not) more important than other living things, age, gender, education, ethnic group, majority religions in the USA, and income were almost irrelevant in explaining the category association. In addition, the polarised answers given to whether the earth is getting warmer or not due to human activity or whether there is no solid evidence for this, some societal issues regarding more pro-environmental behaviour, or the opinion about if humans can slow the pace of climate change, minority religions, and being very conservative, liberal or very liberal have a strong influence in the probability of belonging to each category.

This study provides several important contributions. First, it uses a large, nationally representative sample of over 10,000 US respondents and provides a solid empirical basis for generalising the findings to public attitudes towards CCE and ERE. Second, applying a Fuzzy Hybrid TOPSIS method combined with the ECO-Extended Apostle Model provides a new analytical framework capable of capturing *fuzzy* boundaries of environmental attitudes. In contrast to traditional clustering methods, the fuzzy method supports overlap membership, which essentially describes the imprecise and often uncertain nature of survey responses. Third, the study is pioneering in the sense that it explores the intersection of CCE and ERE beliefs using these mathematical techniques. The study allows environmental scientists, policy makers and practitioners to identify the key drivers and barriers to group membership by examining the four attitudinal groups obtained (not convinced, more convinced of CCE than ERE, more convinced of ERE than CCE, and convinced of both). This result can be used to improve existing climate change education campaigns and environmental regulatory strategies, and to develop more effective and targeted interventions.

However, like any other study, there are some limitations. First, methodologically, the LV scales can be designed to include a broader range of indicators. From a methodological perspective, the LV scales could include more items. For example, CCE could include more indicators differentiating between physical and biological items, such as sea level rise, ocean acidification, change in precipitation patterns from biodiversity change, number of species in danger of extinction, coral bleaching or agriculture productivity impacts. Similarly, ERE could include carbon emissions, pollution, number of particles, water pollution, adaptation and mitigation measures. Second, other latent variables related to these, e.g. citizens' environmental activism, green lifestyle behaviour or environmental justice attitudes, could provide further insights into citizens' behaviour and attitudes towards climate change and regulation.

Third, although the fuzzy logic method allows for a more accurate classification of attitudes, the method is still subject to further robustness empirical checks. For example, subjectivity in the definition of the fuzzification process into TFNs, in determining the α-cut threshold and interpreting the degree of membership can affect the results. Fourth, although relative conditional probability ratios provide informative associations between covariates and group membership, using other statistical models such as latent class analysis, multinomial probit, or structural equation modelling would complement the results, obtaining a causal explanation of these associations. Despite these limitations, the current research provides a novel framework and empirical basis for developing future research on the segmentation of environmental attitudes.

CRediT authorship contribution statement

Juan Carlos Martín: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Alessandro Indelicato:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Ethical approval

This study uses data from an open access dataset (PEW- Wave 106) and does not need any Ethical Approval.

Data availability statement

Data available on American Trends Panel Wave 106 | Pew Research Center (accessed on February 01, 2023).

Ethical

This study did not involve human participants, animals, or sensitive data, and thus, no ethical approval was required. All data used in this research were obtained from publicly available sources, ensuring compliance with all applicable ethical standards.

Declaration of use of generative AI tools

The authors declare that no generative artificial intelligence (AI) tools were used in the writing, analysis, or interpretation of this manuscript. All content has been produced solely by the authors. Where relevant, standard computational tools (e.g., statistical software or reference managers) have been used in accordance with ethical research standards.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssaho.2025.101529.

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