Coordinated school and family environmental education efforts for a generation of eco-surplus culture

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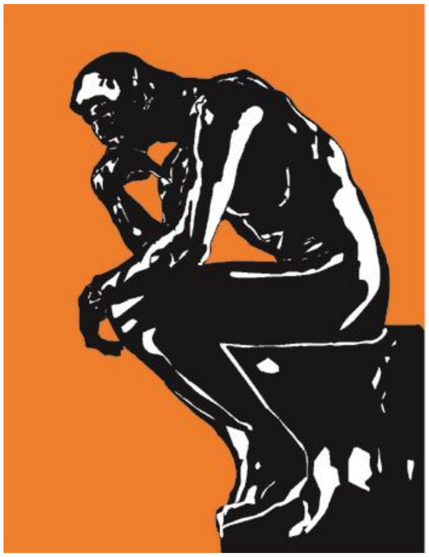

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Abstract

Climate change and environmental degradation are threatening the existence of humanity. The youth have the potential and capability to play a pivotal role in tackling these challenges. Therefore, the current study aims to examine how school and family environmental education can enhance environmental knowledge, willingness to take action, and pro-environmental behaviors among children and young people. The Bayesian Mindsponge Framework (BMF) analytics was utilized on a nationally representative dataset of 2069 Vietnamese primary, secondary, and high school students. The analysis results suggest that school and family environmental education is beneficial for improving students' environmental knowledge and willingness to take environmental actions. Notably, the effect of school education is more substantial for cultivating environmental knowledge, whereas family education has a stronger impact on raising students' willingness than school education. Students with higher levels of environmental knowledge are more likely to conduct pro-environmental behaviors only when they are willing to take environmental actions. If students are unwilling to act, higher environmental knowledge is negatively associated with the likelihood of pro-environmental behavior. Following these findings, we call for coordinated education efforts of schools and families to cultivate students' eco-surplus culture. The education efforts should be implemented along with exposing students to environmental settings and encouraging them to read environmental books.

Keywords: climate change; eco-surplus culture; Mindsponge Theory; nature-based activities; environmental literature

> "The kids should learn to fly, sharpen their eyes and beaks, and strengthen their wings and muscles."
>
> In "Food"; *The Kingfisher Story Collection* (Vuong, 2022)

1. Introduction

Humanity faces critical global challenges that threaten our survival in today's rapidly changing world. Climate change, primarily caused by human activities like burning fossil fuels and deforestation, presents a severe threat (Singh, 2021). Biodiversity loss is another pressing concern, characterized by a rapid decline in species (Nguyen & Vuong, 2021; World Wildlife Fund, 2020). Pollution of the air, water, and land further threatens ecosystems and human health, aggravated by unsustainable resource consumption and habitat destruction (Arneth et al., 2020). Collaboration amongst every sector of society is necessary to address these complex problems (Lenton et al., 2019).

The youth play a crucial part in tackling these challenges. Contrary to stereotypes that often depict them as self-centered or indifferent, many young individuals are deeply concerned about issues that extend beyond their personal interests (van de Wetering et al., 2022). They are driven to contribute to society, actively engage in decision-making, advocate for change, and influence policy (Damon et al., 2003). In some regions, young people are particularly aware of the impending consequences of these challenges, which fuels their passionate support for environmental agendas (O'brien et al., 2018). In addition, the youth are also proactive agents of change, providing creative ideas and advocating for a sustainable future (Zummo et al., 2020). Their activism, innovative thinking, and entrepreneurial spirit invigorate environmental movements. Notable young activists like Greta Thunberg and Jamie Margolin raise environmental awareness and establish sustainable businesses that contribute to both economic and environmental well-being (Marris, 2019; O'brien et al., 2018).

Scientia potentia est [Knowledge is Power]. Learning is a direct pathway for young individuals to become aware of global issues and accumulate relevant knowledge to protect and restore the environment. Within the learning process, school and family education is the primary source of information (Vuong et al., 2021a). Nurturing courageous and capable leaders who can navigate and deal with the ever-expanding environmental crisis is essential. Otherwise, shielding these future trailblazers from the currents of progress raises the question: Who will emerge as guides for humanity? (O'brien et al., 2018; Petrova et al., 2021).

Nowadays, educators face a formidable task: preparing students with the knowledge and skills needed to address global issues that go beyond the standard curriculum, including environmental issues (Majewska, 2023). Existing literature consistently emphasizes the significance of formal school education (Lukman et al., 2013) and family upbringing in shaping the environmental knowledge of young individuals (Katz-Gerro et al., 2020). Environmental education in schools is instrumental in shaping environmentally conscious and responsible citizens (Parra et al., 2020). Consistent research emphasizes the benefits of structured environmental education programs in the context of formal schooling (Ardoin et al., 2018; Stern et al., 2014). Compared to peers who do not have access to these programs, participants in these initiatives often exhibit greater environmental knowledge (Meyer, 2015; van de Wetering et al., 2022). This underscores environmental education's importance in enhancing students' comprehension of environmental issues, subsequently influencing their knowledge, attitudes, intentions, and behaviors (Wang et al., 2022).

As for family education, it also plays a pivotal role in shaping students' environmental knowledge and attitudes (Iwaniec & Curdt-Christiansen, 2020). Parents' environmental commitments and interests can create an academic atmosphere at home that nurtures an interest in ecological knowledge (Payne, 2005). In a study of Danish families, Grønhøj and Thøgersen (2012) discovered that adolescents' pro-environmental behaviors were strongly influenced by the dominating norms within the family and observation of their parents' behaviors. The study of Chinese families further confirmed that children are more likely to adopt eco-friendly habits if they see their parents doing so (Jia & Yu, 2021). In other words, parents can act as role models for their children and gradually build their eco-surplus mindsets and behaviors (Nguyen & Jones, 2022a). Activities like gardening, recycling, and conservation efforts at home can help expose children to environmental concepts from an early age (Jia et al., 2022), gradually establishing the children's connectedness with nature. Although family and school education can be combined to offer various avenues for cultivating environmental consciousness, comparative research on the impacts of family and school environmental education on environmental knowledge, willingness to take environmental actions, and pro-environmental behaviors remains limited.

The relationship between knowledge and behavior has garnered considerable attention from researchers, with some arguing that educating individuals about environmental issues can lead to behavioral change (Boyes & Stanisstreet, 2012), assuming that better-informed individuals are more likely to adopt sustainable practices (Heeren et al., 2016; Zsóka et al., 2013). However, this connection is intricate and challenges the notion that a lack of knowledge is the primary driver of unsustainable behaviors. For example, despite many individuals acknowledging human responsibility for climate change, their actions often do not align with this awareness (Heeren et al., 2016; Levine & Strube, 2012; Steg & Vlek, 2009). Sometimes, highly educated people are also those who are more likely to conduct unsustainable behaviors (Drury, 2011; Nguyen & Jones, 2022b; Sandalj et al., 2016).

While knowledge is undeniably influential (Geiger et al., 2019), it does not act in isolation as the sole determinant of behavior (Davim & Vieira, 2021). The connection between environmental knowledge and pro-environmental behavior might be contingent on the willingness to take action because simply possessing knowledge may not lead to action due to a lack of motivation (van de Wetering et al., 2022; Zhao & Huangfu, 2023). For instance, someone may be aware of the environmental impact of plastic waste but lack the motivation to reduce their plastic consumption. Environmental behavioral intentions play a crucial role in predicting actual pro-environmental behaviors (Liu et al., 2020). However, whether the willingness to take action moderates the relationship between environmental knowledge and pro-environmental behaviors is still underresearched, especially among children and young people.

Various theoretical models explore factors influencing the adoption of environmental knowledge and behavior, including the Theory of Reasoned Action, the Theory of Planned Behavior (Ajzen, 1991), and social-psychological models (Ajzen et al., 2011). These models investigate how knowledge can predict behavior and whether willingness to take action mediates the relationship between knowledge and behavior (Conner & Norman, 2022; van de Wetering et al., 2022). However, these theories seem to lack the comprehensiveness and dynamics to simultaneously explain the impacts of school and family education on environmental knowledge and willingness to take action and how environmental knowledge and willingness interact with each other to predict eco-surplus culture. Theories or frameworks founded on the information-processing perspective might fulfill this objective more effectively. The approach derives from the metaphysical premise that our universe (or physical reality) is constituted of information (Davies & Gregersen, 2014). When information is considered the foundation on which physical reality is constructed, it enables the study of numerous complex and dynamic phenomena in various disciplines, like evolutionary biology and cognitive sciences (Davies & Gregersen, 2014; Dyson, 1999; Li et al., 2022).

To address the gaps mentioned above, this research aims to enhance our understanding of how school and family environmental education can help enhance environmental knowledge, willingness to take action, and pro-environmental behaviors, subsequently building an eco-surplus culture among children and young people (Nguyen & Jones, 2022a). The current study has four primary objectives:

- Examine whether school and family environmental education can improve students' knowledge of environmental issues.
- Examine whether school and family environmental education can enhance students' willingness to participate in taking environmental actions.
- Examine whether students' knowledge of environmental issues can improve the likelihood of conducting pro-environmental behaviors.
- Examine whether the willingness to take environmental actions moderates the association between environmental knowledge and pro-environmental behavior.

The Mindsponge Theory, an information-processing theory of the mind, was employed to assist in reasoning about the psychological processes underlying these associations and proposing Hypotheses (see Subsection 2.1). The Bayesian Mindsponge Framework (BMF) analytics, combining the reasoning strengths of Mindsponge Theory and advantages of Bayesian inference, was applied to a dataset of 2069 students in Vietnamese primary, secondary, and high schools.

2. Methodology

2.1. Theoretical foundation and hypotheses

The current study utilized the Mindsponge Theory as a theoretical framework to support the hypotheses (Vuong, 2023). The theory is a novel theory of information processing in the human mind, which was formulated by integrating empirical findings from a range of ecological and physiological systems, extending from cellular to molecular levels. The concept of the "mindsponge" is a metaphorical representation of the mind as a sponge, capable of expelling unnecessary information and absorbing useful information that aligns with or complements the given context (Vuong & Napier, 2015). The Mindsponge Theory views a mind as an information collection-cum-processor that has goal(s) and priority, depending on the demand of the system. Ensuring existence through survival, growth, and reproduction is the fundamental objective of the system. To achieve its goal and keep its priority, the mind performs subjective cost-benefit analyses that seek to maximize the system's perceived benefits while minimizing its perceived costs (Vuong et al., 2023; Vuong et al., 2021b). In general, the mind is not a passive recipient of information but an active processor of information that is able to select and absorb information from the surrounding environment, filter inappropriate information, and generate responses to solve problems and adapt to the environment (Vuong et al., 2022).

The mindset has a significant impact on the mind's output production, input acquisition, and filtering processes of the mind. Mindset, from the perspective of the Mindsponge Theory, is a collection of trusted values (beliefs or trusted information). As information is viewed as the most fundamental item in information processing, the terms "information," "idea," and "value" can be used interchangeably (Davies & Gregersen, 2014; Dyson, 1999). To be clear, "idea" and "value" might be thought of as the mind's subjective interpretations of the information that convey them. Fundamentally, the mindset developed due to the mind's (or the brain's) ability to store information – or memory. Also, it is not a constant set of information or values but continuously interacts with the surrounding environment. When the absorbed information passes the filtering system of the mind, it will be integrated into the mindset as trusted values. As a result, the content of the mindset changes over time to better match mental representations to reality (Nguyen, Le, et al., 2023).

According to the information-processing mechanism of Mindsponge Theory, multiple factors can contribute to knowledge accumulation, subsequently influencing the person's psychology and behaviors (Vuong et al., 2022). Among them, information availability and accessibility are two fundamental elements. The physical existence of information in reality is referred to as information availability, whereas information accessibility refers to whether a person can perceive and obtain the information if it exists. As a result, when students can receive environmental education at school or home, they tend to absorb environment-related information and develop their pool of environmental knowledge. Among the absorbed information, there might be information associated with the meaning and benefits of the environment to humans, so it contributes to generating the students' intention to take environmental actions (or willingness to take environmental actions). Based on this reasoning, we proposed the following four Hypotheses (H):

> **H1:** Environmental education at school is positively associated with the student's level of environmental knowledge
>
> **H2:** Environmental education at home is positively associated with the student's level of environmental knowledge
>
> **H3:** Environmental education at school is positively associated with the student's degree of willingness to take environmental actions
>
> **H4:** Environmental education at home is positively associated with the student's degree of willingness to take environmental actions

Behaviors, from the perspectives of the Mindsponge-based information process, are the outcomes of the information optimization process that is conducted to interact with the surrounding world. Such behaviors can be proactive (with intention) or reactive (without intention but with stimulus from the environment) (Nguyen, Le, et al., 2023). In this context, pro-environmental behavior is deemed to be influenced by proactive factors (i.e., information existing in the mindset) rather than reactive factors (i.e., information immediately absorbed from the environment). Thus, the student's likelihood of conducting pro-environmental behavior is contingent on how the information is processed within the mind. Specifically, if the students obtain more environmental knowledge, they will have higher awareness, perceived power, and even willingness to take action. As a result, they will be more likely to conduct pro-environmental behaviors (e.g., protecting the environment and saving energy). However, higher knowledge is not necessarily translated into behaviors, as the optimization process is also dependent on other information existing in the mindset that affects the value system (i.e., motivation-related information). When the students are willing to take environmental actions, with more knowledge, they will be more likely to conduct pro-environmental behaviors as such action is perceived beneficial. For instance, the perception of environmental benefits relative to personal costs is pivotal in driving pro-environmental behavior, with people more inclined to participate in such actions when they perceive greater environmental benefits compared to personal costs, reflecting the human tendency to optimize actions for personal gain (Wyss et al., 2022). In contrast, if the students are unwilling, with more knowledge, their minds will tend to optimize the opposite way, resulting in a lower likelihood of conducting pro-environmental behavior. Based on this assumption, we proposed the following Hypotheses:

> **H5:** Environmental knowledge is positively associated with the student's likelihood to conduct pro-environmental behavior.
>
> **H6:** The student's willingness to take environmental actions moderates the relationship between environmental knowledge and pro-environmental behavior.

2.2. Model construction

2.2.1. Variable selection and rationale

In the current study, we employed the dataset of 2069 students to test our hypotheses. The dataset was collected by Nguyen et al. (2021), peer-reviewed, and published in *Data in Brief*. The dataset provided the nationally representative resources to examine Vietnamese students' global citizenship awareness, abilities, and attitudes. The dataset was an outcome of the "Studying on Vietnam Global Citizenship" project carried out by the Vietnam National Institute of Educational Sciences. The project was conducted from 2017 to 2020 to assess the status of global citizenship in Vietnam to assist Vietnamese comprehensive education reform (Thái, 2019). The survey collection design and plan were approved and adhered to the ethical guidelines and regulations of the Vietnam National Institute of Educational Sciences.

The questionnaire was designed by educational experts referring to a variety of global citizenship definitions and criteria for global citizens. The questionnaire's items mostly focus on the concept of global citizenship, which is comprised of global problem awareness, cognitive, socio-emotional, and behavioral domains, and Oxfam's curriculum for global citizenship (Oxfam, 2015; UNESCO, 2015). Before the questionnaire was distributed, it had been piloted at the Experimental School of Education Science (Hanoi, Vietnam) with the participation of 39 primary students, 45 lower secondary students, and 40 upper secondary students. After piloting, certain items and language were changed, and experts reviewed the questionnaire again.

The large-scale nationally representative survey collection was performed following the cluster sampling method. Fifty-four schools in six provinces and cities of three main regions of Vietnam (North, Middle, and South of Vietnam) were selected to mitigate the biases induced by sociocultural differences across regions. In each province, nine schools were selected among three districts, with one elementary school, one middle school, and one high school representing each district. The survey included both schools in rural and urban areas.

Before the survey collection, local education managers and school administrators were contacted and briefed beforehand about the survey's objectives, contents, procedures, and participants. Students participating in the project and their guardians were informed by the school administrators about the project and the survey. All participants and their guardians had confirmed volunteering and signed consent forms before the survey started. Students completed the survey within 30 minutes at school. Finally, responses from 2379 students were obtained, with 814 being elementary school students, 776 being secondary school students, and 789 being high school students. During the data cleaning process, 310 responses were removed because of missing data, resulting in a final dataset of 2069 valid responses.

For constructing the statistical models in the study, five variables were generated from the original dataset (see Table 1). Specifically, to estimate the environmental knowledge that the students were educated at school and home, variables *School_EnvironmentInfo* and *Guardians_EnvironmentInfo* were used, respectively. *School_EnvironmentInfo* and *Guardians_EnvironmentInfo* were generated from variables *Q4_1* and *Q5_1* in the original dataset. The respondent's level of environmental knowledge is measured by the composite variable *EnvironmentIssueKnowledge*, which was generated by averaging variables *Q1_1*, *Q1_2*, and *Q1_3* in the original dataset. The respondent's willingness to participate in activities to protect the environment or save resources was proxied by variable *WillingnesstoAct*, which was generated from variable *Q2iv_16* in the original dataset. Finally, variable *EcosurplusBehavior*, generated from variable *Q3_5* in the original dataset, was used to represent respondent's pro-environmental behavior.

Table 1. Variable description

Variables	**Description**	**Type of variable**	**Value**
School_EnvironmentInfo	Whether the respondent has been taught how to explore and participate in solving global issues such as environmental protection, energy-saving, etc. at school	Binary	Yes = 1 No = 0
Guardians_EnvironmentInfo	Whether the respondent's parents/relatives discuss with them global issues such as environmental pollution, climate change, etc.	Binary	Yes = 1 No = 0
EnvironmentIssueKnowledge	Respondent's level of environmental knowledge about environmental pollution, climate change, and risk of resource depletion	Numerical	1 = I have never heard of this 2 = I've heard about this, but I would not be able to explain what it is 3 = I've heard about this, but I would not be able to explain what it is

			4 = I know this well, and I would be able to explain this well
WillingnesstoAct	Respondent's degree of willingness to participate in activities to protect the environment or save resources in their schools or living place (for example, planting green trees, cleaning, keeping public places clean, using water, electricity, etc.)	Numerical	1 = Disagree 2 = Partially agree 3 = Agree 4 = Strongly agree
EcosurplusBehavior	Whether the respondent participated in protecting the environment or saving energy at school or living place	Binary	Yes = 1 No = 0

2.2.2. Statistical models

For testing whether school and family environment education improve the environmental knowledge of students, we constructed Model 1 as follows:

$$EnvironmentIssueKnowledge \sim normal(\mu, \sigma) \tag{1.1}$$

$$\mu_i = \beta_0 + \beta_1 * Guardians\_EnvironmentInfo_i + \beta_2 * School\_EnvironmentInfo_i \tag{1.2}$$

$$\beta \sim normal(M, S) \tag{1.3}$$

The probability around μ is determined by the form of the normal distribution, whose width is specified by the standard deviation σ. μ_i indicates the level of environmental knowledge of student i; $Guardians\_EnvironmentInfo_i$ indicates whether student i's parents/relatives discussed with him/her about environmental issues; $School\_EnvironmentInfo_i$ indicates whether student i's school teaches environmental issues. Model 1 has four parameters: the coefficients, β_1 and β_2 , the intercept, β_0, and the standard deviation of the "noise", σ. The coefficients of the predictor variables are distributed as a normal distribution around the mean denoted M and with the standard deviation denoted S.

Similarly, we constructed Model 2 to test whether school and family environmental education improves students' willingness to participate in environmental actions.

$$WillingnesstoAct \sim normal(\mu, \sigma) \tag{2.1}$$

$$\mu_i = \beta_0 + \beta_1 * Guardians\_EnvironmentInfo_i + \beta_2 * School\_EnvironmentInfo_i \tag{2.2}$$

$$\beta \sim normal(M, S) \tag{2.3}$$

$WillingnesstoAct_i$ indicates student i's degree of willingness to participate in environmental actions. Model 2 has four parameters: the coefficients, β_1 and β_2 , the intercept, β_0, and the standard deviation of the "noise", σ.

Finally, to test whether students' willingness to participate in environmental actions affects (or moderates) the relationship between environmental knowledge and pro-environmental behavior, Model 3 was constructed.

$$EcosurplusBehavior \sim normal(\mu, \sigma) \tag{3.1}$$

$$\log\left(\frac{\pi_i}{1-\pi_i}\right) = \beta_0 + \beta_1 * EnvironmentIssueKnowledge_{\ i} + \beta_2 * EnvironmentIssueKnowledge * WillingnesstoAct_{\ i} \tag{3.2}$$

$$\beta \sim normal(M, S) \tag{3.3}$$

$EcosurplusBehavior_{\ i}$ indicates student i's likelihood to conduct pro-environmental behaviors at school or living place. β_2 indicates the coefficient of the non-additive effects of $EnvironmentIssueKnowledge_i * WillingnesstoAct_{\ i}$ on $EcosurplusBehavior$. If the coefficient is significant, students' willingness to participate in environmental actions is deemed to affect (or moderate) the relationship between environmental knowledge and pro-environmental behavior. Figure 1 demonstrates the logical network of Model 3.

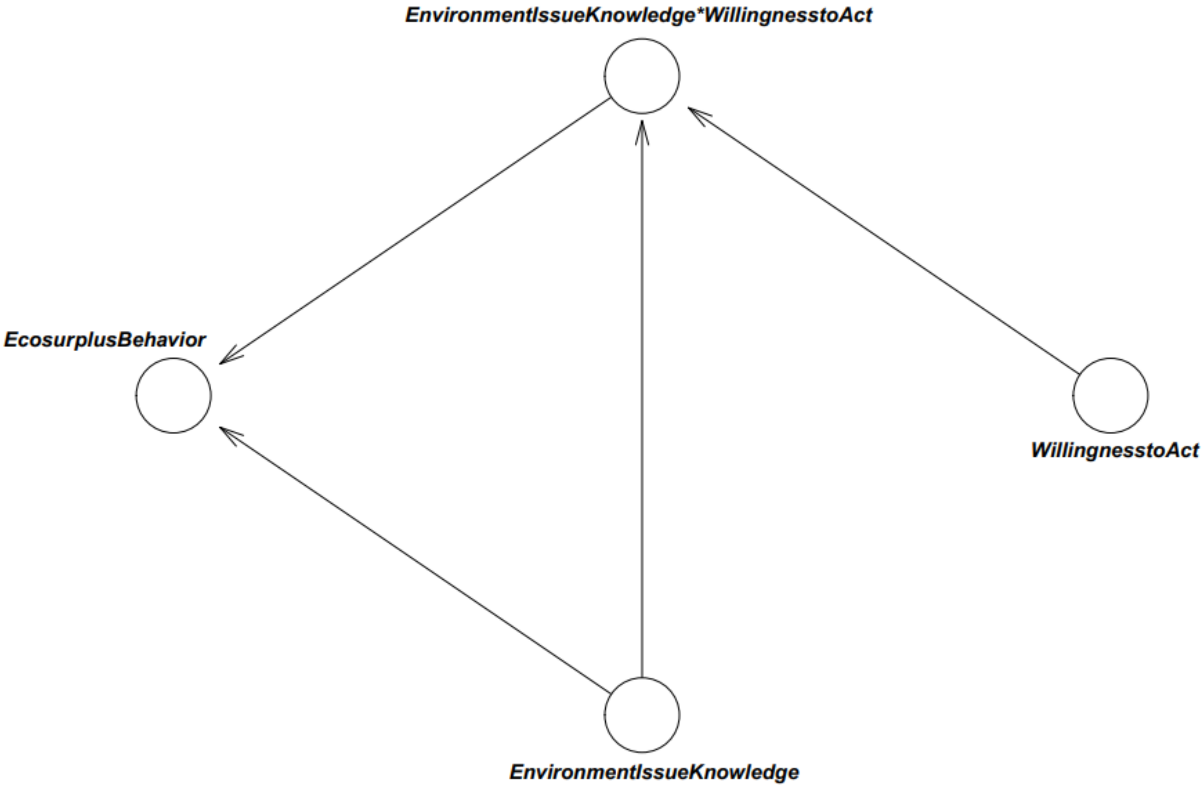

Figure 1. Logical network of Model 3

2.3. Analysis and validation

The current investigation used Bayesian Mindsponge Framework (BMF) analytics for several reasons (Nguyen et al., 2022; Vuong et al., 2022). The method combines the inferential benefits of Bayesian analysis and the logical reasoning powers of Mindsponge Theory. These two approaches are highly compatible (Nguyen et al., 2022). Moreover, the Bayesian inference treats all properties (including the known and unknown ones) probabilistically (Csilléry et al., 2010; Gill, 2014), so it facilitates the prediction of parsimonious models. However, Bayesian analysis can still handle complex models like multilevel and nonlinear regression frameworks thanks to the Markov chain Monte Carlo (MCMC) method (Dunson, 2001). Compared to the frequentist method, Bayesian inference also offers several key benefits, such as using credible intervals for result interpretation rather than confidence intervals and *p*-values (Halsey et al., 2015; Wagenmakers et al., 2018).

Bayesian analysis requires selecting the appropriate prior during the model construction process. Due to the exploratory nature of this study, we employed uninformative priors or a flat prior distribution to provide as little prior information as possible for model estimation (Diaconis & Ylvisaker, 1985). Following a successful model fit, we used Pareto-smoothed importance sampling leave-one-out (PSIS-LOO) diagnostics to inspect the models' goodness of fit (Vehtari & Gabry, 2019; Vehtari et al., 2017). LOO is computed as follows:

$$LOO = -2LPPD_{loo} = -2\sum_{i=1}^{n} \log \int p(y_i|\theta)p_{post(-i)}(\theta)d\theta$$

$p_{post(-i)}(\theta)$ is the posterior distribution based on the data minus data point i. The *k*-Pareto values are used in the PSIS method for computing leave-one-out cross-validation, which helps identify observations with a high degree of influence on the PSIS estimate. Observations with *k*-Pareto values greater than 0.7 are deemed influential and may be problematic for accurately estimating leave-one-out cross-validation. It is common to consider a model to fit with the data when the *k* values are below 0.5.

If the data fit the model well, then we would proceed to the convergence diagnostics and the interpretation of the results. Both statistical values and visual illustrations can be used to validate the convergence of Markov chains. Statistically, the effective sample size (*n_eff*) and the Gelman–Rubin shrink factor (*Rhat*) can be used to assess the convergence. The *n_eff* value represents the number of iterative samples that are not autocorrelated during stochastic simulation. If *n_eff* is larger than 1000, it is generally considered that the Markov chains are convergent, and the effective samples are sufficient for reliable inference (McElreath, 2018). Meanwhile, the *Rhat* value is the potential scale reduction factor or the Gelman–Rubin shrink factor (Brooks & Gelman, 1998). If *Rhat* value exceeds 1.1, the model does not converge. Typically, the model is deemed convergent if *Rhat* = 1. Besides the statistical values, the Markov chains' convergence was also validated visually using trace plots, Gelman–Rubin–Brooks plots, and autocorrelation plots.

The **bayesvl** open-access package in R was used in performing the Bayesian analysis, as it has good visualization capabilities (La & Vuong, 2019). The analysis was conducted with four Markov chains and 5000 iterations, with the first 2000 iterations for warmup. For transparency and scientific cost reduction, all data and code snippets of this study were deposited onto an Open Science Framework (OSF) server (Vuong, 2018): https://osf.io/av5fp/.

3. Results

3.1. Model 1

Before interpreting the results, it is necessary to assess Model 1's goodness of fit with the data. As seen in Figure 2, all the estimated *k*-values are below the 0.5 threshold, indicating a good signal of fit between the model and the data.

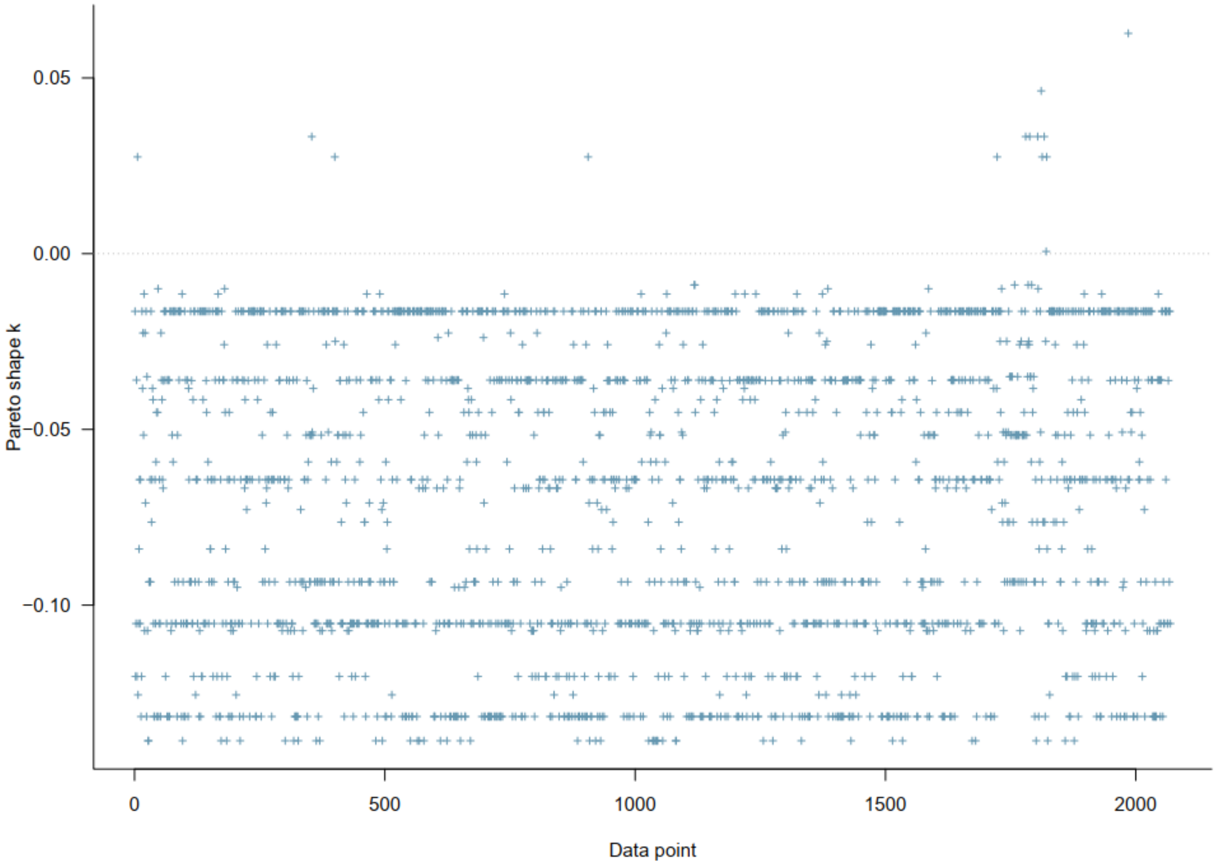

Figure 2. Model 1’s PSIS-LOO diagnosis

The statistics of Model 1’s posterior distributions are shown in Table 2. All the *n_eff* values are larger than 1000, and *Rhat* values are equal to 1, so it can be deemed that Model 1’s Markov chains are well-convergent. The convergence of Markov chains is also reflected through the trace plots in Figure 3. Specifically, all the chains’ values fluctuate around a central equilibrium after the 2000th iteration.

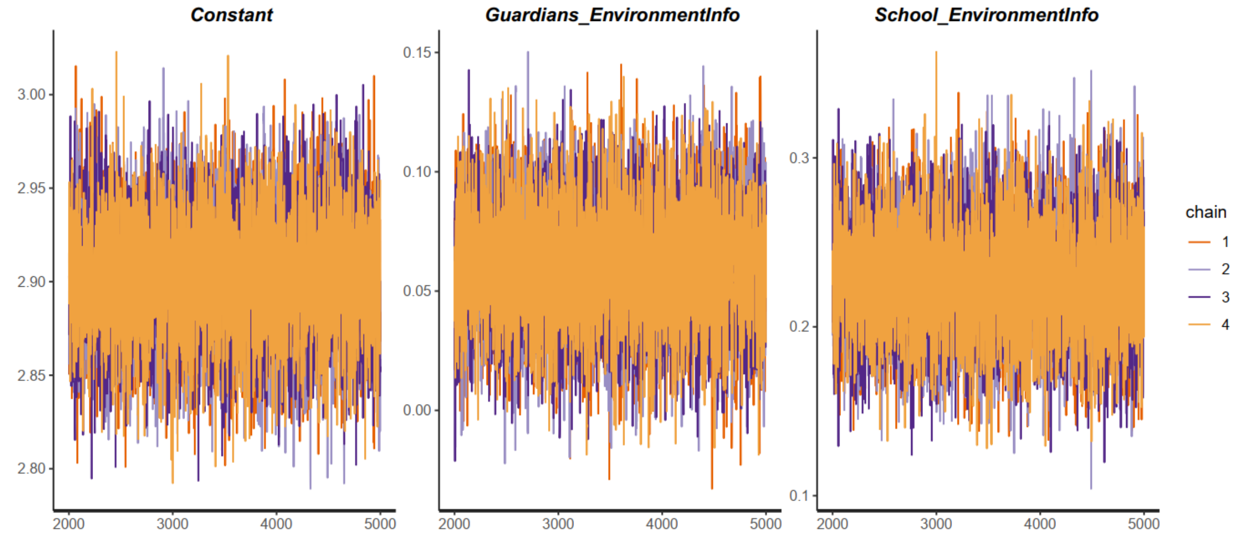

Figure 3. Model 1's trace plots

The Gelman-Rubin-Brooks plots and autocorrelation plots also signify the good convergence of Markov chains. The Gelman-Rubin-Brooks plots are used to assess the ratio between the variance between Markov chains and the variance within chains. The *y*-axis illustrates the shrink factor (or Gelman-Rubin factor), while the *x*-axis demonstrates the iteration order of the simulation. In Figure 4, the shrink factors of all parameters drop rapidly to 1 before the 2000th iteration (within the warmup period). This manifestation suggests that there is no divergence among Markov chains.

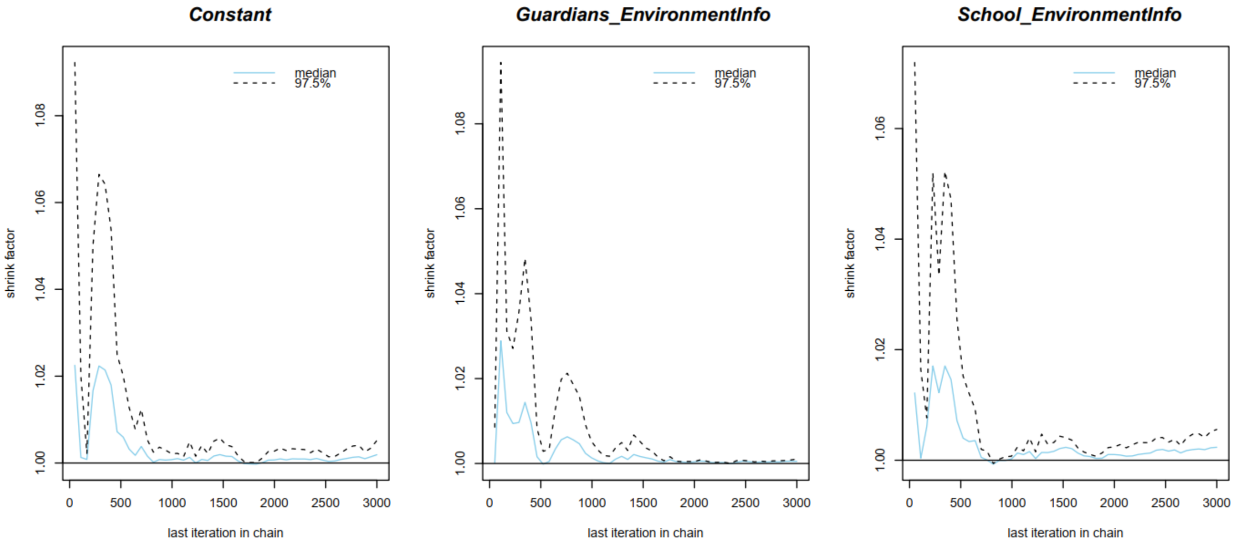

Figure 4. Model 1's Gelman-Rubin-Brooks plots

The Markov property refers to the memoryless property of a stochastic process. In other words, the iteration values are not autocorrelated with the past iteration values. The autocorrelation plots are employed to evaluate the autocorrelation levels among iteration values. The charts in Figure 5 show the average autocorrelation of each Markov chain along the *y*-axis and the lag of the chains along the *x*-axis. Visually, all the Markov chains' autocorrelation levels decline swiftly to 0 after a few number of lags (before 5), suggesting that the Markov property is held and the Markov chains are well-convergent.

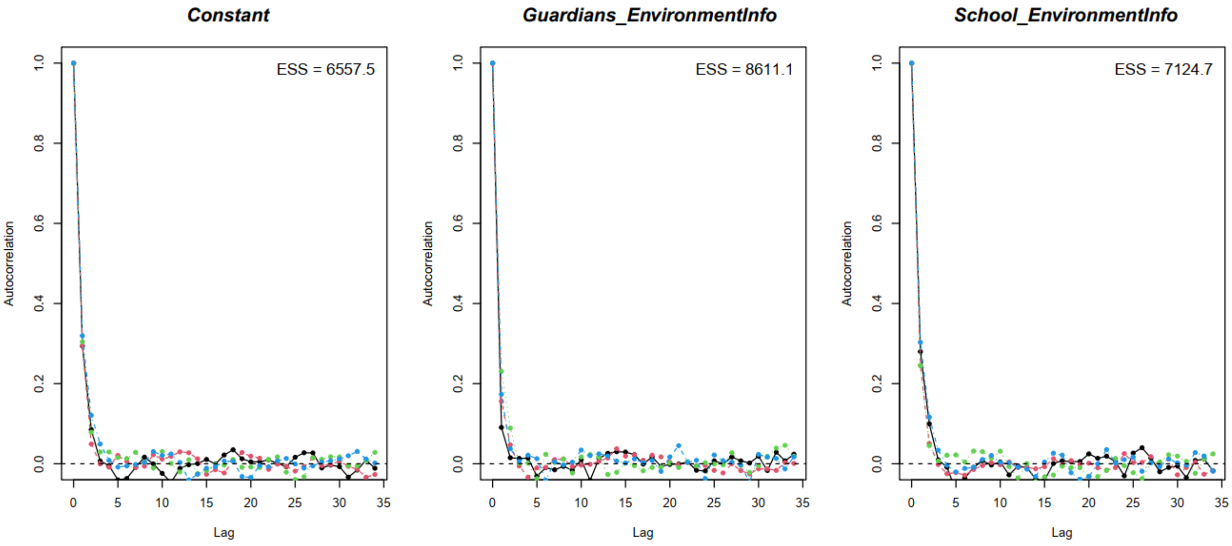

Figure 5. Model 1's autocorrelation plots

Since all the diagnostics confirm the convergence of Markov chains, the simulated results are eligible for interpretation. The estimated results of Model 1 show that school and family education on environmental issues have positive effects on the students' level of environmental knowledge ($M_{Guardians\_EnvironmentInfo\_Model1} = 0.06$ and $S_{Guardians\_EnvironmentInfo\_Model1} = 0.03$; $M_{School\_EnvironmentInfo\_Model1} = 0.23$ and $S_{School\_EnvironmentInfo\_Model1} = 0.03$). The posterior distributions of the two coefficients are illustrated in Figure 6. As the coefficients' distributions are entirely located on the right side of the *x*-axis's origin, the positive effects of both school and family education can be deemed highly reliable. Notably, school education's effect on students' environmental knowledge is significantly greater than that of family education.

Table 2: Estimated results of Model 1

Parameters	**Mean**	**SD**	**n_eff**	**Rhat**
Constant	2.90	0.03	6421	1
Guardians_EnvironmentInfo	0.06	0.03	8426	1

School_EnvironmentInfo	0.23	0.03	6952	1

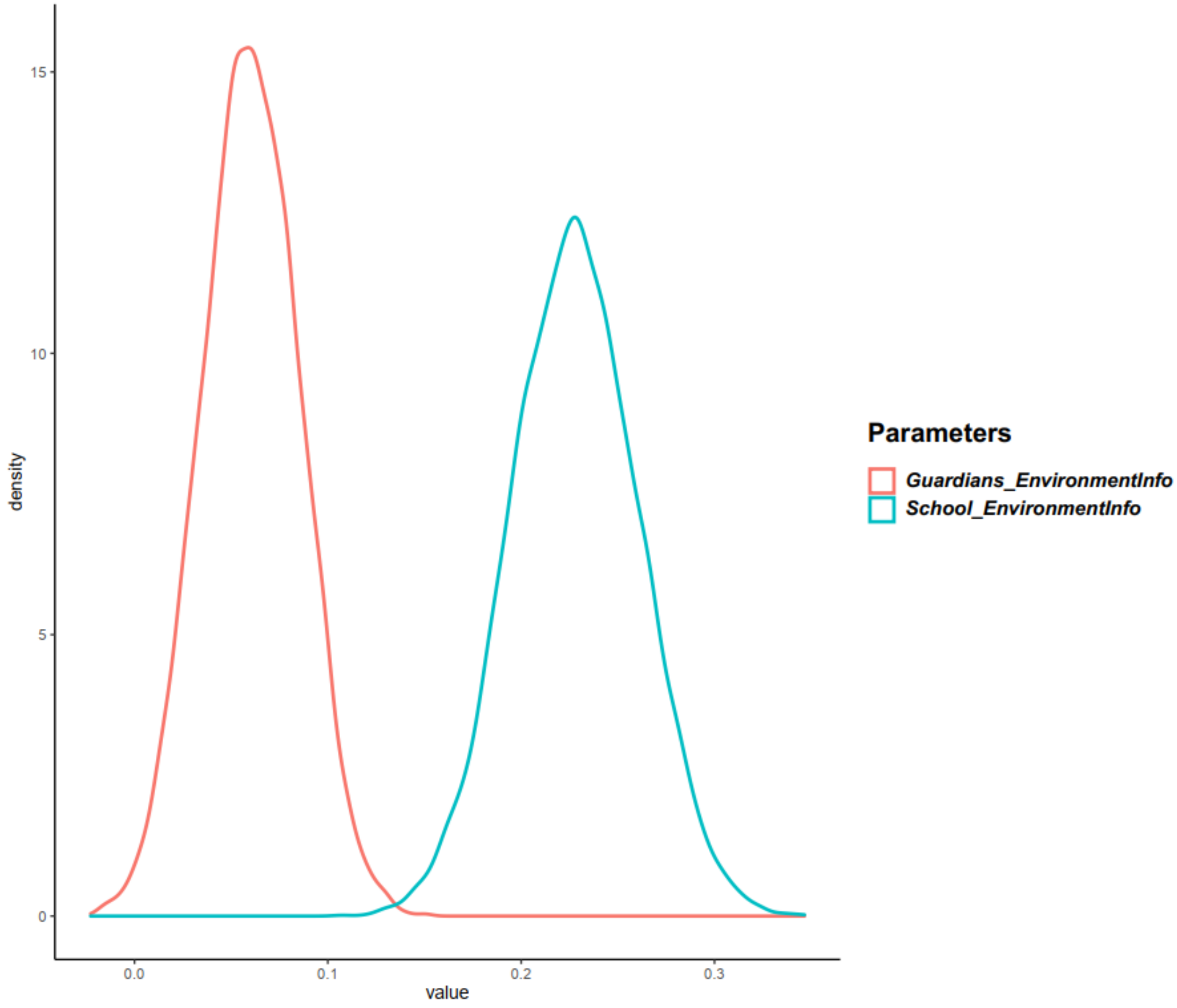

Figure 6. Model 1's posterior distributions

3.2. Model 2

The PSIS-LOO test of Model 2 is shown in Figure 7. All the estimated *k*-values are below the 0.5 threshold, so the model's goodness of fit with the data is considered to be acceptable.

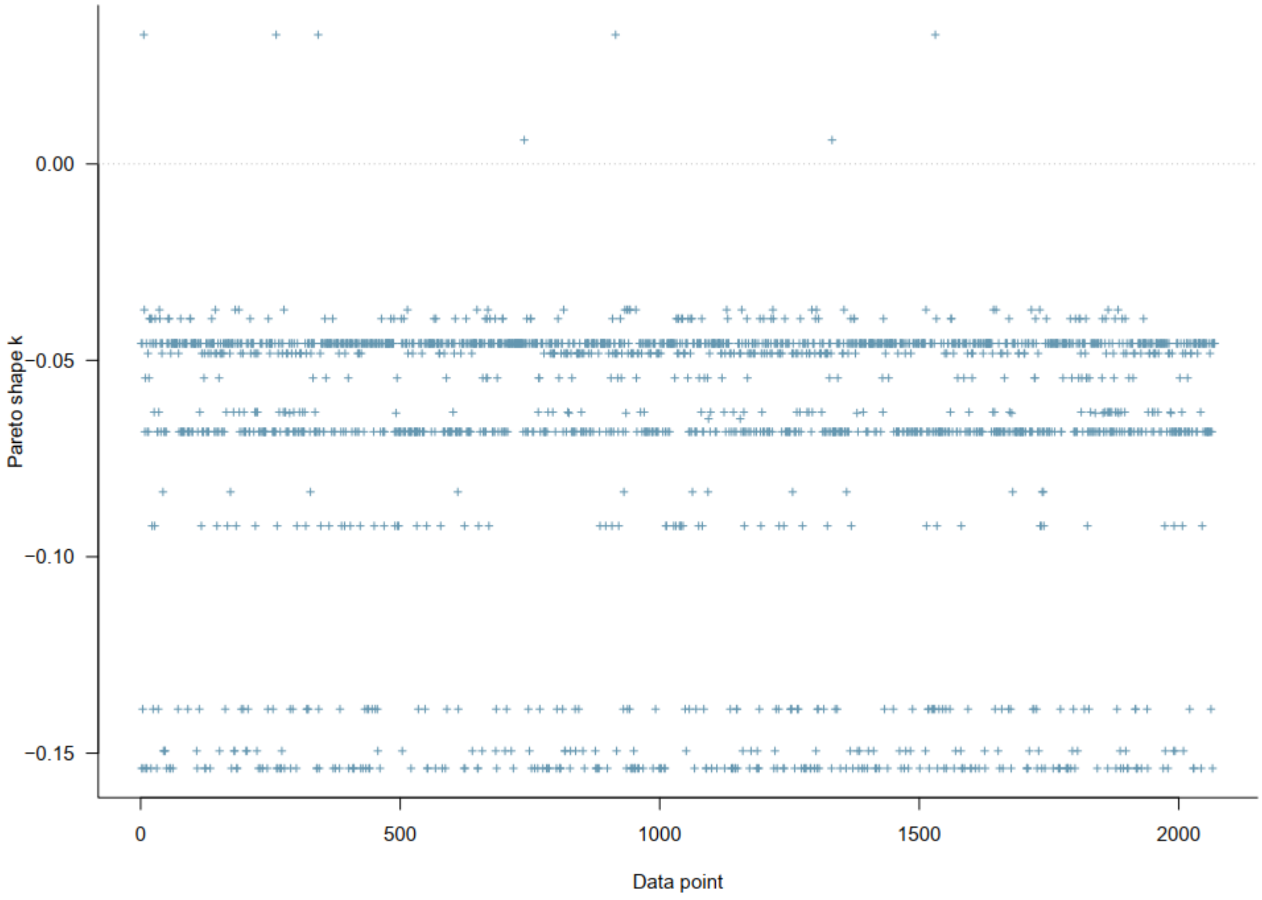

Figure 7. Model 2's PSIS-LOO diagnosis

The statistical values of *n_eff* (larger than 1000) and *Rhat* (equal to 1) in Table 3 imply the convergence of Model 2's Markov chains. The trace plots, Gelman-Rubin-Brooks plots, and autocorrelation plots also confirm the convergence (see Figures A1-A3). Thus, the simulated results of Model 2 are eligible for interpretation.

Table 3: Estimated results of Model 2

Parameters	Mean	SD	n_eff	Rhat
Constant	3.11	0.04	6282	1
Guardians_EnvironmentInfo	0.28	0.03	8932	1
School_EnvironmentInfo	0.12	0.04	6652	1

The simulated results of Model 2 in Table 3 suggest that the environmental education of schools and families has a positive impact on the willingness to participate in environmental actions ($M_{Guardians\_EnvironmentInfo\_Model2} = 0.28$ and $S_{Guardians\_EnvironmentInfo\_Model2} = 0.03$; $M_{School\_EnvironmentInfo\_Model2} = 0.12$ and $S_{School\_EnvironmentInfo\_Model1} = 0.04$). The coefficients' posterior distributions presented in Figure 7 are located on the positive side of the *x*-axis, hinting at the high reliability of the positive effects of family and school education. Unlike Model 1's results, the effect magnitude of family education on students' willingness to participate in environmental actions is significantly greater than that of school education.

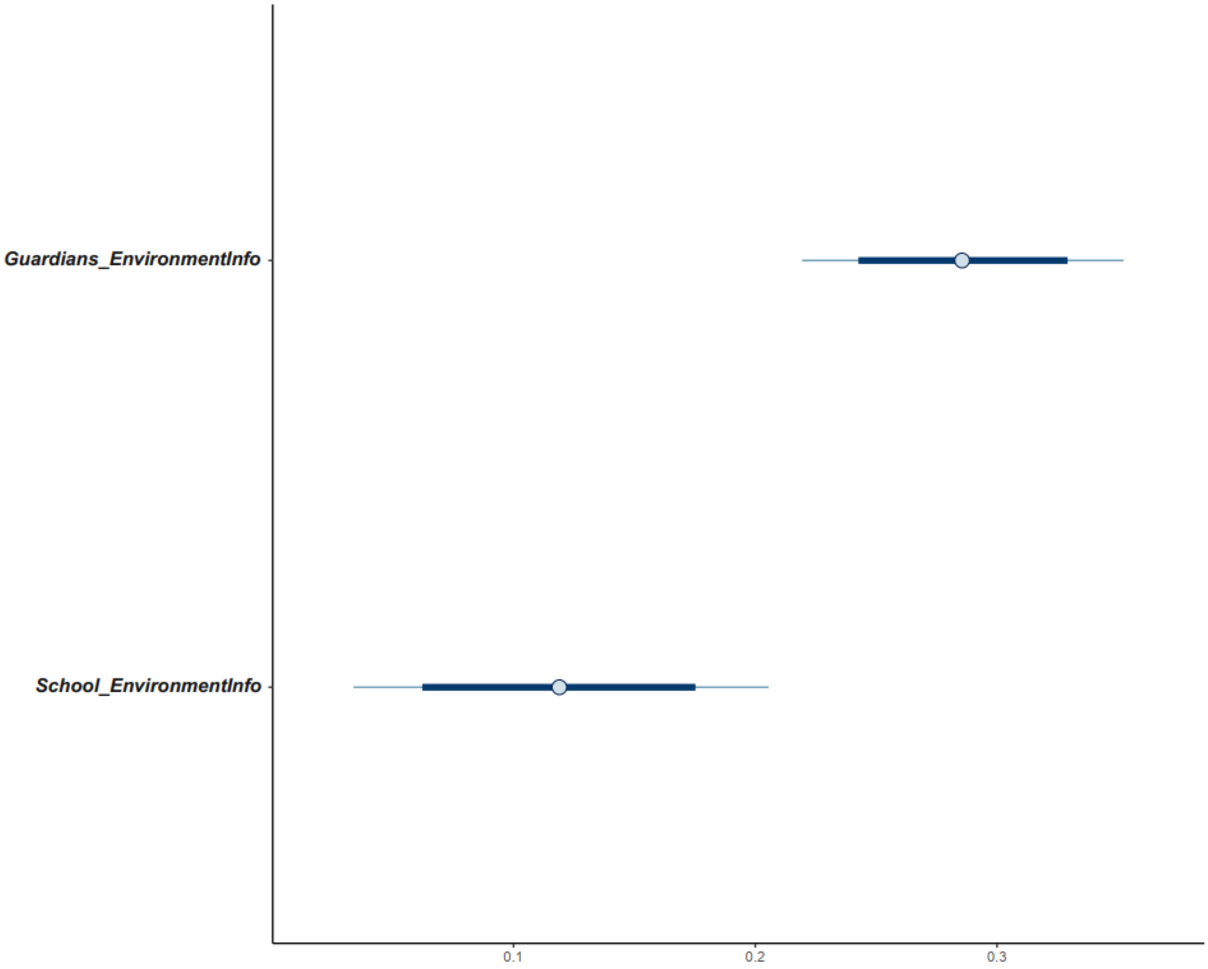

Figure 8. Model 2's posterior distributions

3.3. Model 3

The PSIS-LOO test's result shown in Figure 8 of Model 3 suggests that the Model has a good fit with the dataset since all the *k*-values are below the 0.5 threshold.

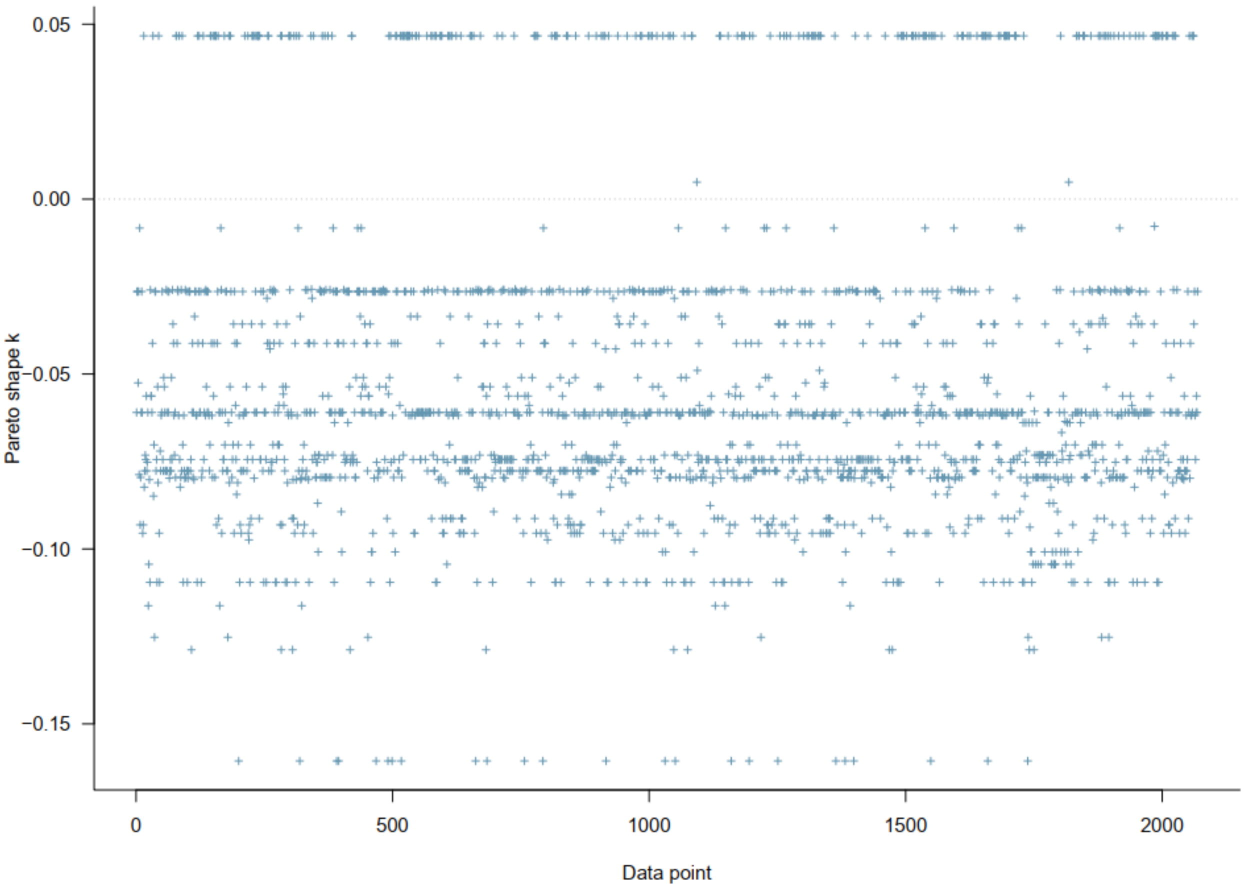

Figure 9. Model 3's PSIS-LOO diagnosis

All the statistical and visual convergence diagnostics of Model 3 validate the good convergence of its Markov chains (see *n_eff* and *Rhat* values in Table 3 and the trace plots, Gelman-Rubin-Brooks plots, and autocorrelation plots in Figures A4-6, respectively).

Table 3: Estimated results of Model 3

Parameters	Mean	SD	n_eff	Rhat
Constant	0.41	0.33	3050	1
EnvironmentIssueKnowledge	-0.45	0.14	3821	1
*EnvironmentIssueKnowledge*WillingnesstoAct*	0.21	0.02	4366	1

The estimated results in Table 3 suggest that students' environmental knowledge has a negative impact on their likelihood of conducting pro-environmental behavior

($M_{EnvironmentIssueKnowledge\_Model3}$ = -0.45 and $S_{EnvironmentIssueKnowledge\_Model3}$= 0.21), but its effect is positively moderated by their willingness to participate in environmental actions ($M_{EnvironmentIssueKnowledge*WillingnesstoAct\_Model3}$ = 0.21 and $S_{EnvironmentIssueKnowledge*WillingnesstoAct\_Model3}$= 0.02). The posterior distributions of the two coefficients in Figure 10 lie entirely on the negative or positive side of the *x*-axis, suggesting the high reliability of the results.

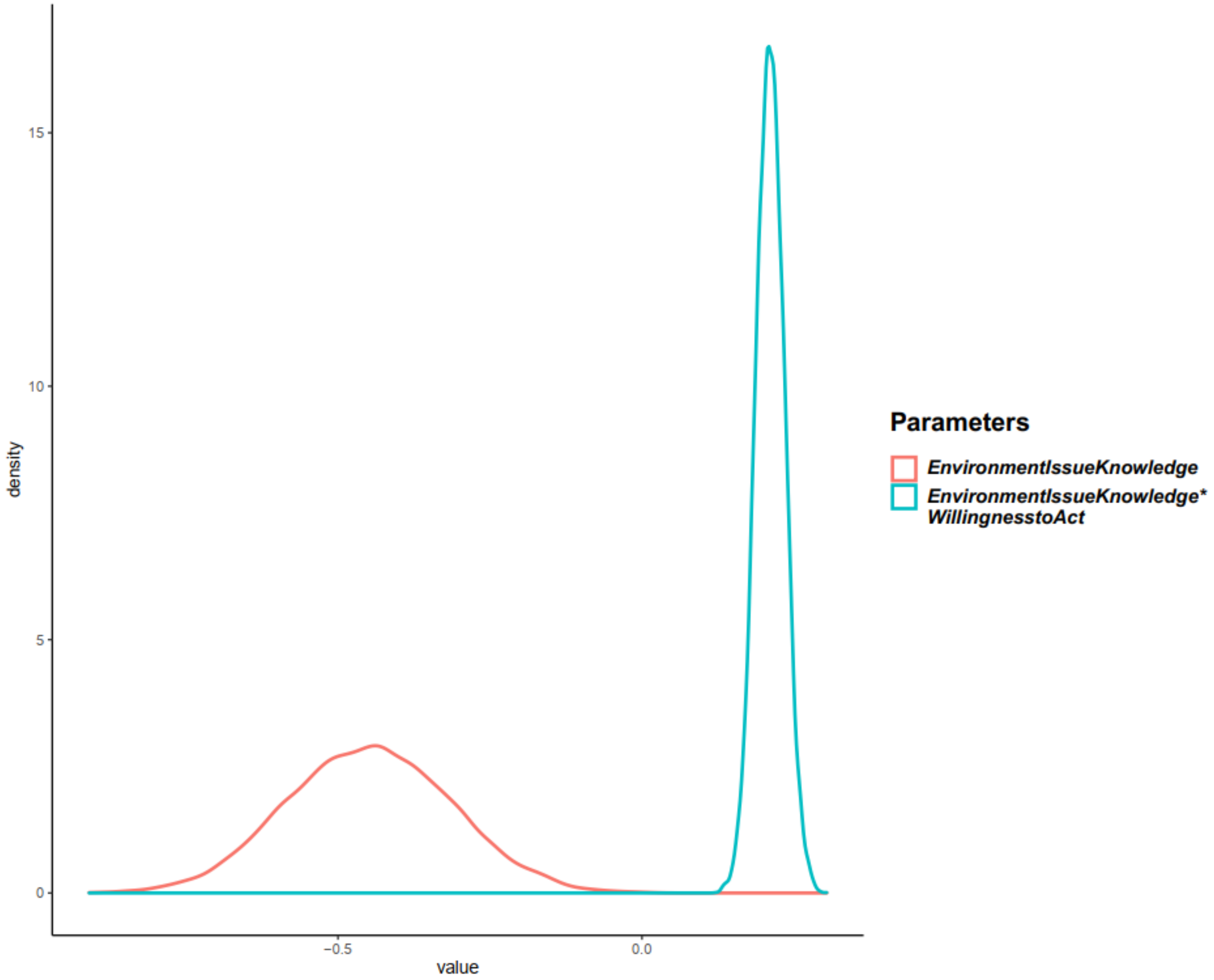

Figure 10. Model 3's posterior distributions

To better interpret Model 3, we inserted the mean values of the coefficients into Equation 3.2 to calculate the students' probability of taking pro-environmental action. The mean values were chosen because they are the values that have the highest possibility to occur. The calculated probability is shown in Figure 11. As can be seen, for students unwilling to participate in environmental actions (i.e., students disagreeing), the more environmental knowledge they obtain, the less probability they have to conduct pro-environmental action. However, if students are willing to participate (i.e., students agreeing and strongly agreeing), environmental knowledge will have positive effects on the likelihood of conducting pro-environmental behavior.

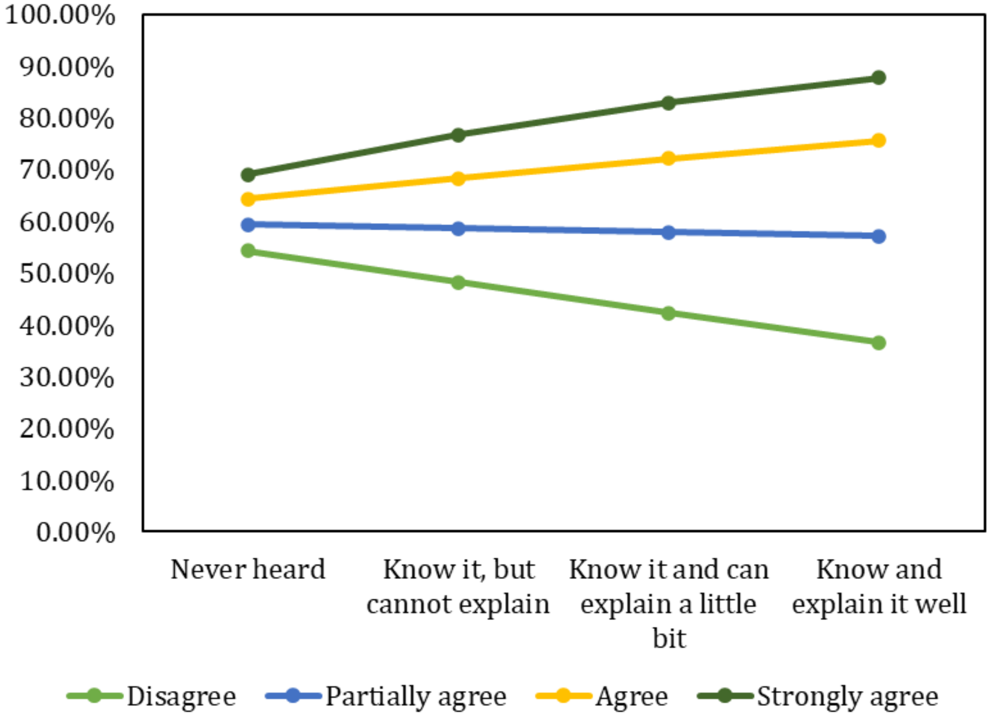

Figure 11. Estimated probability of conducting pro-environmental behavior

4. Discussion

In the current research, we employed the BMF analytics on a nationally representative dataset of Vietnamese students to examine how environmental education at school and family affects students' environmental knowledge and willingness to take environmental actions. We found that exposure to school and family environmental education is beneficial for students to develop their environmental knowledge and environmental action participation willingness. These results confirm the Mindsponge Theory's assumptions that information availability and accessibility are influential toward the mind's collection of information (or knowledge). They are also aligned with previous students that environmental education at school and family is essential for shaping young individuals' environmental knowledge, consciousness, and responsibility (Katz-Gerro et al., 2020; Lukman et al., 2013; Parra et al., 2020). Given the lack of climate change and disaster risk reduction content in the formal curriculum (Kieu et al., 2016), we suggest the government rapidly consider sustainability education a pivotal component of formal education and integrate it into the curriculum.

The comparative results also indicate that environmental education at school has a more substantial effect on environmental knowledge than that at home. Meanwhile, environmental education at home has a greater impact on students' willingness to take action. These findings can be explained by the different types of information the students absorb from education at school and family.

The main sources of environment-related information for environmental education at school are the textbooks and teachers. Information from these sources is aggregated and structured following a formal education system, so the provided environmental information's depth and width might be greater than information provided by students' parents/relatives. This can help the students learn and understand environmental concepts better, resulting in a stronger positive effect on environmental knowledge. However, such an education method is more theoretical than practical, especially in Vietnam. As for environmental education at home, students might have their parents/relatives as role models and more chances to interact with nature (Grønhøj & Thøgersen, 2012; Jia et al., 2022; Jia & Yu, 2021; Payne, 2005). Students might integrate more motivation-related information into their mindsets by observing, imitating, and learning from their parents/ relatives, subsequently generating the willingness to take environmental actions. In addition, actual activities like gardening, recycling, and conservation efforts at home might also help students recognize the benefits of the environment. When the mind perceives the environment as beneficial, it will tend to absorb more information associated with protecting and restoring the environment.

Another major finding of the study implies that environmental knowledge can positively affect the students' pro-environmental behaviors, but such an effect is conditional on the student's willingness to take action. This result validates the Mindsponge information-processing assumptions made above. Specifically, when the student is willing to take environmental actions, they will optimize their knowledge (information in the mind) to translate it into behaviors. Therefore, the more environmental knowledge the student has, the more likely they will conduct pro-environmental behavior. In contrast, when the student is unwilling, the optimization process will work in the opposite way, where environmental knowledge might be used to avoid conducting pro-environmental behavior. If the unwillingness is reinforced over time, it can even lead to denialist mindsets confronting climate change reduction and environmental conservation efforts (Dunlap & McCright, 2010; Lees et al., 2020). Therefore, for a sustainable future for the youth, we strongly recommend coordinated environmental education efforts from both families and schools to not only shape the students' eco-surplus mindsets through natural connections but also equip them with sufficient environmental knowledge (Nguyen & Jones, 2022a; Vuong, 2021).

For effectively building the eco-surplus mindsets for students, schools and families can create more opportunities for students to interact with nature. Exposure to environmental settings through outdoor activities, green spaces, and animals can be beneficial for developing students' empathic relationship with nature, raising their belief in environmental degradation, and improving their test performance and recovery from stressful experiences (Li & Sullivan, 2016; Nguyen, Nguyen, et al., 2023; Palmberg & Kuru, 2000). Environmental books are also a good transmitter of environment-related information that can increase students' awareness and develop their eco-surplus mindsets (Hsiao & Shih, 2016; Mobley et al., 2010; Vuong, 2020a). However, school and family should be the facilitators to direct students to read books that inform readers about the larger socio-political and economic issues in addition to environmental considerations (Echterling, 2016; Schneider-Mayerson, 2018). Books oversimplifying environmental issues as individual actions but lacking civic engagement will "do little to prepare young people for the socio-environmental challenges we face now and in the future" (Echterling, 2016). Sometimes, they might even lead to radical environmentalist behaviors that can lose the public's trust and support toward environmental protection efforts, such as attacking works of art, causing traffic jams, and destroying private properties (Gayle, 2022; Grieshaber, 2023; Joshi, 2023). For transitioning countries, like Vietnam, ensuring the economic growth for poverty eradication, macroeconomic stability, and energy security is also important agendas (Chính & Hoàng, 2009). Thus, radical environmentalist actions might cause negative impressions about environmental agenda, hindering the process of adopting green growth.

The study is not without limitations, so we report them here for transparency (Vuong, 2020b). Given that the dataset exclusively consists of Vietnamese samples, it is necessary to be cautious when applying the findings to other nations. It is also advisable for future studies to validate the information-processing reasoning approach of Mindsponge Theory across different countries and contexts, encompassing a wide range of age groups. Furthermore, the assessment of children's and young people's environmental psychology and behaviors relies on self-reporting, which might incur subjective bias.

Appendix

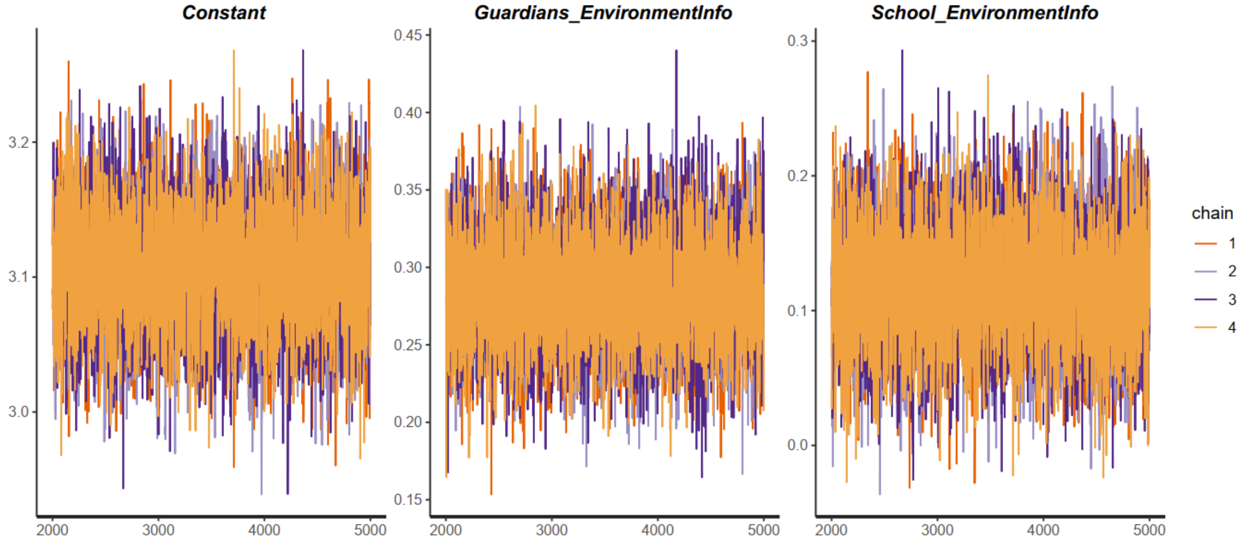

Figure A1. Model 2's trace plots

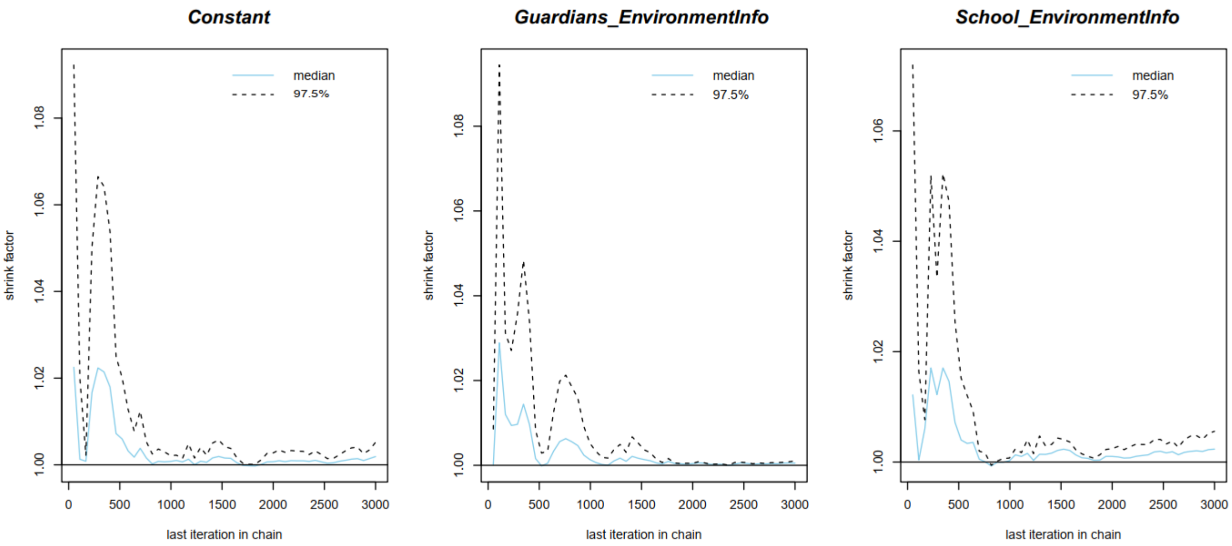

Figure A2. Model 2's Gelman-Rubin-Brooks plots

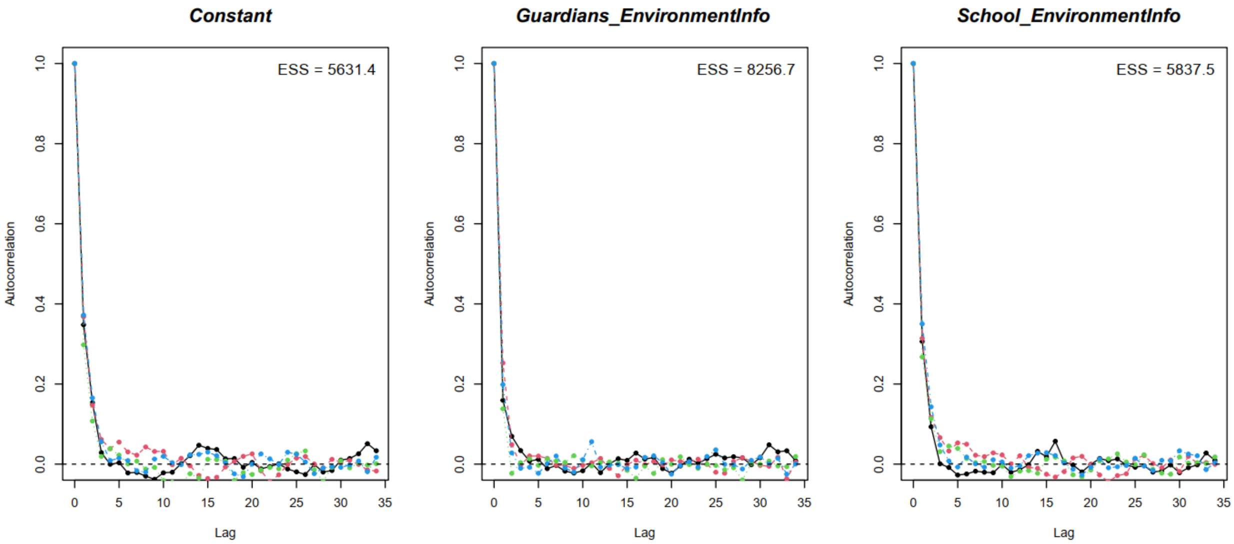

Figure A3. Model 2's autocorrelation plots

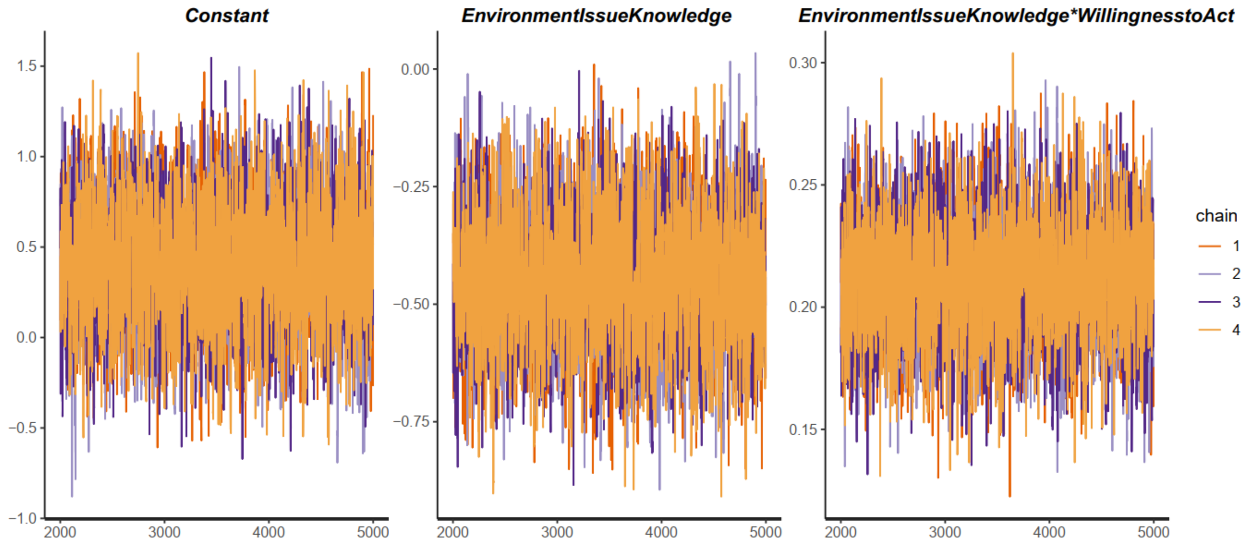

Figure A4. Model 3's trace plots

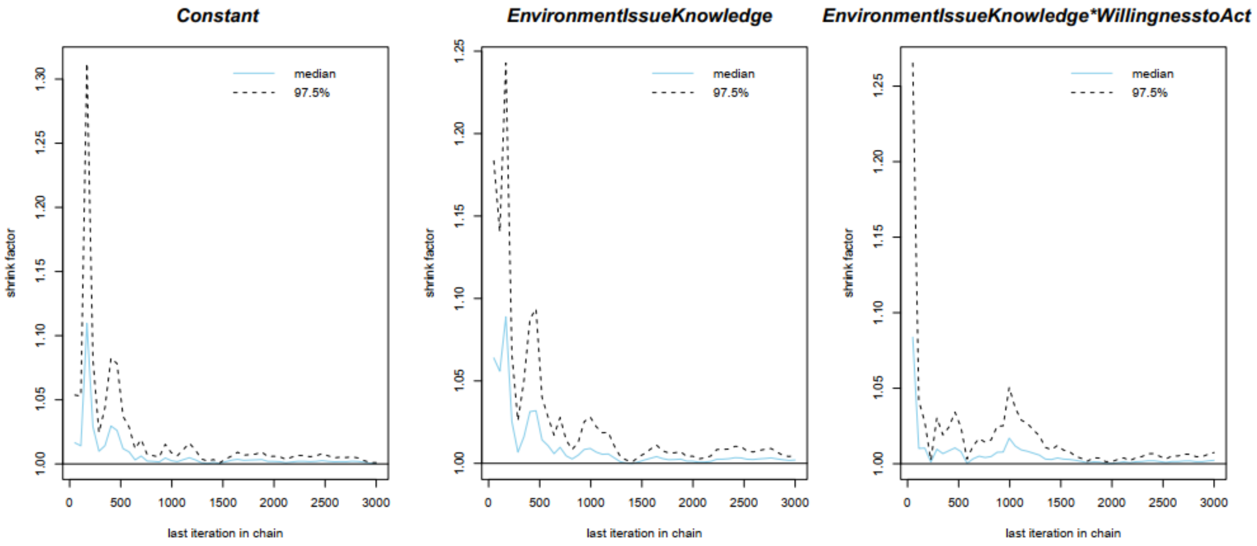

Figure A5. Model 3's Gelman-Rubin-Brooks plots

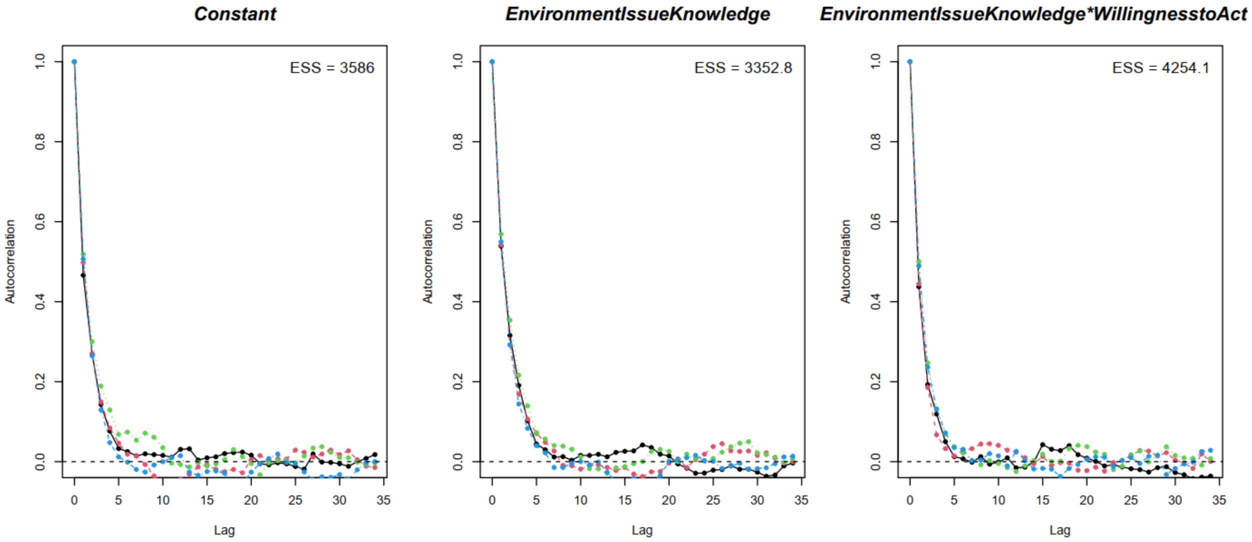

Figure A6. Model 3's autocorrelation plots

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