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Household-Level Strategies to Tackle Plastic Waste Pollution in a Transitional Country

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Abstract: As one of the world's fastest-growing economies, Vietnam is tackling environmental pollution, particularly plastic waste. This study contributes to the literature on environmental culture and practical solutions by better understanding households' behaviours and motivations for (i) sorting waste, (ii) contributing to the environmental fund and (iii) relocating. The questionnaire-based interview method was used to randomly collect information from 730 households in 25 provinces in Vietnam during February 2022. Bayesian regression models, coupled with the mindsponge mechanism, were applied to analyse the data. The results showed that people's strategies and responses to plastic waste pollution vary: 38.63% of respondents were sorting waste at home, 74.25% of households agreed to contribute to the environmental fund, and 23.56% had a plan to relocate for a better living place. The households' strategies and intentions were driven by several structural and contextual factors such as age of household head, income, care about the environment, and the perceived effects of polluted waste. More importantly, communication was a robust variable in sorting waste decisions, which suggested that better communication would help increase people's awareness and real actions in reducing plastic waste and ultimately improving the environment. These findings will benefit the ongoing green economy, circular economy, and green growth transition toward more sustainable development, particularly in developing and fast-population-growing countries.

Keywords: plastic waste pollution; household; Bayesian regression; circular economy; Vietnam

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1. Introduction

As waste is one of the most challenging problems of our time, the circular economy has recently attracted a great deal of research interest. The current economic growth model will soon face the limit of material resources because we live in a finite world [1]. Vietnam has stressed the role of a circular economy as a means of sustainable development in the Law on Environment Protection 2020 and the National Green Growth Strategy for the 2021–2030 period, with a vision by 2050. Waste is a resource that should be treated prudently to retrieve its economic value and limit its environmental impacts. In that sense, a circular economy is vital for humankind to ease our footprints on the Earth system, restraining our economic system within the ecological boundaries supporting life [2,3]. Moreover, improving waste treatment contributes directly to six out of seventeen Sustainable Development Goals, namely SDG 3 (well-being), SDG 6 (water and sanitation), SDG 11 (sustainable cities), SDG 12 (sustainable consumption), SDG 14 (ocean protection), and SDG 15 (biodiversity).

Plastic waste management is a main theme of the circular economy. The so-called "white pollution" resulting from urbanisation and economic expansion is now a global threat [4]. Plastic takes many years to disintegrate, harming living creatures and producing microplastic pollution along the way. There is growing evidence that microplastic can pose serious human health threats [5]. The COVID-19 pandemic has worsened the problems with millions of tons of medical plastic waste that will have a drastic impact for hundreds of years to come [6]. The severity of plastic pollution in Vietnam has increased dramatically due to its fast industrialisation and growing consumerism [7]. The amount per capita has increased ten-fold, from 3.8 kg to 41 kg during the period 1990–2015 [8]. Of the 3.6 million tons of plastic waste the country produces annually, only 10 to 15% is recycled [9]. Every year, Vietnam leaks 730,000 tons of plastic waste into the sea [10]. This dismal record has made the country one of the five biggest ocean plastic polluters, together with China, Indonesia, the Philippines and Thailand [11].

Vietnam's recycling industry is underdeveloped. The sector struggles with poor management, outdated technology, and inefficient waste classification [8]. A substantial part of the recycling activities are conducted by the informal sector resulting in wasteful use of electricity and water and environmental problems of noise, dust, wastewater leakage, health-damaging gases and plastic scraps [7]. Vietnam desperately needs to retrofit the industry with new investments. To fund the transition, the government intends to increase the environmental tax on plastic bags and materials, revise the scheme of domestic waste collection and treatment fees, and launch a new extended producer-responsibility (EPR) regime. As consumers are the final payers (direct or indirect) of such initiatives, it is crucial to understand the public understanding and response to plastic pollution. These insights are also essential for designing awareness campaigns and behaviour interventions concerning government, international organisations, and local NGOs.

This study explores households' awareness of and reaction to plastic issues with a novel data set from a survey of eight provinces in Northern Vietnam. Employing the Bayesian mindsponge framework (BMF) [12–14], the paper evaluates three families' strategies: plastic waste classification, contribution to the waste management fund, and "white pollution"-induced migration. Besides identifying the determinants of willingness to sort plastic waste and the ability to pay for waste management which are the concerns of many plastic waste policies, this work also investigates the ideation of relocation due to plastic pollution. Although the harmful impacts of plastic issues have been well researched, whether or not it is a significant motive for moving is a largely unexplored topic. Moreover, so far, there is little literature that has addressed multiple tactics to deal with plastic pollution with a holistic approach. Based on the mindsponge framework, an information processing mechanism, we anticipate that, like air pollution [15–17], plastic pollution could be a potential reason for the "brain drain" phenomenon in Vietnam, which has received scant attention from researchers. This work attempts to fill the research gap in the existing literature with a comprehensive framework and the powerful properties of Bayesian inference. The study is expected to provide insightful inputs for policy-makers, environmental activists, and researchers in the field of plastic waste management in particular and the circular economy in general.

2. Literature Review

It is widely believed that the Earth is choking on plastic, so plastic pollution induced by human activities has increasingly been seen as a global menace. One million plastic bottles are bought globally every minute, up to five trillion plastic bags are used annually, and even more than 400 million tonnes of plastic waste are generated annually [18]. According to OECD [19], the amount of plastic waste produced worldwide has doubled over the past two decades, with just 9% being properly recycled and the majority ending up in landfills, burned, or leaked into the environment.

Amid the COVID-19 pandemic, there was recorded an upsurge in the use of protective single-use equipment such as face masks made of plastics [20] and take-away food [21],

which has exacerbated an already bad situation of land and marine environments being affected by plastic littering. A rise of 44.8% in plastic waste can be attributed to packaging and 13.2% to medical products during the pandemic [22].

Statistics suggest that Asia is responsible for 80% of the plastics discharged, and Vietnam ranks fourth globally as a major ocean plastic polluter [23]. In Vietnam, 2.62 million tonnes of plastics are disposed of each year, which results in a loss of 75% of the material value of plastics, equivalent to over USD 2.2 billion annually [24]. Meanwhile, waste management is a global challenge, especially in developing countries [25]. This is because the increases in population, income level and urbanisation have led to waste proliferation.

The effects of plastic bottles, bags, etc., in landfills can continue for hundreds to a few thousand years, which has dire consequences for humans and the environment. Plastic pollution can impede ecosystems' adaptive capabilities to climate change and hinder food production since microplastics in marine environments negatively impact aquatic organisms' eating, growth, spawning and survival [26,27]. The open combustion of plastic debris and exposure to pathogenic micro-organisms on plastics take a heavy toll on human well-being [20]. Microplastics are responsible for many health issues such as respiratory, immune, reproductive, and digestive systems [28]. The ingestion of water or food contaminated with plastic is the primary source of plastic pathways into the human body [29], which can bring on cytotoxicity and metabolic disorders [30].

Measures to combat plastic pollution can be classified into three categories: government, scientific, and individual. Government and higher authorities can introduce stringent laws on plastic restrictions, allocate state funds for proper waste management and promote pro-environmental practices through communication in official national channels. Vietnam's government has already enforced many laws, resolutions and decrees, such as the 2020 Law on Environmental Protection, Decree 08/2022/ND-CP, Circular 02/2022/TT-BTNMT. About 1.5 per cent of government spending or VND 25.6 trillion was devoted to environmental mitigation. Most of this spending was on solid and liquid waste management, in which solid waste management received a fund of VND 10 trillion on average during the 2018–2020 period [31]. Regarding scientific solutions, scientists worldwide have long sought to develop better recycling methods. A potential way to recycle plastic on a mass scale lies with the common Zophobas morio "super worm" which can eat through polystyrene, thanks to a bacterial enzyme in its gut. In the long term, researchers aim to engineer enzymes to degrade plastic waste in recycling plants through mechanical shredding, followed by enzymatic biodegradation [32]. On an individual level, people have different responses in the face of pollution, in general, and plastic pollution, in particular. Research into pollution-induced migration in Vietnam confirms a positive relationship between environmental stressors and a citizen's intention to move away from undesirable polluted areas to a new residence [15] based on personal psychological cost-benefit analysis. Pollution can result in a potential brain drain in the source country or region, in the case of migration, which is usually true for developing countries. However, there is scant research into individuals' responses to pollution and the motives behind their decided course of action.

Vietnam discharges more than 1.8 million tonnes of plastic waste per year. Vietnamese per capita plastic waste has increased more than tenfold in the last three decades to 41.3 kg per person in 2018, which was the third highest in Southeast Asia [33]. The Vietnamese government has sought to address plastic pollution, aiming to achieve zero disposable plastic use nationwide by 2025, yet these efforts have largely gone unnoticed. According to a survey conducted by WWF-Vietnam [34], merely 2.3 per cent of the respondents were aware of environmental programs and regulations on waste discharge and environmental protection, posing an enormous challenge for the government.

Socioeconomic factors have significantly impacted households' responses to environmental problems. Income is one of the major determinants of willingness to pay (WTP) for waste management services [35–38]. Although most studies reported that the WTP was more remarkable for the better-off, the reverse was true regarding recycling behaviour

decisions [39,40]. However, Han et al. (2019) [41] found no significant correlation between income and willingness to sort waste. Furthermore, the gender of the household head is an essential element in understanding WTP and household waste management behaviours. Overall, women are responsible for housework, including cooking, cleaning and disposing of waste; hence, they possess more knowledge of waste management [42]. Thus, women were more likely to recycle or sort waste and had a higher probability of paying more for waste management than men [41,43]. Nevertheless, some studies reported that the gender variable was statistically insignificant, and no relationship was found [35,44,45].

Age is usually found to be a predictor of recycling behaviours and WTP. It is generally believed that younger household heads could be more educated and have a more assertive pro-environmental attitude than older ones. Previous studies have found the age variable to influence WTP negatively [36,37,46], yet participation in waste separation and recycling increased with age [39,47–49]. Another critical variable is education. Educated people are expected to be aware of plastic pollution and its ramifications, hence more willing to pay for waste management services and engage in waste classification [36,38,41,44–46,50–53]. This is because public WTP and willingness to sort waste are closely linked to social responsibility and environmental awareness, which are influenced by all educational groups [41]. Interestingly, according to Khuc et al. (2022) [15], many households might consider moving to other areas when faced with environmental pollution, which is also influenced by the aforementioned socioeconomic factors.

Public awareness is a key variable influencing environmental actions [54]. Those aware of environmental issues and concerned with environmental protection are more likely to pay for waste management services and display "green" behaviour [35,37,41,42,50]. The media plays a vital role in heightening public awareness. It has been shown that the percentage of willingness among respondents who received environmental protection messages via the media and the local authorities was higher than that among those who did not. In particular, demonstration projects significantly influenced not only public environmental awareness but also different types of public willingness to participate in waste management [41].

Moreover, Han et al. (2019) [41] reported a positive relationship between the perception of environmental deterioration in their surroundings and WTP. The environmental effects on their lives could urge them to modify their behaviours, and under adverse circumstances, these people might decide to move to other places [15]. In the study conducted in Nepal by Maskey & Singh (2017) [35], the authors found that the availability of waste management services in the local areas affected the willingness to pay for the service. Thus, the quality of the service might also influence households' WTP as those who are satisfied with the service provided are more likely to contribute financially to maintain and improve the service. It could then be assumed that satisfaction with the environmental quality of their living areas and waste management services might also reduce displacement intention.

In order to elicit households' WTP, the contingent valuation method (CVM) could be deemed the most common approach [35,37,46,52]; in addition to the common single-bounded dichotomous choice CVM [38], the double-bounded CVM is increasingly employed due to its efficiency [36,50]. When it comes to the determination of factors influencing WTP, most studies used the logistic regression model [35,41,44,46,48,50,53]. In Padi et al.'s study (2015) [37], the authors used the probit model to establish the determinants of households' WTP for improved solid waste management, while a visitation model developed using the Poisson regression method was employed in Sidique et al.'s study (2010) [47] to analyse the variables that influence visits to drop-off recycling sites. Regarding the factors influencing the maximum amount households are willing to pay to address environmental issues, several studies used the tobit regression model [35,37,44,45]. Interestingly, Ezebilo (2011) [45] found that the assumptions required to use the tobit model could not be satisfied; thus, the author employed the censored least absolute deviations (CLAD) estimator as an alternative. As could be noted, when evaluating WTP, especially

in environmental protection, none or very few studies have used the Bayesian regression model to analyse the data.

3. Framework of Household-Based Plastic Waste Reduction

In this study, we propose and adopt a plastic waste reduction conceptual framework [55] (Figure 1). This framework contains three parts: the transforming system, the consumption-production system, and the receiving system. The household is a crucial actor in the first two systems. This is because households participate in producing goods/services and are consumers/beneficiaries of goods/services. Through the production and consumption processes, households generate waste [56,57]. It is noted that this product is difficult to decompose and can take hundreds of years to decompose completely, causing significant environmental pollution [58]. Plastic waste pollution eventually has an impact on human health [59]. The transforming system, which includes various strategies and actions, can help reduce plastic waste and save resources by, for example, reusing and recycling waste, which will ultimately protect the environment and improve people's well-being [60,61].

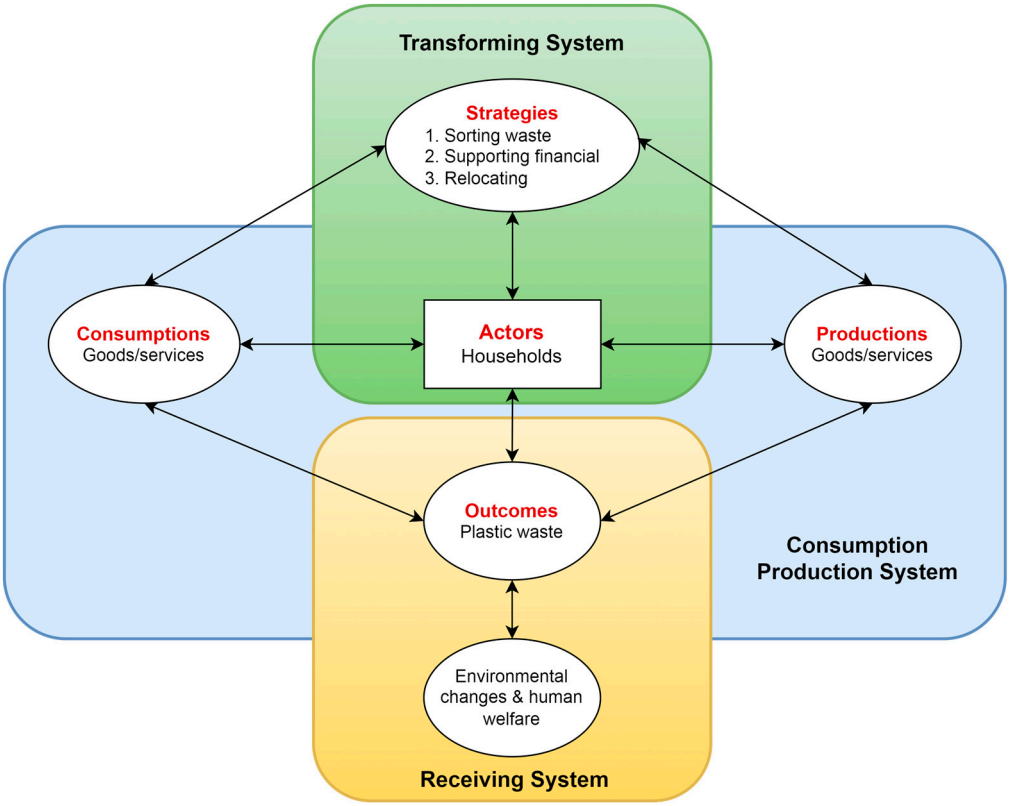

Figure 1. Framework for plastic waste treatment.

The framework shapes our research in several ways. For example, it recognises/considers households to be key actors in the production and consumption of plastic waste. This enables us to target households and investigate their responses/intentions concerning the growing plastic waste problem. More importantly, by participating in any type of environmental protection programme, households can help reduce waste. For example, the greater the number of households participating in waste sorting, the more likely the outcome in reducing plastic waste will be as desired. In this sense, household participation in waste-reduction activities is critical to solving the problem. Based on these characteristics, the framework also supports the construction of household decision models in the following sections.

4. Method

4.1. Study Area

In Vietnam, many landfills in the North are overloaded with waste to the point that the Nam Son landfill put off taking garbage for at least three days to avoid sewer backups due to prolonged rain [62]. In 2020, the garbage crisis was well-documented, in which people stretched tents to prevent garbage trucks from entering the Waste Treatment Complex in protest against delayed resettlement and compensation for housing clearance [63]. In other words, several landfills were blocked, trash piled up and leaked, and downtown districts were swarmed with waste and horrendous smells. Other provinces in Northern Vietnam also confronted plastic waste problems, and the effects on residents' well-being are unquestionable. Therefore, we focused on examining the level of the Northern residents' awareness about domestic waste disposal and their willingness to participate and pay for waste treatment in both urban and rural areas. Furthermore, the brain drain is no longer a novel term in developing countries, so we also aim to test whether plastic pollution induces people to decide on domestic and international migration. In February 2022, we used the random sampling method and conducted an online survey of 730 households in over 25 provinces located in the North (Figure 2).

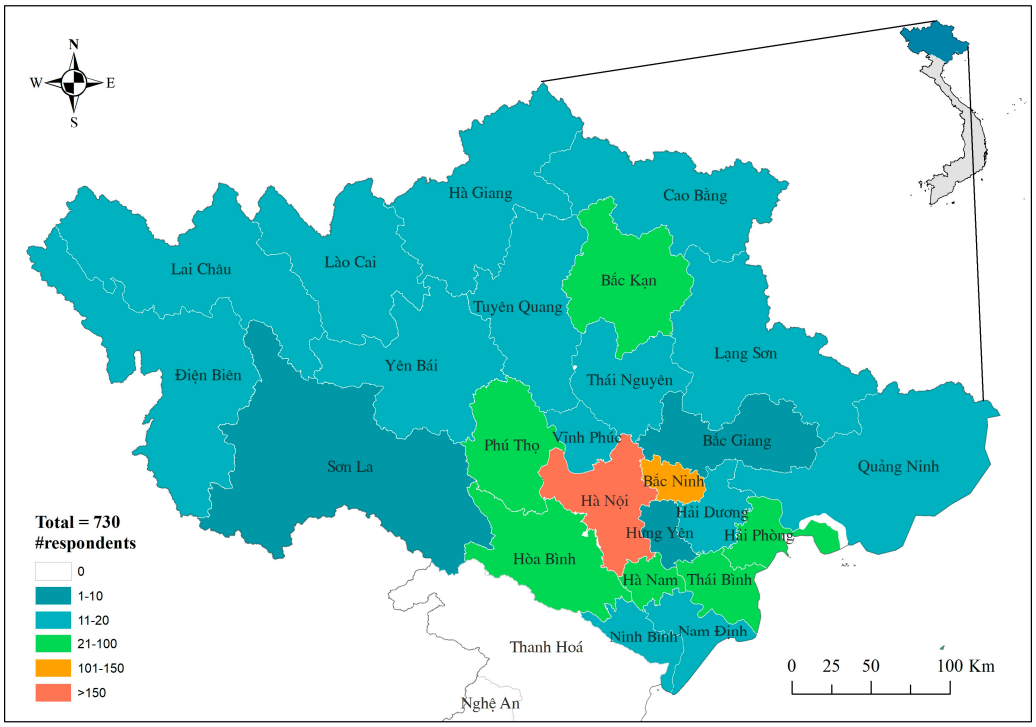

Figure 2. Map of the study area.

4.2. Data Collection

Our survey process included four main steps, from questionnaire design to survey distribution. After a literature review on this area of research, we created the first draft of the questionnaire. Next, a focus group was formed, allowing us to check the intelligibility and explore people's knowledge and experience on this issue. Adjustments were made to ensure that all aspects under study were suitable in Vietnam's context and that all questions were valid, reliable and well structured to meet the research objectives. The subsequent stage involved a pilot survey to test the quality and finalise the questionnaire before carrying out empirical research on a large scale. There were 42 questions divided into four main parts as follows: Part A: Residents' demographics; Part B: Residents' awareness of plastic waste treatment in the locality; Part C: Measures to improve and enhance the efficiency of waste treatment. Part D: Participation and willingness to pay for plastic waste

treatment. Finally, emails and social media platforms were used as the means to distribute our survey. To optimise the data collection process, we recruited and provided collectors with several training sessions to equip them with sufficient knowledge and skills to obtain quality responses from pre-defined research subjects. We employed eight variables to construct three models of residents' reactions to plastic waste: three outcome variables and eight predictor variables (Tables 1 and 2).

Table 1. Variable description.

Variable	Meaning	Type of Variable	Value
WasteSort	Waste sorting at home	Numerical on three points 1–3 scale	1 = Don't know 2 = Yes 3 = No
EnviFund	The intention to contribute to an environmental fund to control and mitigate plastic pollution	Binary	1= Yes 0 = No
Relocate	The intention to relocate to a less polluted place	Binary	1= Yes 0 = No
Age	Age of the respondent	Numerical on four points 1–4 scale	1 = Below 18 2 = 18–30 3 = 30–45 4 = Above 45
Gender	Gender of the respondent	Binary	0 = Female 1 = Male
Income	The average monthly income of the respondent's household (unit: VND million)	Numerical on seventeen points 1–17 scale	1 = Don't know/Don't remember 2 = Below 1 3 = 1–3 4 = 3–5 5 = 5–8 6 = 8–10 7 = 10–15 8 = 15–20 9 = 20–30 10 = 30–40 11 = 40–50 12 = 50–60 13 = 60–70 14 = 70–80 15 = 80–90 16 = 90–100 17 = Above 100
Care	Respondents' concern over plastic pollution	Binary	1= Yes 0 = No
Effects	Respondents' perceived effects of plastic pollution on their lives	Numerical on four points 1–4 scale	1 = No impact 2 = Moderate 3 = High 4 = Severe
CPY	Comparison between current and past plastic pollution in their neighbourhood	Numerical on four points 1–3 scale	1 = Worse 2 = Same 3 = Better
Satisfied	Satisfaction with plastic waste management services	Numerical on five points 1–5 scale	1 = Very dissatisfied 2 = Dissatisfied 3 = Neutral 4 = Satisfied 5 = Vey satisfied
Communication	The act of government communicating information about plastic waste management to the respondent	Numerical on three points 1–3 scale	1 = Don't know 2 = Yes 3 = No

Table 2. Descriptive Results.

Variable	N	Mean	Std. Deviation	Std. Error	Min	95% Confidence Interval for Mean		Max	Range
						Lower Bound	Upper Bound		
WasteSort	730	0.3863014	0.4872349	0.0180334	0	0.3508978	0.4217049	1	1
EnviFund	730	0.7424658	0.4375759	0.0161954	0	0.7106705	0.774261	1	1
Relocate	730	0.2356164	0.4246744	0.0157179	0	0.2047587	0.2664742	1	1
Age	730	2.306849	0.7937217	0.029377	1	2.249176	2.364523	4	3
Gender	730	0.4342466	0.4959975	0.0183577	0	0.3982063	0.4702868	1	1
Income	730	6.668493	3.278934	0.1213588	1	6.430239	6.906748	17	16
Care	730	0.8273973	0.3781626	0.0139964	0	0.7999192	0.8548754	1	1
Effects	730	2.727397	0.7810795	0.028909	1	2.670642	2.784152	4	3
CPY	730	2.979452	0.8467575	0.0313399	1	2.917925	3.040979	4	3
Satisfied	730	2.856164	0.7768047	0.0287508	1	2.79972	2.912609	5	4
Communication	730	2.406849	0.6647769	0.0246045	1	2.358545	2.455153	3	2

4.3. Model Construction

We constructed the empirical model using the Bayesian mindsponge framework (BMF), which employs the mindsponge mechanism of information processing. The BMF method has been proven effective in explaining the decision-making process based on subjective cost-benefit judgments under complicated information processes, especially in this information era [64,65]. To perform statistical analysis, we used Bayesian inference due to its benefits such as combining information with data within a solid decision theoretical framework and providing conditional-on-the-data and exact inferences without reliance on asymptotic approximation [66,67].

Plastic pollution can exert an adverse effect on people's lives. In the light of mindspongecon, because of the variety of personal norms and social norms, people may intend to or take action to deal with the problem on their own, collaborate with the authorities, or even avoid it entirely by migrating domestically and internationally. Apart from the socioeconomic factors such as the age and gender of residents, the perceived environmental effects and awareness of the problems might simultaneously influence these decisions.

Based on this reasoning and the Literature Review in Section 2, we selected eight factors influencing the households' responses, namely sorting waste, contributing to the environmental fund and relocating, to plastic waste pollution. We employed eleven variables to construct three models in this study. There are eight predictor variables and three outcome variables whose descriptions are presented in Table 1. Subsequently, we conducted data collection and initial data analysis. Only significant variables were retained for further interpretation and examination in separate models.

In model 1, we examined the factors influencing the households' waste sorting decisions.

$$\textbf{WasteSort} \sim \propto + \textbf{Care} + \textbf{Age} + \textbf{Communication} + \textbf{Effects} \quad (1)$$

Next, we further examined the degree to which households contributed their finances to environmental funds. Since this is also a strategy to address waste issues involving the participation of households, we used the same set of factors except for Communication, which yielded to Gender, as presented in Model 2.

$$\textbf{EnviFund} \sim \propto + \textbf{Care} + \textbf{Age} + \textbf{Gender} + \textbf{Effects} \quad (2)$$

Lastly, the intention to move to another place due to the impacts of plastic pollution was studied and presented in Model 3. This could provide more insights into

how households might respond to environmental problems and their subjective cost-benefit evaluation.

$$\textbf{Relocate} \sim \propto + \textbf{Income} + \textbf{Age} + \textbf{CPY} + \textbf{Effects} \quad (3)$$

4.4. Methods and Validation

We employed the Bayesian method in this study due to its suitability for our complex models constructed using the mindsponge mechanism. The complex decision-making process involves information, knowledge and the ability to judge. Thus, to understand this process, building parsimonious models was necessary to help improve precision and predictability. The most prominent feature that makes the Bayesian inference approach suitable for parsimonious models is that it treats all properties probabilistically, including unknown parameters [66]. Additionally, the Markov chain Monte Carlo (MCMC) has aided in the Bayesian analysis by enabling the estimation of models with high complexity. The feature of the stochastic processes of Markov chains helps generate many iterative samples and data points, which effectively fit complex models. The technique, therefore, helps meet the large-sample-size requirement for sound estimation [68]. The reproducibility crisis that hinders the reproduction of psychology and social sciences studies [69,70] could be attributed to the wide sample-to-sample variability in the *p*-value [71]. Thus, avoiding the replication crisis by limiting the over-reliance on the *p*-value is another advantage that makes Bayesian probability a wise choice for this study. Furthermore, with the help of the MCMC technique's integration and symmetry assumption independence, Bayesian analysis can precisely estimate the small samples at hand and asymmetric distributions [72,73].

5. Results

- *Model 1: Determinants of Waste classification*

Table 3 provides a breakdown of the factors influencing households' waste sorting decisions. The model's simulated results have a good convergence because the n_eff is greater than 1000 for all the variables, and the Rhat equals 1. The trace plots also confirmed the good convergence of the model (Figure 3a). The posterior value of each parameter is represented on the y-axis, while the x-axis indicates the iteration order. The Markov property is satisfactory because the lines in the middle fluctuate around a very stable central equilibrium and the motions of each line follow a rapid zig-zag pattern. Table 2 shows that all the variables were statistically significant, and only age had a strong negative impact on waste sorting decisions. It should be noted that the strongest relationship was found to be between respondents' concern about plastic pollution and their willingness to sort waste (mean = 0.82). Moreover, all of the distribution of communication and effect variables lie on the positive side of the x-axis, indicating a highly reliable positive association between communication and WS and between effects and WS (Figure 3b). In contrast, the age coefficient lies within the negative zone, meaning that households' willingness to sort waste decreases with age.

Table 3. Estimated results of waste sorting model.

				Percentile						
Variables	**Mean**	**se_Mean**	**Sd**	**2.5%**	**25%**	**50%**	**75%**	**97.5%**	**n_eff**	**Rhat**
a_WasteSort	−4.33	0.01	0.62	−5.55	−4.74	−4.33	−3.92	−3.12	4967	1
b_Care_WasteSort	0.86	0.00	0.27	0.34	0.68	0.86	1.04	1.40	8109	1
b_Age_WasteSort	−0.33	0.00	0.11	−0.56	−0.41	−0.33	−0.25	−0.11	7676	1
b_Communi_WasteSort	0.78	0.00	0.15	0.50	0.68	0.78	0.88	1.07	6327	1
b_Effects_WasteSort	0.74	0.00	0.12	0.50	0.66	0.66	0.82	0.98	6953	1

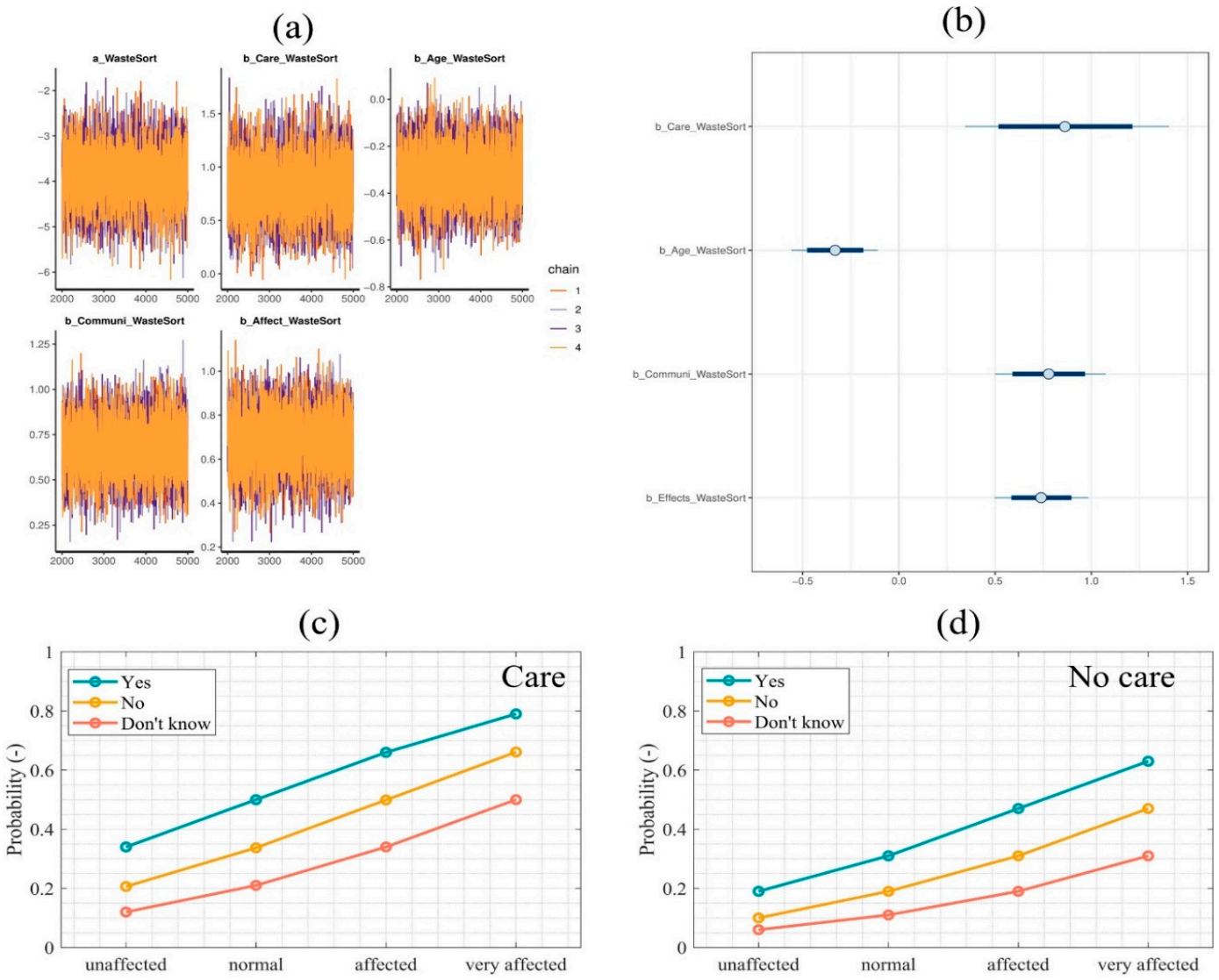

Figure 3. Trace plots for Model 1's posterior parameters (**a**), distribution of posterior coefficients estimated with uninformative priors (**b**), probabilities of sorting waste based on communication levels and perceived effects of household group with care (**c**) and no care (**d**).

From the model, we calculated the probability of households' waste sorting decisions. To be more specific, those who cared about plastic pollution were more likely to engage in waste sorting (Figure 3c,d). Furthermore, the more the respondents felt the severe impacts of plastic pollution, the higher the probability of them being willing to sort waste. It was also evident that communication played a vital role in households' waste sorting decisions. When information about plastic waste collection and treatment was propagated, there was a higher probability that the receivers would sort waste (Figure 3c,d).

- *Model 2: Determinants of fund contributions*

The second model examines the determinants of the respondents' decisions on contributions to the environmental fund, namely their care about the environment, their age, their gender and their perception of the effects of plastic pollution. Table 4 shows the predicted figures for four factors influencing respondents' financial donation to the plastic waste treatment fund. The sample size (n_eff > 1000) and the Gelman shrink factor (Rhat = 1) indicate a good convergence of the model. The high density of plots of variance of the MCMC chains and the MCMC chains' fluctuations around a central equilibrium (Figure 4a) also confirm the model properties are held. It can be clearly seen that the more respondents

care about plastic waste, the more likely they will contribute to the fund (μCare = 1.88 and σcare = 0.24). Furthermore, there is a positive association between the severity of plastic waste effects and the intention to donate (μEffect = 0.47 and σEffect = 0.14). In contrast, intention on contribution is negatively associated with age and gender (μAge = −0.18 and σAge = 0.12; μGender = −0.37 and σGender = 0.20). The interval plot of the model shows that the whole distribution of care and effect lies on the positive side of the axis, indicating a highly reliable positive association with the intention of contributing to the fund (Figure 4b). Meanwhile, the coefficient of age and gender lay within the negative zone and reached the point of zero, meaning their negative influence is statistically insignificant.

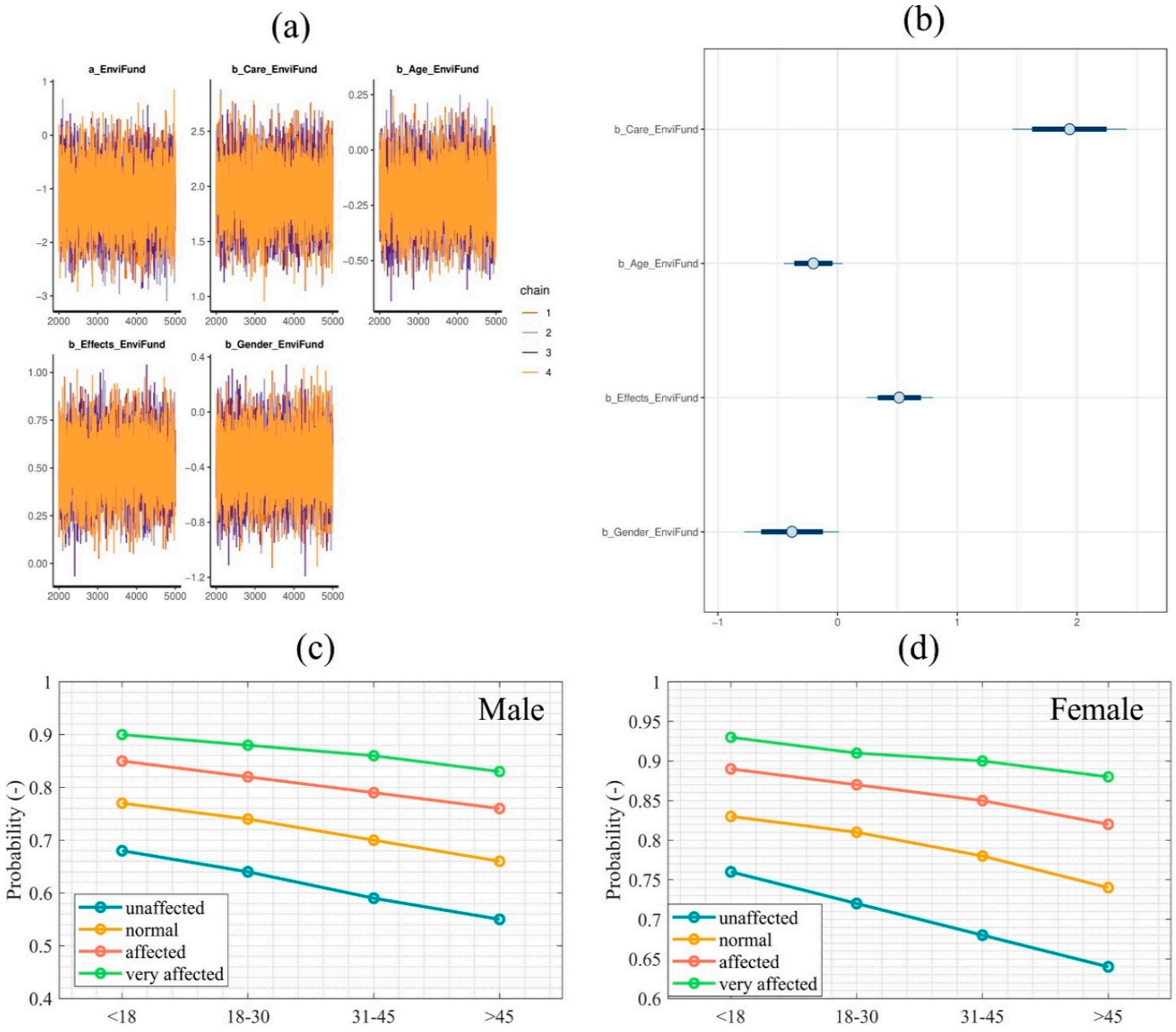

Figure 4. Trace plots for Model 2's posterior parameters (**a**), distribution of posterior coefficients estimated with uninformative priors (**b**), probabilities of supporting environmental fund intention based on age and perceived effects of male (**c**) and female (**d**) respondents.

Table 4. Estimated results of environment fund model.

				Percentile						
Variables	**Mean**	**se_Mean**	**Sd**	**2.5%**	**25%**	**50%**	**75%**	**97.5%**	**n_eff**	**Rhat**
a_EnviFund	−1.17	0.01	0.52	−2.25	−1.52	−1.17	−0.82	−0.14	6772	1
b_Care_EnviFund	1.94	0.00	0.24	1.46	1.77	1.94	2.10	2.41	8872	1
b_Age_EnviFund	−0.20	0.00	0.12	−0.45	−0.29	−0.29	−0.12	0.04	8025	1
b_Effects_EnviFund	0.52	0.00	0.14	0.24	0.42	0.51	0.61	0.80	7430	1
b_Gender_EnviFund	−0.38	0.00	0.20	−0.78	−0.52	−0.38	−0.24	0.01	9899	1

To gain further insights, we compared and contrasted the probability of different groups' contribution decisions regarding gender, age and perceived effects. It was evident that females were more likely to contribute to the environmental fund (Figure 4c,d). The more significant the impact of plastic pollution, the greater the likelihood of contribution, which was valid for all age groups and genders. Last but not least, the probability of contribution decreased with age (Figure 4c,d). In other words, the young are more likely to make a financial donation to the fund than their older counterparts.

- *Model 3: Determinants of relocating intentions*

Table 5 provides a breakdown of the factors influencing households' relocating intentions. The model's simulated results had a good convergence because the n_eff was greater than 1000 for all the variables, and the Rhat equalled 1. The trace plots also confirmed the good convergence of the model (Figure 5a). The posterior value of each parameter is represented on the y-axis, while the x-axis indicates the iteration order. As illustrated, the lines stick around a stable central tendency and follow a rapid zig-zag pattern, demonstrating that the Markov chain is stationary and well mixing. Table 5 further indicates that all the variables, namely age, CPY, income, and effects, were statistically significant. Specifically, there was a strong positive relationship between the perceived effects of plastic pollution and respondents' intentions to relocate due to pollution in their neighbourhood (mean = 0.5). Likewise, most of the distribution of income lies on the positive side of the axis in Figure 5b, indicating a highly reliable positive association between income and relocating (mean = 0.14). On the other hand, age and respondents' opinion of plastic pollution in their neighbourhood compared with previous years were negatively associated with relocating intentions.

Table 5. Estimated results of relocating intention model.

				Percentile						
Variables	**Mean**	**se_Mean**	**Sd**	**2.5%**	**25%**	**50%**	**75%**	**97.5%**	**n_eff**	**Rhat**
a_Relocate	−1.33	0.01	0.61	−2.53	−1.74	−1.33	−0.91	−0.16	5850	1
b_Age_ Relocate	−0.40	0.00	0.13	−0.66	−0.49	−0.40	−0.31	−0.14	8164	1
b_CPY_ Relocate	−0.60	0.00	0.14	−0.87	−0.69	−0.59	−0.51	−0.33	9512	1
b_Income_ Relocate	0.12	0.00	0.03	0.06	0.10	0.12	0.15	0.19	9388	1
b_Effects_Relocate	0.47	0.00	0.13	0.20	0.37	0.47	0.56	0.73	8000	1

The probability of households' relocating intentions due to local pollution was calculated (Figure 5c,d). Specifically, those on a high-income level had more intentions of moving house when environmental issues in the surrounding areas were too severe. In addition, for both low- and high-income households, the impacts of plastic pollution significantly influenced their relocating intentions, with higher probabilities for those most affected. Interestingly, when asked to compare plastic pollution with previous years, the respondents who did not know about the situation were more likely to relocate than those who considered the problem worse.

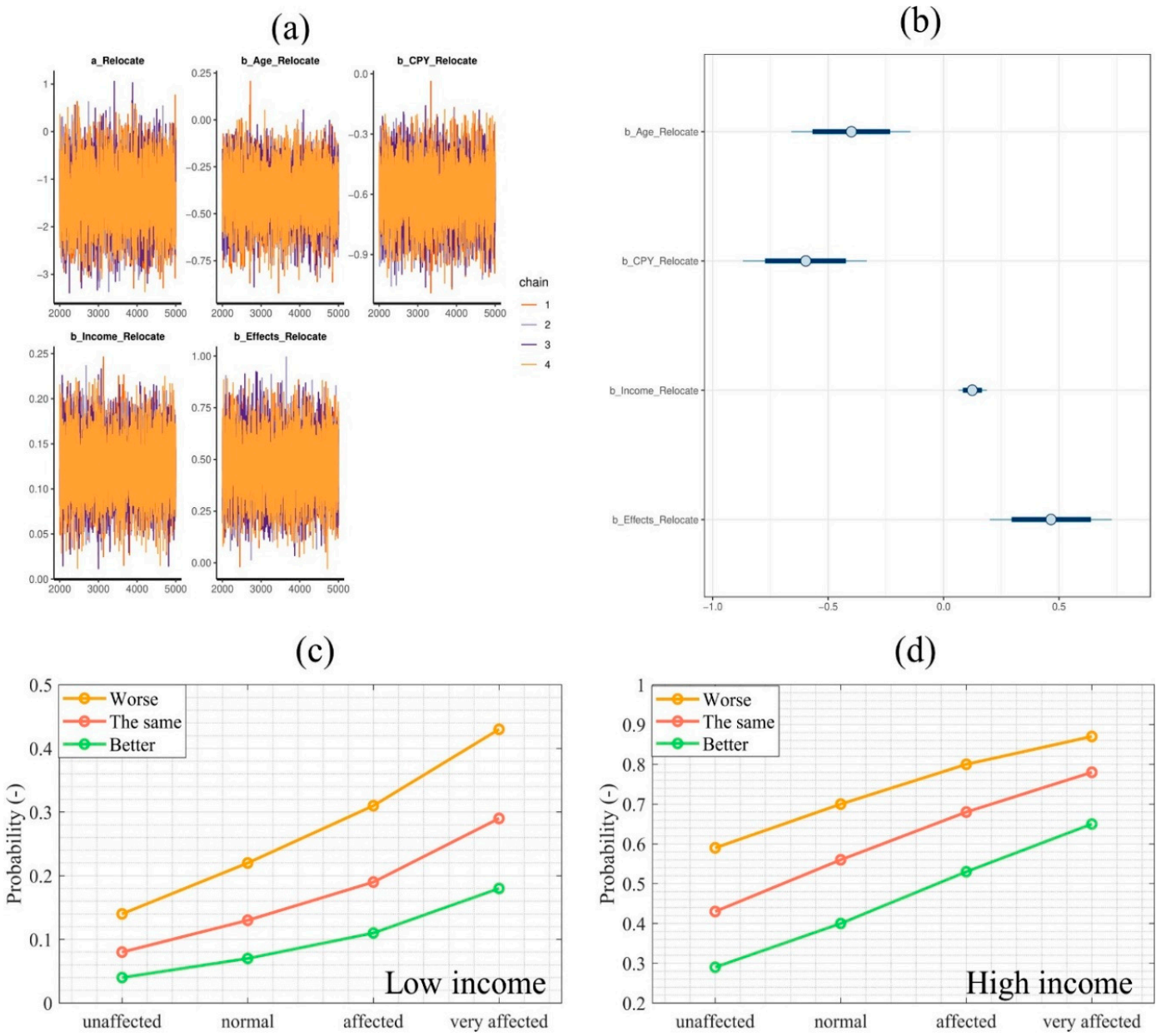

Figure 5. Trace plots for Model 3's posterior parameters (**a**), distribution of posterior coefficients estimated with uninformative priors (**b**), probabilities of relocating based on perceived changes in environment over time and of low (**c**) and high (**d**) income households.

6. Discussions

The current study examined the willingness to contribute to waste management funds, plastic waste-sorting behaviours and relocating intentions due to plastic pollution among 730 households in Northern Vietnam. This study employed the Bayesian mindsponge framework and the logit models to determine the factors influencing the households' responses to plastic pollution. The results showed that age and perceived effects impacted plastic waste sorting, the contribution to waste management funds "white pollution" induced migration. It is also interesting to note that concern over plastic pollution was the most decisive factor predicting willingness to contribute to waste management funds and plastic waste-sorting behaviours in this study. Furthermore, fund contribution and waste sorting were motivated by gender and communication, respectively. Regarding relocating intentions, the respondents' income and the comparison between current and past plastic pollution in the neighbourhood also had significant impact.

Our results showed a positive relationship between individuals' care about the environment and their intentions on waste sorting and contribution to the fund that aims to end plastic pollution. Similar findings were reported in other studies [35,37,41]. It was the same for residents' perceived effects. As expected, concern and impact induce residents to help mitigate this global issue. The chances are that environment-conscious residents will inquire into the relevant matters and grasp the far-reaching effects of plastic pollution on human life to some extent. These all increase their willingness to sort waste [74]. Furthermore, if the fund serving this solution does live up to their expectations, people will be encouraged to join hands to combat plastic pollution. In other words, care and perceived effects, indeed, induce actions [75], and environmental protection starts from the minor step (waste sorting) at the individual level to a more extensive action at the national/regional level (financial donation). We suggest organising activities such as demonstration projects to show the before and after effects of plastic pollution to enhance people's engagement.

Vietnam's government already introduced a new fine regime on those who fail to sort waste on August 25 [76] to facilitate environmental protection, and its success greatly depends on citizens' compliance. Interestingly, our findings suggest that communication positively impacts residents' intentions on waste sorting. If adopted by most households, this practice can ease waste management and processing burdens, promote resource recovery and reduce operational costs. Waste sorting is a relatively novel term for Vietnamese people. This may stem from their indifference to pollution or lack of knowledge of proper methods for waste management at home [77]. The waste-sorting practice is easy, simple, yet effective, and the perceived ease of implementation is a critical driving force [78,79]. Therefore, short education courses on determining and classifying different types of waste should be organised for households and monitored by experts in this field. Governing bodies can consider using official communication channels to boost reliability and highlight the importance of these training sessions. Furthermore, to encourage public participation, the government can devise policies that financially reward households for adopting good environmental practices. The semiconducting principle states that ecological value can be converted into monetary value, yet not vice versa [80]. Rewards come from the national budget, environmental fund, or a fund designated to address plastic pollution.

Research shows that females have a better understanding and knowledge of waste management because they are more engaged in household chores. Although some studies found gender statistically insignificant [35,44,45], our study results found that females were more willing to dedicate money to waste management, which is in line with other research [41]. In Asian countries, women generally pay close attention to family members' health, especially their children's, thus favouring fund donation.

In addition, the younger generation has a higher awareness of environmental issues in general and plastic pollution in particular, compared with the older age group. Moreover, pollution is scientifically proven to exert detrimental ramifications on one's well-being and capabilities [41]. Hence, the young actively seek new practical solutions to plastic pollution, adopt pro-environmental behaviours and knowledge-seeking practices [81]. This supports our findings that young people have a higher probability of all three pro-environmental measures to combat plastic pollution: waste-sorting practice, fund donation and relocation. Furthermore, migration or regional relocation may cause intangible costs such as culture shock [82] from which the young have more time for adaptation and recovery. Those in older age groups may already have a stable, desirable career, so moving to a new living environment can result in a more significant perceived loss of income and higher perceived livelihood risks than for young people. This finding is consistent with research on the association between air pollution and international and/or domestic migration [15]. In Vietnam, culture dictates that the elderly wish to stay in their hometown to pass their old age peacefully; hence, there is a lower probability of plastic pollution-induced domestic and international migration.

We found that significant impacts of sustained and perceived deteriorating plastic pollution are positively associated with residents' relocation decisions. When plastic

pollution is no longer something only in the news, the direct experience of its impacts on daily life wakes people up to seek a solution to plastic pollution. Although relocation can depend on information about living conditions, job opportunities, and living costs in the destination area, the intention to move away from the existing polluted environment is real. Underlying reasons for either domestic or international migration can be explained by choice-making theory [83], the theory of the mindsponge mechanism associated with cost-benefit judgments [84,85] and the theory of serendipity [86]. The decision-making process involves cost-benefit analysis by constant information updating via active search or chance conversations with others, i.e., neighbours. The information can be related to alternative living areas, new nearby landfills, impacts of plastic pollution, and financial support from the government compared to expenses and living expenses in the destination area.

If the benefits outweigh the costs, individuals will decide on a certain course of action, specifically migration. Migration potentially leads to brain drain since, in all likelihood, those migrating are the well-trained and high-quality workforce. A study by Khuc et al. (2022) [15] shows that air pollution incentivises people to migrate; hence, a brain drain in the source country. The responsibility to solve this socioeconomic problem largely hinges on the government and higher authorities, who should carefully consider the locations of landfills to ensure the public's comfortable life. Our findings will encourage countries that have done a good job protecting their residents' living environment. However, our research also signals that severely polluted countries should take steps to enhance living conditions for brain drain prevention.

Our study also finds that higher income increases the likelihood of moving to different living areas or countries. When residing in a new place, households will sustain a colossal relocation cost, especially housing expenses and costs of job loss. Transregional relocation may lead to a moderate increase in household spending yet transnational relocation would cost a fortune. Although developed countries are indicated to suffer less severe pollution [87], living expenses are higher than in developing countries by a wide margin. Therefore, with the inherent high risks, limited financial resources discourage intentions on relocation, thus forcing households on low income to powerlessly accept plastic pollution. This explains why low-income families are either accustomed to or resigned to plastic pollution in the source area or country. In contrast, after a cost-benefit analysis, high income encourages residents to move away from their current polluted residence to less polluted areas.

Since Vietnam, a typical developing country, is dealing with a burgeoning amount of plastic waste, it is crucial to study the drivers of public participation in waste management. This study makes both theoretical and empirical contributions. First, we contributed to the literature by identifying key determinants of households' responses to plastic pollution under the influence of socioeconomic factors and environmental impacts. We also emphasise the role of environmental stressors in the decision-making process, thus helping to enhance the sustainable livelihood framework. Furthermore, our study provides evidence for the authorities to effectively implement policies comprehensively, ranging from the circular economy, public–private partnership in waste management and fund contributions to strengthening the economy with a high-quality workforce [15,88]. Lastly, through this duty, the mindsponge and serendipity framework [89] have been proved a highly effective means to examine and explain the process of decision making, even with such a difficult and complicated decision as migration. This is thanks to their cost-benefit analysis, which is updated regularly where they are exposed to new information through communicating with others or watching the news. However, building an environmental culture can be described as challenging because it takes time and resources for people to change their core values and internalize environmental values [81]. Overall, our findings accentuate the demand for long-term consideration in resource management and environmental policies based on an "eco-surplus culture" [90].

However, our research also has certain limitations. First, the study was conducted online due to the COVID-19 pandemic and its preventive measures [91]. To improve this, we might

seek to collect more data offline and extend our area of research outside Northern Vietnam in the near future. Second, given the data limitations and topic orientation, we did not delve into pollution-induced migration flows. Yet, we intend to examine this issue since it will potentially reveal the seriousness of the respondents' intentions. We might look into their intended destination, domestic or foreign, and the distances from their current living location to extrapolate the future trends and hopefully calculate their cost-benefit analysis. Lastly, our study only identifies the factors influencing waste management strategies; thus, we plan to trace and update this dataset in around 3–5 years to examine the dynamics of behavioural changes over time and focus on each response to enhance the corresponding model.

7. Conclusions

By and large, this paper has three major contributions to the field of waste management and pollution research. First, it empirically confirms the significant effects of a diverse set of variables on multiple households' strategies to face the "white solution," highlighting the role of propaganda and pilot demonstration in shaping public awareness. Second, it explores the risk of brain drain due to plastic pollution, which previous researchers have largely overlooked. Third, in terms of methodology, the Bayesian mindsponge framework (BMF) has been proved as a versatile technique for analysing human reactions to pollution. As the BMF allows the update of information over time, the results can be updated in the future to monitor the impact of new environmental policies. Furthermore, as the probabilities of different reactions are calculated, the government can allocate resources effectively in awareness campaigns. The findings provide insightful inputs for policy-makers, environmental activists, and researchers in the field of plastic waste management in particular and the circular economy in general. The study has stressed the role of communication and awareness, which are the surface level of subtler factors such as trust, transparency, and commitment. Demographic parameters and income are also crucial factors to consider in designing and implementing regional-level policies. A successful plastic-recycling system can only be built with cooperation between the government and society. To mobilize scarce resources for this purpose, the government should encourage public–private partnership initiatives and ensure the participation and monitoring of citizens. Policy-makers should prevent the migration of skilled labour by improving the environmental quality. Meanwhile, they should provide support for low-income people in highly polluted areas to relocate to avoid destructive health impacts. There are various ways this work can be extended. For instance, we can collect the following data to analyse time-chasing behaviours and capture the development in awareness. Furthermore, the scale of the study can be extended to other regions and countries, resulting in comparative data sets. Future research could also look closely into each household's strategy to explore the more profound elements of the complexity of the decision-making process.

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