Supplementary Material for

"Environmental Culture and Willingness to Pay for Clean Air: A Cultural Additivity Perspective and Bayesian Mindsponge Method"

Supplementary Table

S1. Demographic robustness

The primary model was re-estimated with age group, gender, household-head status, and education level included as additive adjustment covariates. The demographic-adjusted specification used the same analytical sample of 604 respondents as the primary analysis.

Table S1. MCMC diagnostics for the primary and demographic-adjusted models

Model specification	Maximum R-hat	Minimum Bulk-ESS	Minimum Tail-ESS	Divergent transitions	Maximum tree depth
Primary Bayesian cumulative ordinal-logit model	1.001	5,705	8,081	0	6
Demographic-adjusted Bayesian cumulative ordinal-logit model	1.001	4,735	7,135	0	5

Note. *R-hat values close to 1.00, large effective sample sizes, and zero divergent transitions indicate satisfactory posterior sampling in both specifications.*

Table S2. Robustness of income interaction effects to demographic adjustment

Focal interaction	Model specification	Posterior mean	Posterior SD	95% posterior interval	P(direction)
Income*PollutionUrgency	Primary model	0.425	0.179	[0.077, 0.774]	0.992
Income*PollutionImpact	Primary model	-0.004	0.176	[-0.351, 0.336]	0.495
Income*AvoidanceBehavior	Primary model	0.376	0.147	[0.087, 0.667]	0.995
Income*AirSatisfaction	Primary model	-0.136	0.176	[-0.484, 0.206]	0.780
Income*PollutionUrgency	Demographic-adjusted model	0.396	0.183	[0.038, 0.756]	0.985
Income*PollutionImpact	Demographic-adjusted model	-0.020	0.182	[-0.377, 0.335]	0.453
Income*AvoidanceBehavior	Demographic-adjusted model	0.410	0.148	[0.115, 0.699]	0.997
Income*AirSatisfaction	Demographic-adjusted model	-0.264	0.181	[-0.617, 0.088]	0.928

Note. *For the three positively hypothesized interactions, the reported directional probability is P(beta > 0). For Income*AirSatisfaction, P(beta < 0) is reported descriptively because H9 is non-directional; H9 is evaluated by whether the*

posterior distribution provides clear evidence that the association varies across income levels. Posterior intervals are the 2.5th and 97.5th percentiles from the sensitivity output.

Table S3. Posterior estimates for demographic adjustment covariates

Demographic characteristic	Posterior mean	Posterior SD	95% posterior interval	P(beta > 0)
Age: Below 21 vs 21–30	0.287	0.260	[-0.222, 0.792]	0.867
Age: 31–40 vs 21–30	-0.332	0.202	[-0.729, 0.071]	0.052
Age: 41–50 vs 21–30	-0.480	0.228	[-0.932, -0.037]	0.017
Age: 51–60 vs 21–30	0.059	0.331	[-0.596, 0.703]	0.569
Age: Above 60 vs 21–30	0.072	0.525	[-0.958, 1.107]	0.556
Gender: Female vs Male	0.059	0.159	[-0.253, 0.368]	0.648
Household-head status: Yes vs No	0.014	0.197	[-0.376, 0.399]	0.530
Education: Secondary school vs Bachelor's Degree	-0.744	0.499	[-1.715, 0.229]	0.066
Education: High school vs Bachelor's Degree	0.072	0.219	[-0.357, 0.503]	0.630
Education: Technical school / College degree vs Bachelor's Degree	-0.183	0.282	[-0.740, 0.365]	0.258
Education: Master's Degree vs Bachelor's Degree	0.319	0.343	[-0.362, 1.007]	0.826
Education: Doctoral Degree vs Bachelor's Degree	0.048	0.731	[-1.382, 1.474]	0.528

Note. *Reference categories are age 21–30 years, Male, non-household-head status, and Bachelor's Degree. Demographic variables are included as adjustment covariates rather than as theoretical components of the focal model.*

Table S4. Predictive comparison and Pareto-k diagnostics for demographic robustness

Model specification	ELPD-LOO	SE of ELPD-LOO	pLOO	LOOIC	Maximum Pareto-k	N(k > 0.7)
Primary model	-967.95	15.97	15.05	1935.90	0.255	0
Demographic-adjusted model	-971.17	16.63	26.56	1942.33	0.284	0

Note. *The ELPD difference for the demographic-adjusted model relative to the primary model was -3.22 (SE = 3.81). Higher ELPD-LOO and lower LOOIC indicate better expected out-of-sample predictive performance. No observation exceeded Pareto-k = 0.7.*

S2. Functional-form sensitivity of the ordinal predictors

Two alternative parameterizations were used to examine whether inference depended on treating the ordinal environmental predictors as equally spaced numeric variables: Bayesian monotonic effects and unrestricted categorical indicators. All specifications retained the same cumulative ordinal-logit outcome model and analytical sample.

Table S5. MCMC diagnostics and PSIS-LOO predictive performance across functional-form specifications

Model specification	Maximum R-hat	Minimum Bulk-	Minimum Tail-	Divergent transition	ELPD-LOO	SE of ELPD	pLOO	LOOIC	Maximum Pareto-k

		ESS	ESS	s		-LOO			
Primary numeric specification	1.001	5,705	8,081	0	-967.95	15.97	15.05	1935.90	0.255
Monotonic-effects specification	1.001	4,329	4,376	0	-967.69	15.80	18.68	1935.38	0.595
Categorical-indicator specification	1.001	5,042	7,958	0	-971.22	15.82	23.81	1942.43	0.382

Note. *All specifications exhibited satisfactory posterior sampling. The monotonic-effects specification was evaluated after moment matching; one observation exceeded Pareto-k = 0.5, and none exceeded 0.7.*

Table S6. Pairwise PSIS-LOO comparisons of functional-form specifications

Model comparison	Absolute ELPD difference	SE of ELPD difference
Primary numeric vs monotonic-effects	0.26	2.61
Primary numeric vs categorical-indicator	3.27	3.20
Monotonic-effects vs categorical-indicator	3.52	2.10

Note. *Absolute ELPD differences should be interpreted together with their standard errors. Differences small relative to their standard errors provide limited evidence of meaningful predictive superiority.*

Table S7. Posterior simplex weights from the monotonic-effects specification

Ordinal predictor	Simplex component	Posterior mean	Posterior SD	2.5%	97.5%
AirSatisfaction	1	0.296	0.203	0.016	0.773
AirSatisfaction	2	0.223	0.184	0.008	0.688
AirSatisfaction	3	0.482	0.248	0.030	0.892
AvoidanceBehavior	1	0.232	0.146	0.018	0.580
AvoidanceBehavior	2	0.768	0.146	0.420	0.982
PollutionImpact	1	0.601	0.226	0.094	0.964
PollutionImpact	2	0.399	0.226	0.036	0.906
PollutionUrgency	1	0.726	0.120	0.473	0.951
PollutionUrgency	2	0.274	0.120	0.049	0.527

Note. *Simplex weights describe the relative contribution of successive ordinal transitions to the overall monotonic effect. Unequal weights indicate non-equidistant transitions but do not by themselves establish substantive inadequacy of the primary numeric specification.*

Table S8. Focal interaction estimates under alternative functional-form parameterizations

Model specification	Focal interaction / contrast	Posterior mean	95% posterior interval
Primary numeric	Income*PollutionUrgency	0.425	[0.077, 0.774]
Primary numeric	Income*AvoidanceBehavior	0.376	[0.087, 0.667]

Categorical indicators	Income*PollutionUrgency: Moderately urgent vs Not urgent	0.840	[0.138, 1.535]
Categorical indicators	Income*PollutionUrgency: Highly urgent vs Not urgent	1.017	[0.290, 1.728]
Categorical indicators	IncomeAvoidanceBehavior: Moderate vs Minimal	0.279	[-0.151, 0.699]
Categorical indicators	Income*AvoidanceBehavior: Extensive vs Minimal	0.796	[0.158, 1.454]

Note. *Categorical-indicator coefficients are defined relative to the stated reference category and are not directly comparable in magnitude with coefficients from the numeric specification. The table documents directional and posterior-support patterns across parameterizations.*

S3. Assessment of the proportional-odds assumption and ordinal-model structural sensitivity

The proportional-odds assumption of the primary Bayesian cumulative ordinal-logit model was assessed through a structured sensitivity analysis that relaxes the common-slope restriction. A common-slope adjacent-category ordinal-logit model was first estimated as a within-family reference, followed by category-specific extensions for Income, PollutionUrgency, PollutionImpact, AvoidanceBehavior, and AirSatisfaction. Within-family comparisons therefore assess whether allowing a given predictor block to vary across response categories improves expected out-of-sample predictive performance. The primary cumulative ordinal-logit model remains the substantive reference specification, while the alternative adjacent-category models are used only for this assumption assessment.

Table S9. Model diagnostics and PSIS-LOO performance for the proportional-odds assumption assessment

Model specification	Maximum R-hat	Minimum Bulk-ESS	Minimum Tail-ESS	Divergent transitions	ELPD-LOO	SE of ELPD-LOO	pLOO	LOOIC	Maximum Pareto-k
Primary Bayesian cumulative ordinal-logit model (proportional odds)	1.001	5,705	8,081	0	-967.9	15.97	15.05	1935.90	0.255
Alternative adjacent-category ordinal-logit model (common slopes)	1.002	5,354	7,874	0	-974.0	15.97	15.89	1948.00	0.388
Alternative	1.001	5,580	8,106	0	-947.8	16.39	22.22	1895.67	0.284

adjacent-category ordinal-logit model (category-specific PollutionUrgency effects)									

Note. *MCMC diagnostics assess sampling reliability and do not themselves assess proportional odds. The proportional-odds assessment is based on predictive comparisons between the common-slope adjacent-category model and its category-specific extensions. All reported Pareto-k values were below 0.5.*

Table S10. Predictor-specific assessment of the proportional-odds/common-slope restriction

Reference model	Alternative model	Difference in ELPD (alternative - reference)	SE of ELPD difference	ELPD difference / SE
Adjacent-category ordinal-logit model (common slopes)	Adjacent-category ordinal-logit model (category-specific Income effects)	-3.05	1.29	-2.37
Adjacent-category ordinal-logit model (common slopes)	Adjacent-category ordinal-logit model (category-specific PollutionUrgency effects)	26.16	7.46	3.51
Adjacent-category ordinal-logit model (common slopes)	Adjacent-category ordinal-logit model (category-specific PollutionImpact effects)	4.50	5.18	0.87
Adjacent-category ordinal-logit model (common slopes)	Adjacent-category ordinal-logit model (category-specific AvoidanceBehavior effects)	-1.78	3.32	-0.54
Adjacent-category ordinal-logit model (common slopes)	Adjacent-category ordinal-logit model (category-specific AirSatisfaction effects)	4.94	4.96	1.00
Primary cumulative ordinal-logit model (proportional odds)	Adjacent-category ordinal-logit model (category-specific PollutionUrgency effects)	20.12	7.04	2.86

Note. *Within-family comparisons between the common-slope adjacent-category ordinal-logit model and each category-specific extension provide the direct sensitivity-based assessment of the common-slope restriction. A positive ELPD difference indicates improved expected predictive performance when that restriction is relaxed for the stated predictor block. The final row is a supplementary cross-family comparison with the primary cumulative proportional-odds model.*

Table S11. Posterior predictive diagnostics for the proportional-odds sensitivity assessment

Model specification	Mean absolute error	Root mean squared error

Alternative adjacent-category ordinal-logit model (category-specific PollutionUrgency effects)	0.000161	0.000252
Alternative adjacent-category ordinal-logit model (common slopes)	0.000629	0.000783
Primary Bayesian cumulative ordinal-logit model (proportional odds)	0.002398	0.003053

Note. *Mean absolute error and root mean squared error summarize deviations between observed WTP-category proportions and posterior-predicted proportions. These descriptive checks complement the PSIS-LOO comparisons used to assess sensitivity to the common-slope restriction.*

Table S12. Conditional predicted-probability sensitivity after relaxing the common-slope restriction for PollutionUrgency

WTP category (thousand VND)	Mean absolute difference in predicted probability	Maximum absolute difference in predicted probability
0	0.0375	0.1064
≤30	0.1047	0.4918
31–50	0.0455	0.2095
51–100	0.0207	0.0941
101–300	0.0383	0.0797
>300	0.0105	0.0717

Note. *Differences are calculated across the Income*PollutionUrgency prediction grid separately for each WTP category. Larger values indicate greater sensitivity of predicted probabilities when the common-slope restriction for PollutionUrgency is relaxed.*

Taken together, the structural sensitivity results indicate a localized departure from the common-slope representation for PollutionUrgency. Allowing category-specific effects improved predictive performance (ΔELPD = 26.16, SE = 7.46) and suggested that the positive association of perceived pollution urgency was more pronounced for transitions toward higher WTP categories. Importantly, this heterogeneity did not materially alter the direction or substantive interpretation of the supported Income*PollutionUrgency interaction. The primary cumulative ordinal model was therefore retained as the parsimonious reference specification, with PollutionUrgency interpreted as an overall association across the ordered WTP outcome.

S4. Prior sensitivity

The primary model was re-estimated using theory-informed informative priors while holding the data, likelihood, structural specification, centering procedure, and MCMC settings unchanged. Directional prior means were used only where the theoretical expectation was sufficiently clear; zero-centred regularizing priors were used for less determinate relationships.

Table S13. Baseline and theory-informed prior specifications

Parameter	Baseline weakly informative prior	Theory-informed informative prior	Prior rationale

Income	Normal(0, 1)	Normal(0.30, 0.50)	Positive theoretical expectation
PollutionUrgency	Normal(0, 1)	Normal(0.30, 0.50)	Positive theoretical expectation
PollutionImpact	Normal(0, 1)	Normal(0.30, 0.50)	Positive main-association expectation
AvoidanceBehavior	Normal(0, 1)	Normal(0.30, 0.50)	Positive theoretical expectation
AirSatisfaction	Normal(0, 1)	Normal(0, 0.50)	Direction not imposed
Income*PollutionUrgency	Normal(0, 0.50)	Normal(0.20, 0.35)	Positive focal moderation expectation
Income*PollutionImpact	Normal(0, 0.50)	Normal(0, 0.35)	Direction conservatively unspecified
Income*AvoidanceBehavior	Normal(0, 0.50)	Normal(0.20, 0.35)	Positive focal moderation expectation
Income*AirSatisfaction	Normal(0, 0.50)	Normal(0, 0.35)	Direction not imposed
Ordinal thresholds	Student-t(3, 0, 2.5)	Student-t(3, 0, 2.5)	Unchanged across specifications

Note. *The prior-sensitivity model changes only the prior specification. Threshold priors are held constant. Zero-centred informative priors regularize plausible magnitude without imposing a directional sign.*

Table S14. Posterior coefficient sensitivity to theory-informed informative priors

Hypothesis	Predictor	Baseline posterior mean (SD)	Informative-prior posterior mean (SD)	Change in posterior mean	Sign preserved
H1	Income	0.334 (0.101)	0.335 (0.100)	+0.001	Yes
H2	PollutionUrgency	0.451 (0.148)	0.450 (0.142)	-0.001	Yes
H3	PollutionImpact	0.295 (0.141)	0.306 (0.136)	+0.011	Yes
H4	AirSatisfaction	-0.203 (0.134)	-0.191 (0.129)	+0.012	Yes
H5	AvoidanceBehavior	0.336 (0.109)	0.338 (0.111)	+0.002	Yes
H6	Income*PollutionUrgency	0.425 (0.179)	0.428 (0.163)	+0.003	Yes
H7	Income*PollutionImpact	-0.004 (0.176)	0.002 (0.164)	+0.006	No
H8	Income*AvoidanceBehavior	0.376 (0.147)	0.379 (0.141)	+0.003	Yes
H9	Income*AirSatisfaction	-0.136 (0.176)	-0.122 (0.164)	+0.014	Yes

Note. *The table compares posterior location and dispersion under the two prior specifications. The small sign change for Income*PollutionImpact occurs around a posterior mean essentially equal to zero and should be read together with its broad posterior uncertainty rather than as evidence of a substantive reversal.*

Supplementary Figure

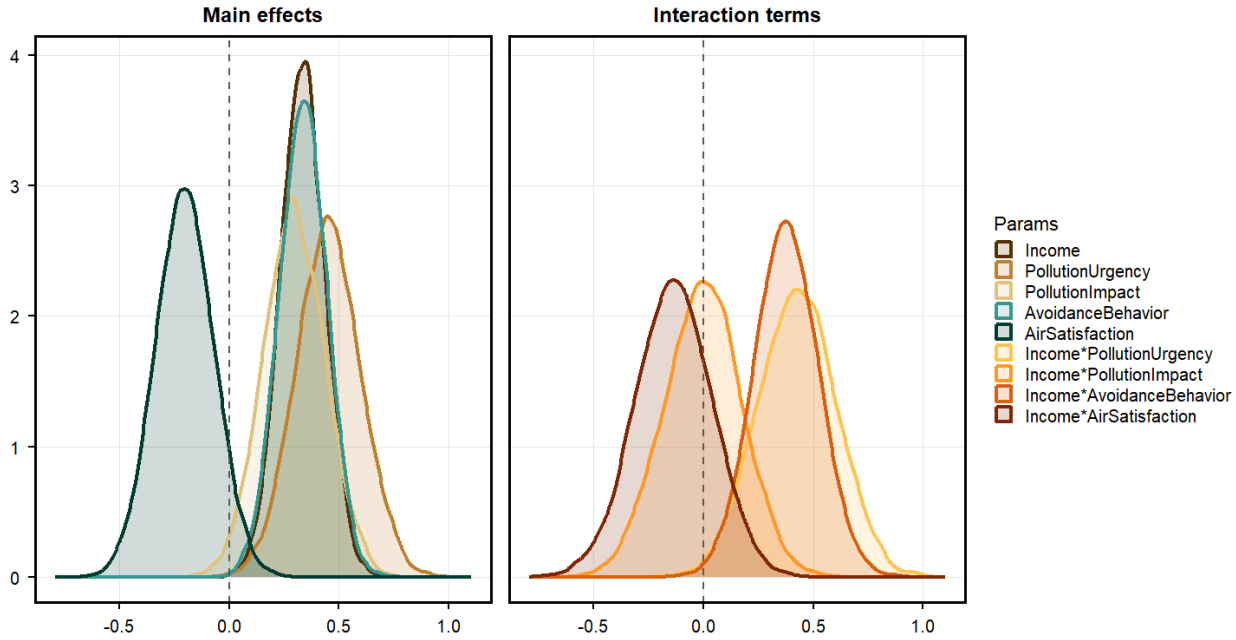


Figure S1. Density plot

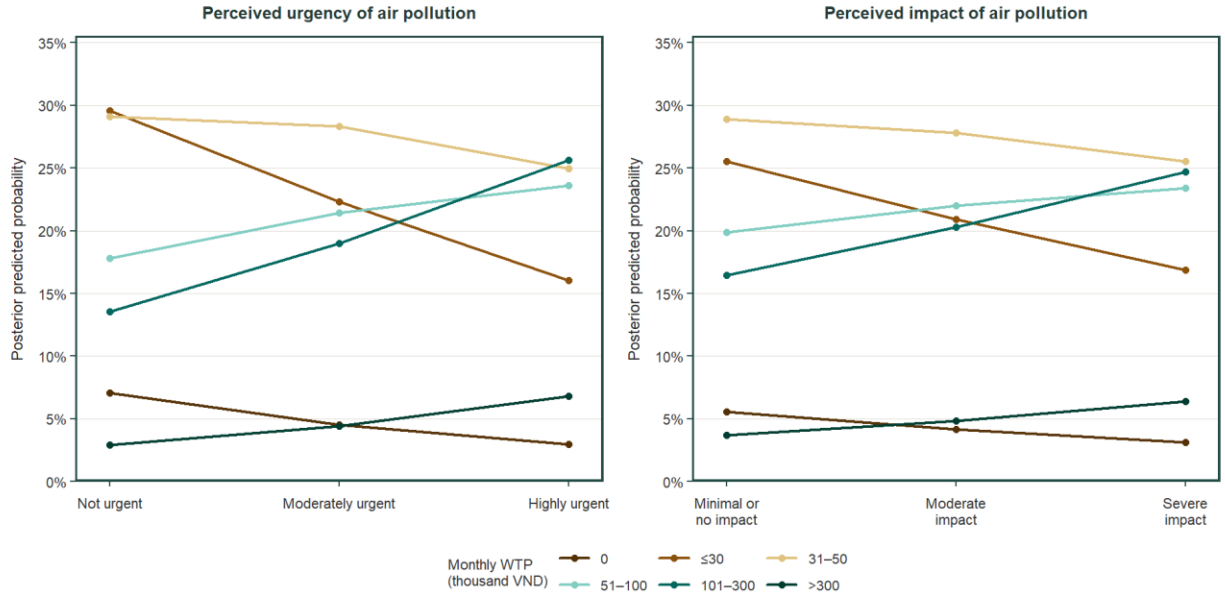


Figure S2. Posterior predicted WTP-category probabilities across levels of perceived pollution urgency and perceived pollution impact.

Note. Lines show posterior mean probabilities for the six observed WTP categories. Category-specific uncertainty bands are not displayed in this supplemental panel; the focal interaction predictions with 95% credible bands are reported in Figure 6 of the main manuscript.

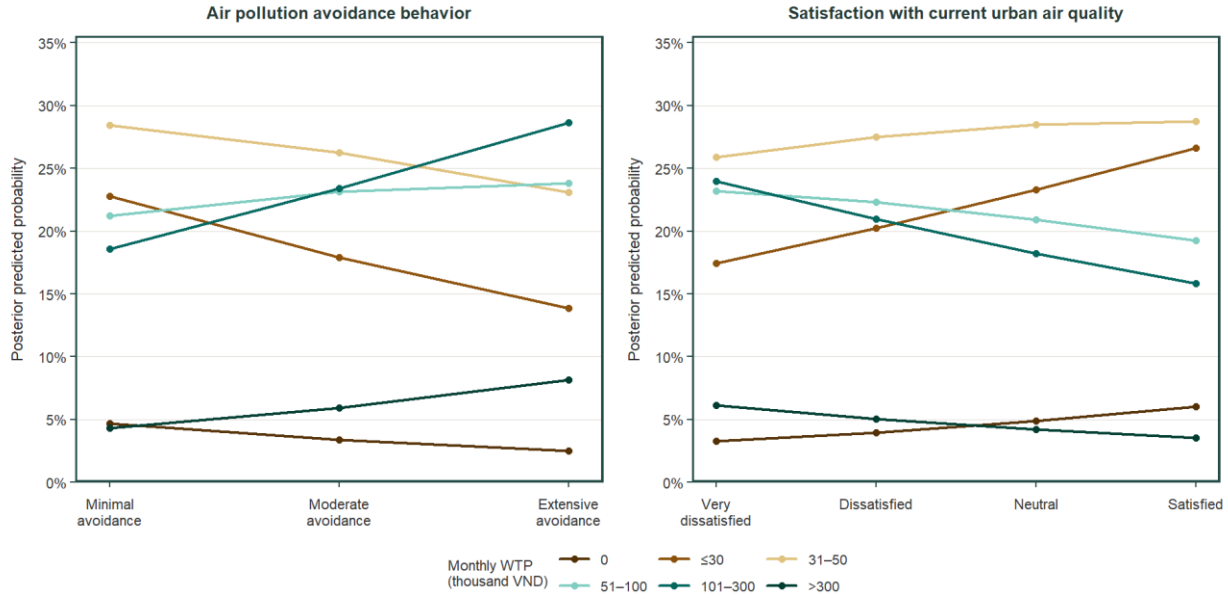


Figure S3. Posterior predicted WTP-category probabilities across levels of avoidance behavior and air quality satisfaction

Note. Lines show posterior mean probabilities for the observed predictor levels. No respondent selected the "Very satisfied" AirSatisfaction category (5), so that unobserved predictor level is not plotted in order to avoid extrapolation beyond observed support. Category-specific uncertainty bands are not displayed in this supplemental panel; the focal interaction predictions with 95% credible bands are reported in Figure 6 of the main manuscript.

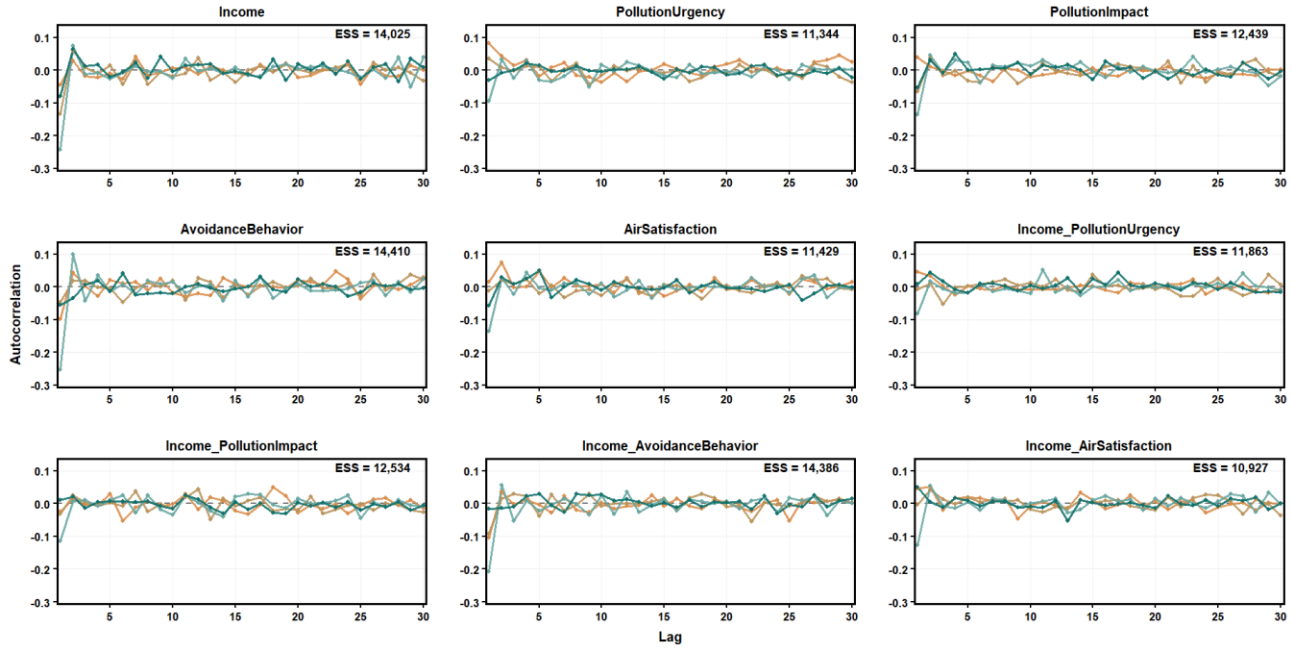


Figure S4. Autocorrelation plots

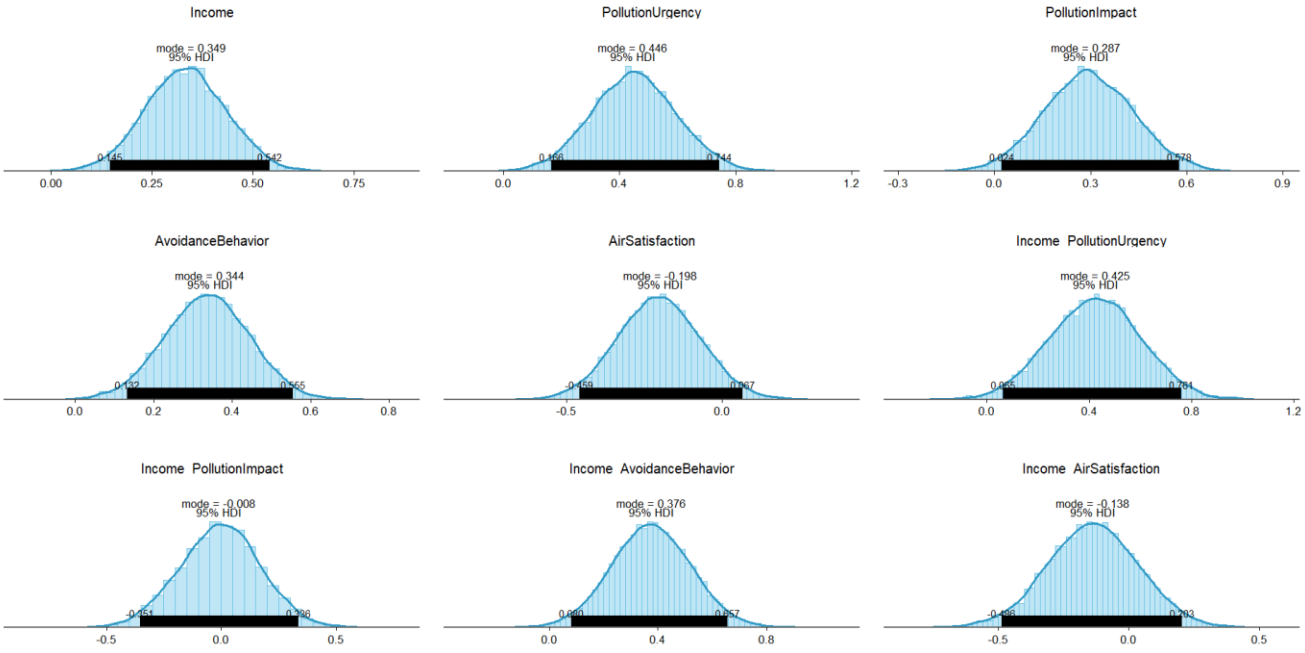


Figure S5. Parameters' posterior distributions with HPDI at 95%

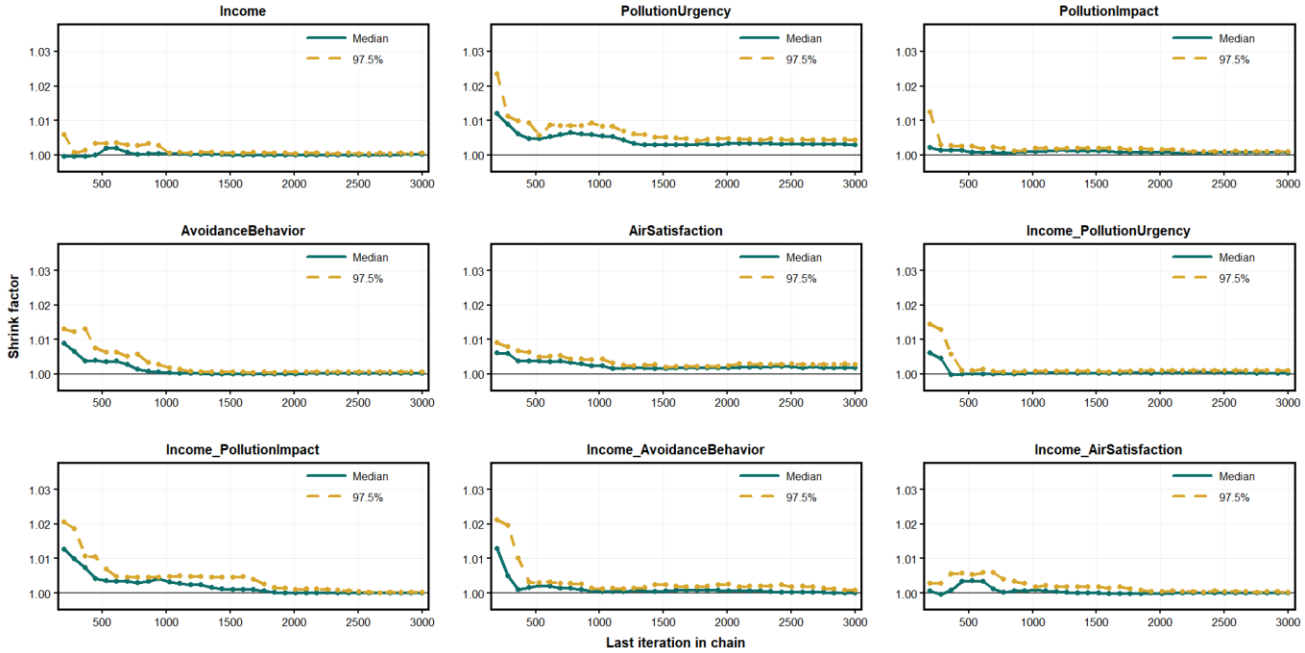


Figure S6. Gelman plot

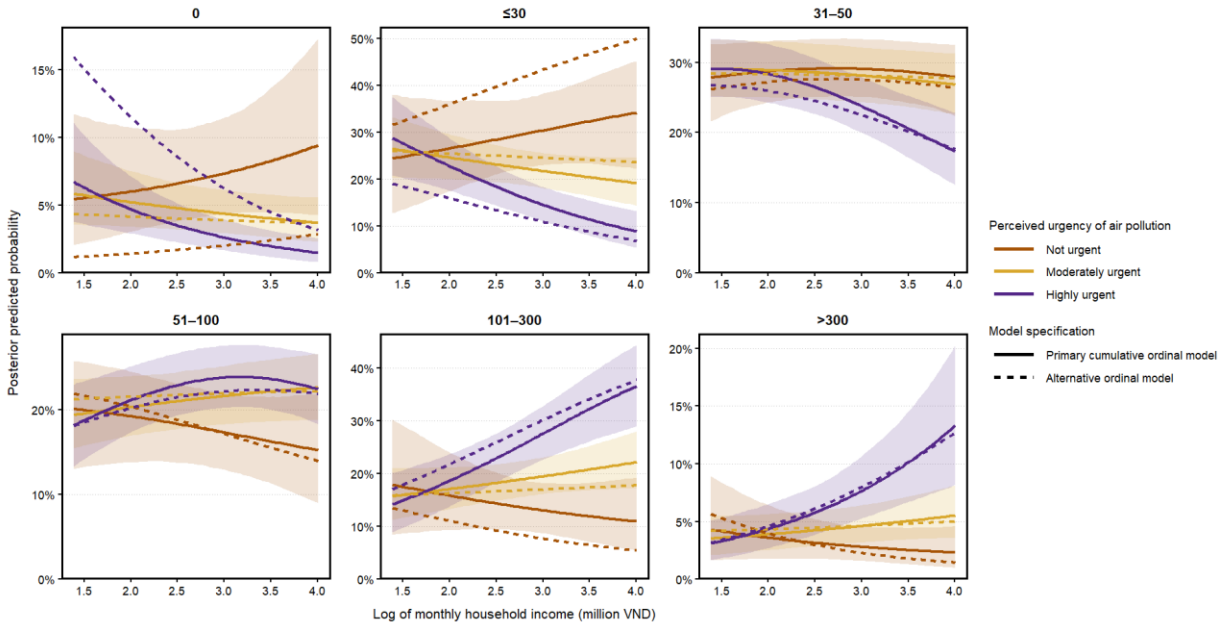


Figure S7. Robustness comparison of posterior predicted WTP-category probabilities under the primary and alternative ordinal model specifications