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Overtourism and Local Environmental Responsibility: Nonlinear Effects of Tourism Demand with Metropolitan-Area Moderation Across Municipalities in South Korea

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Abstract

This study examines how rising tourism demand reshapes residents' environmental responsibility behaviors (ERB) in South Korea, and the moderating role of metropolitan status therein. Using a balanced panel of 174 municipalities over 2015–2023, semi-log regression with a quadratic tourism-demand term and Driscoll–Kraay standard errors is applied to address heteroskedasticity, autocorrelation, and cross-sectional dependence. The estimates show that tourism demand displays a positive effect on ERB (a 6.6% increase in recycling volume proxy per million visitors) up to a certain threshold, beyond which the influence reverses—consistent with an inverted U-shaped relationship under overtourism. Turning points are approximately 11.06 million visitors for non-metropolitan municipalities and 6.95 million for metropolitan ones, where saturation occurs earlier. The negative interaction between metropolitan status and the squared tourism-demand term indicates that the erosion is sharper in metropolitan areas. Among controls, inbound visitor share (+2.8%), regional population (+3.6% per ten thousand residents), resident cost-sharing ratio (+0.4%), tourism special zones (≈1.45 times non-designated areas), tourism complexes (+19.2%), and COVID-19 intervention (≈1.30 times pre-pandemic) are significant, while the fiscal self-reliance ratio exhibits a small adverse impact. These findings suggest tourism policy should favor demand-management over growth-oriented strategies, aligned with regional structural differences and community-based environmental governance.

Keywords: environmental responsibility behavior; inverted U-shape; metropolitan area; overtourism; panel data model; recycling volume; South Korea

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1. Introduction

While tourism has contributed to regional economic growth, it has also resulted in environmental degradation and social imbalances [1–3]. In particular, the recent spatial and temporal overconcentration of tourism demand threatens community sustainability beyond the mere physical problems of traffic congestion, heightened waste generation, and noise pollution [4]. Short-term surges in tourist arrivals sharply increase demand for public services—waste management, sewage systems, and transportation infrastructure—thereby imposing burdens that may exceed local governments' environmental management capacity and disrupt routine operational systems [5]. These cumulative environmental and social pressures not only degrade residents' quality of life but also induce behavioral fatigue, which in turn impairs everyday pro-environmental behaviors such as norm compliance and source-separated waste disposal [6–8].

Against this background of intricate issues, prior studies have primarily focused on the adverse environmental and societal effects of tourism, dissecting overtourism from multiple perspectives. Representative research themes include the irreversible impacts of tourism growth on environmental pollution (CO_2 emissions) [9], the relationship between overtourism and solid waste generation [10], physical pressure and environmental stress in urban tourism contexts [11], nighttime tourism economies and the erosion of local livability [12], tourist–resident conflicts and the differentiation of residents' emotional responses [13], the transition mechanism of resident perceptions from hospitality to hostility [14], and value destruction and communal resistance among residents [15]. Overall, the literature has approached the effects of overtourism along two main lines: one stream rigorously scrutinizes the physical and environmental consequences of increasing tourist volumes, namely waste generation, land-use pressure, and ecological degradation, while the other focuses on social and behavioral adaptations, including changes in residents' perceptions and declines in tourism tolerance.

Despite the accumulation of scholarship on overtourism, less visible yet consequential sustainability dimensions—particularly residents' environmental responsibility behaviors (ERB)—are relatively underexplored in data-driven research. Notable academic and practical gaps thus result (search base: Web of Science, Scopus, ScienceDirect, Google Scholar, and others, as of June 2026; keywords centered on overtourism and environmental responsibility; a combined search returned only two records, neither directly examining residents' ERB—a scarcity in line with prior work that concentrates on tourists rather than host communities [16,17]). Overtourism can transfer the negative externalities of increasing visitor numbers onto residents, weakening their ERB and potentially destabilizing long-established local resource-circulation practices and everyday norms [5,7]. This phenomenon is theoretically linked to a common dilemma, in which individuals' environmental actions become attenuated as the pressure on public goods intensifies [18]. Such dynamics suggest that overtourism should be understood not merely as an issue of tourism revenue or traffic control, but as a process through which local resource governance and residents' everyday pro-environmental behaviors deteriorate.

Accordingly, this study empirically investigates how excessive growth in tourism demand reshapes residents' ERB. Methodologically, the current inquiry holds academic significance by quantitatively testing the relationship between rising tourism demand and residents' ERB. It also carries practical implications by providing a basis for assessing whether tourism policies diminish or strengthen regions' endogenous environmental governance capacity. To examine this structural linkage, the present study adopts South Korea as its research setting. Existing studies on overtourism in South Korea have been concentrated on specific thematic clusters: host-tourist conflict and anti-tourist attitudes in urban historic districts [19,20], psychological carrying capacity and touristification of traditional neighborhoods [21], and social-media-induced transformation in urban centers and fishing villages [22,23], while evidence on nature- and forest-based contexts remains relatively limited [24].

South Korea is particularly suitable for municipal-level comparative analysis, as it exhibits substantial regional variation in tourism demand while maintaining systematically compiled administrative and environmental data at the local government tier [25–28]. Overtourism impacts tend to manifest more clearly at the regional level than at the national scale; tracing how tourism pressure affects residents' ERB across municipalities is therefore both theoretically and empirically important [29]. Moreover, South Korea exhibits relatively compressed cycles of tourism growth, congestion intensification, regulatory intervention, and renewed expansion, making it a case in which the evolution of overtourism and corresponding policy responses can be observed within an accelerated timeframe [30,31]. Being

confined to a single national setting, it offers conditional insights for institutionally comparable contexts rather than a universally generalizable model for all regions undergoing rapid tourism expansion.

Furthermore, this study extends the analytical framework by incorporating interaction effects associated with tourism intensity, recognizing that the focal relationship may vary according to regional structural characteristics [32]. Specifically, regional differences between metropolitan and non-metropolitan areas are specified as a moderator to identify heterogeneity in the effects of tourism demand growth on residents' ERB across localities [32,33]. Regions with higher tourism intensity and those with lower intensity differ in administrative capacity, infrastructure provision, and resident composition; consequently, behavioral responses to escalating visitor pressure are likely to manifest differently across such contexts [34]. In particular, South Korea displays pronounced disparities between metropolitan and non-metropolitan areas in terms of population density, tourism infrastructure, and fiscal capacity, rendering it a suitable context to capture spatial heterogeneity through moderation analysis [25,27,35,36].

The specific research objectives of this study are as follows. First, it empirically analyzes the effects of increasing tourism demand on residents' ERB at the municipal level. Second, it examines whether tourism intensity differences between metropolitan and non-metropolitan areas moderate this relationship. Third, it identifies potential thresholds or transition patterns through which environmental management systems weaken as tourism demand increases. Through these objectives, this study aims to clarify how overtourism generates differentiated environmental and social pressures across local communities, and to derive theoretical and policy implications for municipal tourism governance.

To this end, this study follows a structured research procedure. Beginning with the identification of the research problem, the study proceeds through a review of relevant literature, model specification, the collection of reliable secondary public data, and the construction of an analytical framework. A nonlinear regression model is then estimated, incorporating control and moderating variables centered on overtourism and ERB, to detect potential transition points at which local environmental management systems become imperceptibly undermined once tourism demand exceeds a certain level [37]. Finally, the study derives theoretical and policy implications from the empirical findings.

2. Literature Review

2.1. Overtourism

This section reviews the definition of overtourism and its structural characteristics. Overtourism has been discussed from multiple perspectives in the literature, with scholars framing the concept along dimensions such as destination saturation, residents' quality of life, and the sustainability of host–guest relationships. Goodwin [38] described overtourism as a situation in which local residents (hosts) or visitors (guests) perceive that there are "too many visitors," resulting in an unacceptable deterioration in residents' quality of life or the visitor experience. Similarly, Koens et al. [11] defined overtourism as tourism that exerts excessive negative impacts on host communities and natural environments.

In addition, Alonso-Almeida et al. [39] conceptualized overtourism as a phenomenon in which the positive economic and social outcomes generated by the tourism sector are undermined, thereby provoking resistance among local residents. Notably, the UNWTO [40] characterized overtourism as a state in which tourism severely deteriorates both resident well-being and visitor satisfaction. In essence, overtourism can be understood as a condition in which tourism activity exceeds a destination's carrying capacity, placing community life, environmental systems, and local infrastructure under sustained and compounding strain.

Indeed, overtourism intensifies congestion at tourist sites and amplifies pressure on waste management, transportation networks, and ecological resources, which leads to physical environmental degradation [2,41]. Moreover, the concentration of tourism activity fosters commercialization and compromises local living conditions, giving rise to social fractures such as heightened resident fatigue and deepening community conflicts [42]. Collectively, rising tourism demand sharply expands public service needs, which in turn compounds fiscal and administrative burdens and ultimately forms a structural vicious cycle that erodes municipal environmental management systems [43]. A recent study [44] has extended this discussion beyond congestion itself, reframing overtourism as a set of multifaceted challenges encompassing climate and environmental stressors, the depletion of local resources, and emerging strains on urban governance.

In the South Korean context, rapid tourism growth, the influx of inbound visitors, and widening regional disparities have accelerated the accumulation of both physical and social impacts of overtourism, thereby stimulating a growing body of related research [30,36,45,46]. This pattern emerges more sharply at the local level, where tourism-related shocks are filtered through variations in municipal administrative capacity, infrastructure limits, and degrees of social capital, which produce markedly differentiated outcomes even in response to comparable increases in tourism demand [33,34,47]. These contextual characteristics, therefore, justify specifying tourism demand as the key explanatory variable and tourism intensity as a moderating factor in the analytical framework.

2.2. Overtourism and Environmental Responsibility Behaviors

Specifically, the concept of ERB is introduced to further examine overtourism, providing a basis for understanding the less visible sustainability dimensions that are central to the current study [48]. This study construes ERB not as individual attitudes or institutional outcomes, but as collective practices—such as routine household waste separation—that are repeatedly enacted and accumulated in residents' everyday lives [49,50]. To facilitate a more comprehensive view of ERB, the theoretical foundations of local knowledge systems are reviewed first. Local knowledge systems refer to the environmental management practices, norms, and experiential knowledge that residents have developed through daily life—encompassing locally embedded rules, resource-circulation processes, and livelihood-based modes of land and material use [51]. Through such systems, context-specific and application-oriented management capacities emerge in alignment with regional characteristics and resource-circulation structures. As local knowledge systems weaken, the normative foundations that support residents' ERB are gradually undermined, leading to a decline in individual pro-environmental conduct and a corresponding deterioration of collective management behaviors [52].

Within the tourism literature, ERB and local knowledge systems have also drawn scholarly attention, though primarily through cross-sectional or case-study approaches (e.g., [5,48,53]). Much of this work relied on proxy indicators—such as recycling volumes and recycling rates—to measure ERB. In this context, the breakdown of local knowledge systems is posited to mediate the relationship between overtourism and ERB. Concretely, rising tourism demand triggers a commons dilemma that diminishes the perceived effectiveness of individual actions and weakens social norms, through which overtourism progressively destabilizes ERB in less visible ways [18,54]. The adverse effects of overtourism have been predominantly examined with a focus on intensified physical environmental burdens, including waste generation, traffic congestion, and land-use pressures. However, empirical research addressing changes in ERB and local knowledge systems has remained scarce [41,44,55]. Such relational effects are also insufficiently investigated in the South Korean context (search base: KCI [Korea Citation Index], RISS, DBpia, KISS, e-article, and

Scholar, as of June 2026; keywords centered on overtourism, environmental responsibility, and recycling; a combined search returned no records), further underscoring the need for municipal-level empirical analysis.

2.3. Metropolitan vs. Non-Metropolitan Tourism Intensity Moderation

In this part, the theoretical and empirical rationale for specifying the moderator is established by explaining how the relationship between overtourism and ERB may vary with place-based conditions. Of particular interest is the possibility that the main effect of overtourism on ERB may operate differently across regions with varying levels of tourism intensity. The notion can be understood not merely as the number of visitors, but as the extent to which tourism demand strains a locality's carrying capacity and the spatial scope of local community life [32,56]. That is, the concept integrates factors including the ratio of visitors to residents, spatial density, and the capacity of transportation and environmental infrastructure. Accordingly, even identical increases in tourist volumes may generate markedly different environmental and social burdens in diverse regions [29,32,56,57]. In the case of South Korea, these attributes are structurally differentiated between metropolitan and non-metropolitan areas [35,58]. Empirically, the country exhibits substantial spatial disparities in both inbound and domestic tourist flows, yielding pronounced contrasts in the pressure that tourism demand places on local communities [45,59–61].

From the preceding viewpoint, variations in tourism intensity are more realistically captured as structural differences rooted in locale-specific characteristics rather than as marginal gaps in any single indicator [56,62]. Building on this rationale, the present study operationalizes tourism intensity not through continuous indicators but through metropolitan versus non-metropolitan status, used as a binary proxy [33,63]. Metropolitan status denotes a category of areas that systematically vary across the attributes outlined above, thereby effectively representing underlying distinctions between regions [35,64]. Such an approach also offers methodological advantages. When continuous indicators of tourism intensity, such as visitor-to-resident ratios, are used in panel data, they may introduce multicollinearity or unstable temporal fluctuations; by contrast, metropolitan status is time-invariant and exogenous, providing a more stable basis for moderation analysis [65,66]. Consistent with this position, previous studies (e.g., [2,29,32,67]) have reported that in localities with high tourism dependence or relatively limited infrastructural capacity, the negative effects of increasing tourism demand tend to accumulate more rapidly.

These findings suggest that regions with higher tourism intensity respond more sensitively to changes in tourism demand, and the resulting shocks exert a stronger imprint on residents' ERB. In South Korea's policy landscape, tourism debates have consistently centered on mitigating excessive concentration in the metropolitan core while promoting the dispersion of tourism demand toward non-metropolitan areas. This dichotomous framework aligns with approaches that seek to manage tourism demand while simultaneously addressing region-specific environmental burdens [30,68]. Taken together, conceptual, methodological, and policy considerations jointly justify treating tourism intensity in the South Korean setting as a destination-level attribute indexed by this proxy. Consequently, metropolitan status is employed as a moderating variable to examine structural heterogeneity in overtourism effects.

In this study, the metropolitan category refers not to officially designated cities in general but to the Capital Region—Seoul, Incheon, and Gyeonggi Province (the Seoul Capital Area). Indeed, tourism demand in South Korea is heavily concentrated in the Capital Region; about 78.7% of inbound leisure visitors visited Seoul in 2015 [69], and roughly half of all domestic visitors to Jeju, the country's leading destination, originate in the Capital Region [59]. This structural concentration leaves it particularly vulnerable

to overtourism [45]. Across this densely concentrated region, saturation surfaces less from ordinary growth in tourism demand than from pressure accumulating beyond a threshold [11,40]. Recent urban-tourism work similarly reports that tourism intensity shapes urban and resident outcomes in a nonlinear rather than monotonic fashion [70,71]. *METRO* is therefore specified as a binary moderator rather than a mean-shift dummy, a form that stays exogenous and time-invariant while yielding a clear metropolitan/non-metropolitan contrast for policy interpretation, isolating the nonlinear vulnerability that emerges once visitor pressure exceeds local absorptive capacity.

2.4. Control Variables

This section delineates key control variables that may operate as covariates and discusses their theoretical foundations and empirical evidence in order to more clearly isolate the relationship between overtourism and ERB. Regional population size directly affects the absolute levels of municipal solid waste generation and recycling activities, thereby serving as a fundamental structural factor that explains spatial variation in ERB [72,73]. More importantly, population size is likely to be highly correlated with principal explanatory variables—including tourism demand, infrastructure scale, and fiscal capacity. The correlation requires its incorporation as a control to disentangle the net effect of tourism [35,67,72]. In addition, the proportion of inbound visitors reflects the relative presence of cultural outsiders among tourists in a given region, which functions as a social-contextual condition that may influence residents' ERB [54,74–76]. As the share rises, local communities may strengthen environmental responses aimed at image management and order maintenance; the variable should therefore be controlled separately from overall tourism demand effects [42,74,77].

The fiscal self-reliance of the sanitation budget and the resident cost-sharing ratio are institutional indicators of whether a region's environmental management system relies on central government grants or is funded through local and resident-based revenues [78,79]. The former measures the extent to which a municipality finances waste management through its own-source revenues, representing the capacity for autonomous operation of the local environmental administration system without dependence on intergovernmental transfers [80]. The latter denotes the proportion of waste treatment costs directly borne by residents and captures the institutional structure of cost sharing, along with the behavioral incentives tied to residents' financial responsibility for environmental stewardship [81]. Such fiscal and institutional differences can bear directly on environmental outcomes independently of tourism demand, thereby necessitating control to prevent overestimation or underestimation of the effects of tourism—and, by the same token, helping to isolate the behavioral signal of the proxy (i.e., recycling volume) from its institutional drivers.

The level of tourism development can affect not only the scale of tourist inflows but also the composition of waste generation and management practices, which warrants separate control from tourism demand itself [2,82]. The designation of tourism special zones and tourism complexes represents the degree to which tourism activities are institutionally organized and spatially concentrated within a region. Tourism special zone status reflects whether a region is legally and administratively designated for centralized tourism management, encompassing spatial congestion structures associated with the clustering of commercial and leisure functions and increased population mobility [83,84]. The number or presence of tourism complexes indicates the extent of planned tourism infrastructure concentration and corresponds to the development intensity through which large-scale accommodation- and leisure-oriented activities shape local environmental burdens [82,85].

COVID-19 constitutes an exogenous shock that disrupted local environmental management conditions through sharp declines in tourism demand, changes in consumption

patterns, and shifts in waste streams [86,87]. If such temporal disturbances remain uncontrolled, the relationship between tourism demand and ERB may be distorted; the variable is therefore included as a covariate in the analysis.

2.5. Research Questions

Based on the review of prior studies, three key issues are identified. First, existing research has predominantly emphasized the physical and environmental impacts of tourism, while studies that structurally analyze behavioral and intangible dimensions—namely residents' ERB and local knowledge systems—remain comparatively few. Second, although the cumulative effects of tourism demand and the gradual evolution of residents' ERB should be observed over time, much of the prior empirical work has been based on cross-sectional designs, which constrains the ability to capture structural changes across municipalities. Third, even at comparable levels of tourism demand growth, its influence may diverge depending on regional tourism intensity and local absorptive capacity; however, few studies have explicitly tested this heterogeneity by incorporating tourism intensity—including tourism density or capacity constraints—as a moderating factor.

Given these limitations, the current research argues that the impacts of overtourism on regional sustainability should be analyzed from a more structural and dynamic perspective. Most notably, further empirical inquiry is required to clarify how rising tourism demand alters residents' ERB in municipal settings. In addition, the present study tests the moderating role of tourism intensity (proxied by metropolitan status) to more precisely characterize regional heterogeneity in these effects. Accordingly, the following research questions (RQ) are proposed:

RQ1. *How do increasing tourism demand and the resulting overtourism dynamics affect residents' ERB at the municipal level?*

RQ2. *Does the relationship between overtourism and residents' ERB differ between metropolitan and non-metropolitan areas?*

RQ3. *How are structural and institutional factors—including regional population size, the proportion of inbound visitors, environmental fiscal structures, levels of tourism development, and the COVID-19 shock—associated with residents' ERB, and in what manner do they qualify the estimated effects of tourism demand?*

3. Materials and Methods

3.1. Variable Selection

Drawing on prior research, this study explores the structural relationship between overtourism and residents' ERB and selects core explanatory variables to enter the regression model. Specifically, tourism demand and its squared term—embodying the nonlinear (inverted U-shape) dynamics of overtourism [11,38–40]—are treated as the primary predictors [18,43,54]. Alongside these, tourism intensity [29,32,56,57], approximated by metropolitan status, is taken as the moderator that may inflect this relationship. Within the analytical framework, several covariates are included to adjust for confounding biases. These cover the proportion of inbound visitors [54,74–76], regional population size [67,72,73], the fiscal self-reliance of the sanitation budget [78,80], the resident cost-sharing ratio [81], tourism special zone status [83,84], the number of tourism complexes [82,85], and a COVID-19 intervention [86,87] for the temporal shock. Notably, the two fiscal covariates additionally control for institutional drivers of recycling volume—the operational proxy of ERB. Table 1 presents the composition of independent variables included in the research model on overtourism and residents' ERB, together with their theoretical implications.

Table 1. Summary of input variables and theoretical foundations.

Category	Variable	Expected Effect (Theoretical Sign)	References
Independent variables	Tourism demand	Greater tourism expands environmental management capacity, raising ERB (+).	[18,43,54]
	Overtourism	Beyond a critical threshold of tourism demand, congestion and administrative overload weaken ERB (−).	[11,38–40]
Moderator	Metropolitan status	Superior infrastructure and administrative capacity yield higher environmental management responsiveness (+).	[29,32,56,57]
Interaction terms	Tourism demand × Metropolitan status	Faster resource mobilization in metropolitan areas amplifies the positive effect of tourism demand (+).	[29,32,45,56,57,59–61]
	Overtourism × Metropolitan status	Metropolitan structural density accelerates negative effects under overtourism (−).	[2,29,32,45,59–61,67]
Control variables	Inbound visitor share	A higher inbound visitor share strengthens image management and normative compliance, boosting ERB (+).	[54,74–76]
	Regional population size	A larger population enhances economies of scale and institutional consolidation of recycling systems (+).	[67,72,73]
	Fiscal self-reliance ratio of the sanitation budget	Stronger fiscal self-reliance reinforces administration-led management, reducing individual recycling variability (−).	[78,80]
	Resident cost-sharing ratio	A higher resident cost-sharing ratio internalizes cost awareness, promoting recycling participation (+).	[81]
	Tourism special zone status	Institutionally designated management bolsters environmental upkeep activities (+).	[83,84]
	Number of tourism complexes	More tourism complexes enable concentrated operation of waste management systems (+).	[82,85]
	COVID-19 intervention period	Post-pandemic hygiene awareness and waste management reorganization fortified ERB (+).	[86,87]

3.2. Data Collection

For the empirical analysis, secondary quantitative data were sourced primarily from nationally recognized public data portals to ensure reliability and consistency. At the outset, residents' ERB were operationalized using recycling volume, for which household-level municipal data were obtained from the Korean Statistical Information Service (KOSIS). It is treated here not as a direct measure of residents' environmental attitudes but as a revealed, indirect indicator of their ERB—an observed behavioral outcome [49,88,89]. Objective recycling quantities have already been used as the dependent variable in municipal- and regional-level panel regressions, estimated directly against socioeconomic and policy covariates [90–93]. Municipal recycling data cover the living-sphere waste stream, which by statute also encompasses waste from small businesses without dedicated discharge facilities—tourism-related restaurants, cafés, and lodging—so the aggregate scales partly with population and visitor numbers (the Wastes Control Act of the Republic of Korea, Article 2). By the same statutory scope, the variable excludes industrial, construction, designated, and large-emission-facility streams, and therefore does not represent a region's total waste. These businesses are nonetheless local actors whose recyclables enter the records

only through the same sorting act required of households, so their inclusion mirrors the reality of a tourism-pressured locality rather than contamination of the measure. Their sorting is thus counted as behavior, while the volume their scale mechanically generates is absorbed by the controls for tourism demand, tourism special zone status, and the number of tourism complexes.

Critically, under the volume-based disposal fee—chargeable general waste, but recyclables collected at no volume-based charge—and mandatory source separation, recorded recycling is not an automatic or infrastructural by-product but the outcome of deliberate sorting by residents and businesses [88,94,95]. This mandate sets the institutional condition but does not guarantee full compliance: enforcement and deterrence matter, and households may evade the fee through illegal dumping, so recorded recycling reflects realized, variable participation [96,97]. Within the model, the scale effects of tourism and commerce are absorbed by these same tourism-related controls; the resident population enters as its own control; time-invariant structural conditions are captured by municipality fixed effects; fiscal and institutional conditions, by the sanitation-budget and cost-sharing controls; and season-driven population shifts, by the annual data frequency. The non-behavioral drivers raised as alternatives are thus partialled out rather than left in the residual, so the remaining within-municipality variation can be read as a scale-adjusted behavioral signal—identified by ruling these alternatives out rather than by assumption, without claiming to eliminate all confounding [65,98].

In this study, recycling volume was selected as the proxy over the recycling rate. The rate expresses the share of generated waste that is separated and thus indexes the relative efficiency of source separation; its denominator, however—total waste generation—depends not only on population and consumption but also on tourism inflows [99–101]. Because tourists themselves generate waste, rising tourism demand directly enlarges that denominator, so the rate may move independently of residents' actual sorting effort, allowing the tourism effect to become mechanically entangled through it [102]. Recycling volume, by contrast, captures the amount that residents and businesses actually sort and set out, directly measuring the magnitude of source-separation behavior that this study seeks to explain [103,104]. Population scale is arguably better handled by including resident population as a covariate and controlling for fixed effects than by pre-dividing into a ratio; the former is more flexible and less prone to spurious correlation [105,106]. The rate is also a fraction bounded within [0, 1] that would call for a fractional-response model, whereas the log of recycling volume fits naturally into the semi-log panel used here [107]. Finally, under Korea's volume-based waste fee, recyclables are collected free of charge and recorded as quantities (tons), with the recycling rate derived from them [88,94]. Recycling volume was therefore judged the more appropriate measure for examining how overtourism affects the magnitude of residents' source-separation behavior.

Furthermore, tourism demand was measured from visitor entry data for major tourist attractions published by the Korea Culture and Tourism Institute and the TourGo platform. The designation of tourism special zones, along with the number of tourism complexes, was retrieved from the Tourism Development Information System (TDSS). Data on regional population size, the fiscal self-reliance of the sanitation budget, and the resident cost-sharing ratio were also compiled from KOSIS. Apart from these, the overtourism phenomenon and the proportion of inbound visitors were constructed through additional processing of the source data. Dummy variables were created to represent metropolitan status and the COVID-19 intervention period based on regional and temporal characteristics. The temporal scope of the study was defined to build a panel dataset. Ultimately, a balanced panel comprising 174 municipalities over a nine-year period (2015–2023) was assembled without missing values, ensuring full compatibility with the research objectives.

Table 2 describes the units of measurement and data sources for the extracted and derived explanatory variables.

Table 2. Units of measurement and data sources.

Variable	Data Content	Unit	Source
Environmental responsibility behaviors	Household waste recycling volume	tons	KOSIS
Tourism demand	Number of visitors at major tourist attractions	persons	KCTI/TourGo
Overtourism	Squared term of tourism demand	—	Processed
Metropolitan status	Capital region indicator	dummy	Generated
Tourism demand × Metropolitan status	Interaction term	—	
Overtourism × Metropolitan status	Interaction term	—	
Inbound visitor share	Proportion of inbound visitors	%	Processed
Regional population size	Regional resident population	persons	KOSIS
Fiscal self-reliance ratio of the sanitation budget	Self-reliance ratio of sanitation budget	%	
Resident cost-sharing ratio	Cost-sharing ratio for waste management	%	
Tourism special zone status	Designation of tourism special zone	dummy	TDSS
Number of tourism complexes	Tourism complex count	count	
COVID-19 intervention period	Pandemic period indicator	dummy	Generated

Note: (1) KOSIS = Korean Statistical Information Service, KCTI = Korea Culture and Tourism Institute, TDSS = Tourism Development Information System. Note (2) "Processed" denotes variables transformed from existing data; "Generated" denotes dummies and interaction terms constructed by the researcher.

3.3. Data Transformation

First, an assessment of the normality of the dependent variable revealed substantial right-skewness, with concentration in the upper-value range, as evidenced by the Kolmogorov–Smirnov statistic ($D = 0.425$, $p < 0.001$) and the Shapiro–Wilk statistic ($W = 0.626$, $p < 0.001$). To stabilize the distribution and facilitate comprehension of the results, a semi-log functional form was adopted. This transformation allows the estimated coefficients to be interpreted as relative percentage changes in residents' ERB associated with a one-unit change in each independent variable. Tourism demand was rescaled in units of one million visitors to enhance clarity, and its squared term was added to capture potential nonlinear effects of tourism pressure. Doing so relaxes the linear assumption that the marginal effect of tourism demand remains constant across all its levels. This mirrors the logic of the Environmental Kuznets Curve, which posits a nonlinear threshold rather than a fixed relationship [3]. The specification is consistent with overtourism, which implies that the initially positive effect of tourism demand may weaken or reverse once pressure exceeds the destination's absorptive capacity. The squared term is therefore not a separate direct measure of overtourism, but a nonlinear tourism-pressure term that lets the model test for diminishing or reversing marginal effects and estimate the corresponding turning point. Metropolitan status, the COVID-19 intervention period, and tourism special zone status were coded as dummy variables, with a value of 1 when the condition applied and 0 otherwise. Here, *METRO* denotes municipalities in the Capital Region—Seoul, Incheon, and Gyeonggi Province.

In estimating moderation effects, interaction terms between tourism demand (and its squared term) and metropolitan status were generated. To mitigate potential multicollinear-

ity, all constituent variables were mean-centered prior to constructing these interaction terms, following Aiken and West [108]. The resulting centered products were then included in the analysis. Other variables—including the proportion of inbound visitors, the fiscal self-reliance of the sanitation budget, and the resident cost-sharing ratio—were retained in their original ratio scales, while the number of tourism complexes was treated as a continuous count variable. Finally, regional population size was expressed in units of ten thousand residents for readability.

The baseline regression model is formally given in Equation (1).

$$\begin{aligned} \ln ERB_{it} = \beta_0 + \ & \beta_1 TOUR_{it} + \beta_2 TOUR^2{}_{it} + \beta_3 METRO_i + \beta_4 TXM_{it} \\ & + \beta_5 TXM^2{}_{it} + \beta_6 FOREIGN_{it} + \beta_7 RESIDENT_{it} \\ & + \beta_8 CLEAN_{it} + \beta_9 BURDEN_{it} + \beta_{10} SPECIAL_{it} \\ & + \beta_{11} COMPLEX_{it} + \beta_{12} COVID19_t + \varepsilon_{it} \end{aligned} \quad (1)$$

In this specification of ln*ERB*, β_1 through β_{12} denote the regression coefficients of the explanatory variables, where β_0 is the intercept, i covers the 174 municipalities, t represents the nine annual time points, and ε signifies the idiosyncratic error term. The dependent variable, *ERB*, refers to environmental responsibility behaviors, proxied by recycling volume. *TOUR* denotes tourism demand, while $TOUR^2$ models its nonlinear effect and is interpreted as the tourism-pressure component. Accordingly, the marginal effect of tourism demand is not constant but varies with its level, given by $\beta_1 + 2\beta_2 \cdot TOUR$, so that a positive β_1 with a negative β_2 implies an influence that diminishes and may reverse as demand rises. *METRO* is a dummy variable indicating whether a municipality belongs to the metropolitan area. *TXM* and TXM^2 represent the interaction terms between *TOUR* and *METRO*, and between $TOUR^2$ and *METRO*, respectively, reflecting moderation effects associated with tourism intensity. Among the control variables, *FOREIGN* indicates the proportion of inbound visitors, *RESIDENT* denotes the regional population size, *CLEAN* represents the fiscal self-reliance of the sanitation budget, and *BURDEN* refers to the resident cost-sharing ratio for waste management costs. In addition, *SPECIAL* and *COMPLEX* denote tourism special zone status and the number of tourism complexes within a municipality, respectively. Finally, *COVID19* is a dummy variable indicating the COVID-19 intervention period. Furthermore, Figure 1 illustrates the theoretical framework proposed in this study.

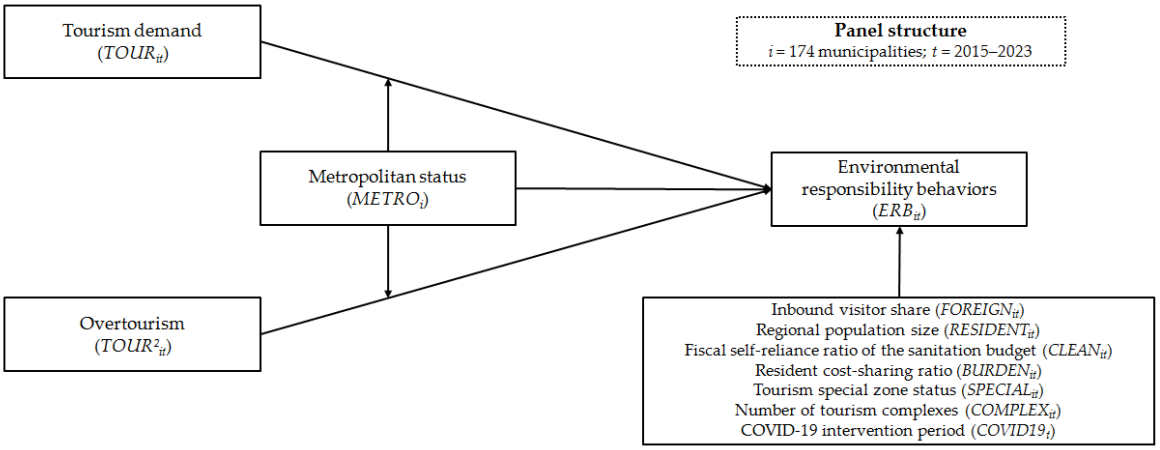


Figure 1. Research model.

3.4. Analytical Modeling

In this study, a panel data model that accommodates both spatial and temporal variations across municipalities was applied. This approach allows for the simultaneous consideration of regional heterogeneity and time-series dynamics, which renders it espe-

cially suitable for analyzing changes in residents' ERB as overtourism intensifies across regions in South Korea [109]. Panel data analysis is generally classified into the fixed effects (FE) model and the random effects (RE) model, depending on the structure of the error term and the underlying assumptions regarding unobserved heterogeneity. The FE model assumes that slope coefficients are identical across units, while intercepts are allowed to vary, thus controlling for unobserved, time-invariant individual characteristics. In contrast, the RE model treats individual-specific effects as stochastic components and rests on the assumption that these effects are uncorrelated with the explanatory variables across all time periods.

Due to these differences, the FE model eliminates individual-specific effects through within transformation, leaving time-invariant explanatory variables unidentifiable. More specifically, by demeaning these time-invariant characteristics, the estimator removes persistent differences in collection infrastructure, system maturity, and geography by construction rather than by assumption [65]. The RE model, conversely, permits the simultaneous estimation of both time-varying and time-invariant variables, conditional upon the assumption that individual effects are uncorrelated with the explanatory variables [110]. Both models can be expressed using the following baseline specification as shown in Equation (2):

$$Y_{it} = \alpha + \beta x_{it} + u_i + \varepsilon_{it} \quad (2)$$

where Y_{it} denotes the dependent variable; i indexes municipalities; t denotes time; α represents the intercept; and β is the vector of coefficients. The term x_{it} refers to the set of explanatory variables, u_i absorbs unobserved individual-specific effects, and ε_{it} denotes the residual error term.

The fundamental distinction between the FE and RE models lies in the treatment of u_i: the FE model regards it as a parameter to be estimated, whereas the RE model assumes it to be a random variable. Moreover, the RE model requires the assumption that u_i is uncorrelated with the explanatory variables, an assumption that is not imposed under the FE model framework. When it is necessary to further control for unobserved characteristics that vary over time but are common across units, the model can be extended as expressed in Equation (3) below:

$$Y_{it} = \alpha + \beta x_{it} + u_i + v_t + \varepsilon_{it} \quad (3)$$

In this specification, v_t represents unobserved time-specific effects that affect all municipalities simultaneously. This formulation corresponds to a two-way error component regression model. When the individual-specific effect, u_i, is treated as a fixed parameter, the model becomes a two-way fixed effects (TWFE) model; when it is assumed to be a random variable, it becomes a two-way random effects (TWRE) model. The most appropriate model for interpretation is selected through a series of statistical tests.

The Chow test is employed to assess the adequacy of the FE model relative to the pooled ordinary least squares (OLS) model, while the Lagrange Multiplier (LM) test evaluates the suitability of the RE model against the pooled specification. Lastly, the Hausman test is used to determine whether the FE or RE model provides consistent and efficient estimates. Beyond model selection, panel data are often subject to econometric issues such as heteroskedasticity, autocorrelation, and the presence of time-fixed effects. Accordingly, this study systematically diagnoses these issues and identifies the optimal model specification to ensure robust and reliable inference. The turning points of the quadratic relationship—obtained as $-\beta_1/(2\beta_2)$ from Equation (1)—are derived from the estimated coefficients via the delta method, and each is reported as a point estimate with its 95% confidence interval (CI). All statistical analyses were conducted using Stata/MP 15.0 (StataCorp LLC, College Station, TX, USA).

4. Results

4.1. Descriptive Statistics

Prior to model estimation, descriptive statistics for all variables were examined, with the results reported in Table 3. The panel-dataset summaries present the overall means along with the decomposition of variation into "between" and "within" components (shown as the corresponding rows in Table 3). In particular, the "between" standard deviation (SD) reflects dispersion in municipality-level means, whereas the "within" SD captures year-to-year variation within each municipality over the study period. The partitioning reveals that major tourism-related variables—such as *TOUR*, $TOUR^2$, and TXM^2—exhibit substantial between-municipality variation, suggesting pronounced regional heterogeneity in tourism behaviors. By contrast, *COVID19* is the only variable whose within-municipality SD exceeds its between-municipality SD, since the pandemic period is defined identically across the entire panel and therefore contributes solely to within-municipality temporal variation. For all other variables, between-municipality variation remains the dominant source. Overall, the descriptive patterns point to a mixed structure in which both core analytical and control variables register heterogeneous spatial and temporal differences. This underscores the need for more rigorous diagnostic tests to determine the most appropriate panel data model for the subsequent empirical analysis.

Table 3. Descriptive statistics of the input variables.

Variable (Unit)	Stat	Mean	SD	Variable (Unit)	Stat	Mean	SD
ln*ERB* (log)	overall between within	4.183	1.255 1.197 0.388	*RESIDENT* (10,000 persons)	overall between within	19.348	22.609 22.628 1.326
TOUR (million visitors)	overall between within	2.028	2.215 2.060 0.827	*CLEAN* (%)	overall between within	25.586	13.166 10.710 7.695
$TOUR^2$ (million visitors^2)	overall between within	9.016	22.834 20.669 9.817	*BURDEN* (%)	overall between within	22.806	16.262 15.502 5.036
METRO (dummy)	overall between within	0.195	0.397 0.398 0.000	*SPECIAL* (dummy)	overall between within	0.178	0.383 0.380 0.053
TXM (centered)	overall between within	0.047	1.312 1.223 0.482	*COMPLEX* (count)	overall between within	0.184	0.576 0.566 0.114
TXM^2 (centered)	overall between within	1.723	10.498 9.229 5.047	*COVID19* (dummy)	overall between within	0.444	0.497 0.000 0.497
FOREIGN (%)	overall between within	0.889	2.849 2.352 1.616				

Note: (1) No. of observations: overall = 1566; between = 174; within = 9. (2) Variable definitions are provided in Tables 1 and 2; ln*ERB* denotes the natural-log transformation of recycling volume; *TXM* and TXM^2 are mean-centered interaction terms. (3) For each variable, "overall" is the pooled SD, "between" is the cross-municipality SD, and "within" is the within-municipality (over-time) SD.

4.2. Multicollinearity Diagnostics

In panel data analysis, some degree of multicollinearity is often unavoidable due to the time-series nature of the observations. Distortions arising from temporal dependence can be partially addressed through the inclusion of fixed effects [111]. However, assessing

multicollinearity among independent variables calls for a separate diagnostic procedure. Thus, a variance inflation factor (VIF) test was conducted, and Table 4 summarizes the findings. Although acceptable thresholds for multicollinearity may vary across studies, all explanatory variables yield VIF values comfortably below the conventional cutoff of 10, suggesting that multicollinearity does not pose a substantive concern in the present analysis (the mean VIF falls to 1.43 once the quadratic and interaction terms are excluded) [112]. While some correlation is observed between tourism demand and its squared term, such an association is theoretically expected and does not constitute an abnormal empirical pattern in the context of nonlinear social phenomena.

Table 4. Variance inflation factor (VIF) diagnostics for the explanatory variables.

Variable	VIF	1/VIF	Variable	VIF	1/VIF
TXM^2	7.646	0.131	*METRO*	1.739	0.575
TXM	6.487	0.154	*RESIDENT*	1.692	0.591
$TOUR^2$	4.561	0.219	*FOREIGN*	1.494	0.669
TOUR	4.187	0.239	*COMPLEX*	1.240	0.806
BURDEN	2.171	0.461	*SPECIAL*	1.129	0.886
CLEAN	1.934	0.517	*COVID19*	1.040	0.962

Note: Mean VIF = 2.943; all VIF values are below the conventional threshold of 10, indicating no severe multicollinearity among the explanatory variables.

4.3. Model Estimation

To identify the most suitable panel model for analyzing residents' ERB, this study compared several candidate models—the pooled OLS model, the FE model, and the RE model, with the latter two accounting for both individual- and time-specific effects. The estimation results are presented in Table 5. First, Model (1) reports the pooled OLS estimates, in which neither individual- nor time-specific effects are controlled. The coefficients of *TOUR*, *METRO*, *RESIDENT*, *BURDEN*, *COMPLEX*, and *COVID19* were statistically significant at the 1% level, and their estimated signs aligned with the theoretical expectations. Notably, the nonlinear term $TOUR^2$ and the interaction term TXM^2 also achieved significance. Yet, when unobserved heterogeneity exists across regions or over time, the FE and RE models may be preferable to the pooled OLS model. Model (2) provides the FE estimates, with time-invariant individual heterogeneity at the municipal level controlled. Model (3) reports the RE results, treating regional effects as random variables drawn from a common distribution. To compare the pooled OLS and FE models, a Chow test was conducted. The results, $F(173, 1381) = 17.84$, $p < 0.001$, confirm that the FE model fits the data significantly better than the pooled OLS model. Likewise, the LM test comparing the pooled OLS and RE models yielded $\chi^2(1) = 2285.89$, $p < 0.001$, rejecting the null hypothesis of no random effects (see Table 6).

Subsequently, the Hausman test was performed to determine the proper model between the FE and RE models. The test result, $\chi^2(11) = 73.01$, $p < 0.001$, refutes the null hypothesis—that the RE estimator is consistent and efficient—and supports the FE model due to potential correlation between individual effects and the regressors, rendering the RE estimator inconsistent. The importance of accounting for cross-sectional heterogeneity is further evident in the estimated ρ values of the FE and RE models, which were 0.751 and 0.646, respectively.

Table 5. Estimation results across the alternative panel models.

	(1) Pooled OLS		(2) FE		(3) RE		(4) DK		(5) HT-AM		(6) TWFE		(7) TWRE	
TOUR	0.110	***	0.066	***	0.078	***	0.066	***	0.069	***	0.047	**	0.076	***
$TOUR^2$	−0.007	***	−0.004		−0.005	**	−0.004	**	−0.004		−0.002		−0.005	*
METRO	0.223	***	0.000		0.186		0.000		0.193		0.000		0.188	
TXM	0.001		−0.011		−0.027		−0.011		−0.025		−0.016		−0.026	
TXM^2	−0.011	***	−0.002		−0.002		−0.002	**	−0.001		−0.001		−0.002	
FOREIGN	0.011		0.028	***	0.027	***	0.028	***	0.028	***	0.030	***	0.027	***
RESIDENT	0.031	***	0.036	***	0.036	***	0.036	***	0.038	***	0.034	***	0.037	***
CLEAN	0.002		−0.001		0.000		−0.001	**	−0.001		−0.002		0.000	
BURDEN	0.026	***	0.004	**	0.012	**	0.004	***	0.004	**	0.003		0.011	***
SPECIAL	−0.010		0.374	**	0.107		0.374	***	0.349	**	0.373	**	0.121	
COMPLEX	0.131	***	0.192	**	0.141	**	0.192	***	0.173	**	0.169	*	0.144	**
COVID19	0.265	***	0.259	***	0.266	***	0.259	***	0.259	***	0.332	***	0.265	***
Constant	2.781	***	3.210	***	3.031	***	3.210	***	3.120	***	3.180	***	3.046	***
F	356.47	***	18.67	***	—		1639.59	***	—		12.68	***	—	
χ^2	—		—		810.16	***	—		581.79	***	—		721.37	***
R^2_{within}	—		0.130		0.119		0.130		—		0.142		—	
$R^2_{between}$	—		0.693		0.760		—		—		0.683		—	
$R^2_{overall}$	0.732		0.639		0.699		—		—		0.631		—	
σ_u	—		0.669		0.521		—		0.646		0.687		—	
σ_e	—		0.386		0.386		—		0.384		0.384		—	
ρ	—		0.751		0.646		—		0.739		0.762		—	
n	1566		1566		1566		1566		1566		1566		1566	

Note: (1) Dependent variable is ln*ERB*. (2) Variables: *TOUR* = tourism demand; $TOUR^2$ = overtourism (squared tourism demand); *METRO* = metropolitan status; *TXM* = *TOUR* × *METRO*; TXM^2 = $TOUR^2$ × *METRO*; *FOREIGN* = inbound visitor share; *RESIDENT* = regional population size; *CLEAN* = fiscal self-reliance of the sanitation budget; *BURDEN* = resident cost-sharing ratio; *SPECIAL* = tourism special zone status; *COMPLEX* = number of tourism complexes; *COVID19* = COVID-19 intervention period. (3) Models: Pooled OLS = pooled ordinary least squares; FE = one-way fixed effects; RE = one-way random effects; DK = fixed effects with Driscoll–Kraay standard errors; HT-AM = Hausman–Taylor/Amemiya–MaCurdy estimator; TWFE = two-way fixed effects; TWRE = two-way random effects. (4) Significance: ***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 6. Diagnostic tests and fit measures for panel model selection.

Test	Statistic	*p*-Value
Chow Test	$F_{(173,\ 1381)} = 17.840$	<0.001
LM Test	$\chi^2_{(1)} = 2285.890$	<0.001
Hausman Test	$\chi^2_{(11)} = 73.010$	<0.001
Time-fixed Effect Test	$F_{(7,\ 1546)} = 0.510$	0.831
Modified Wald Test	$\chi^2_{(174)} = 29{,}355.700$	<0.001
Wooldridge Test	$F_{(1,\ 173)} = 23.373$	<0.001
Pesaran CD Test	$CD = 6.305$	<0.001

Notes: Chow Test compares pooled OLS against the FE model; LM Test compares pooled OLS against the RE model; Hausman Test compares the FE against the RE model; Time-fixed Effect Test examines the joint significance of year dummies; Modified Wald Test diagnoses group-wise heteroskedasticity; Wooldridge Test diagnoses serial autocorrelation; Pesaran CD Test examines cross-sectional dependence in panel residuals.

Meanwhile, Models (6) and (7) correspond to the TWFE and TWRE models, respectively. In two-way error component models, however, including both individual and time effects simultaneously may lead to a considerable loss of degrees of freedom, which can compromise the estimates [98]. In practice, the estimates from these models produced unstable outcomes, with discrepancies in the theoretical signs of several coefficients and the absence of statistical significance for key variables. Crucially, the test for time-fixed effects gave $F(7, 1546) = 0.51$, $p = 0.831$, signaling that the use of time-fixed effects was not statistically justified. Consequently, time-fixed effects were excluded from the final model

selection (some year dummies were omitted to ensure model identification, given linear combinations with *COVID19* and *SPECIAL*).

Building on this, additional model diagnostic tests were carried out to choose the appropriate model more conservatively, as shown in Table 6. The Modified Wald test ($\chi^2(174) = 29{,}355.70$, $p < 0.001$) demonstrated group-wise heteroskedasticity, the Wooldridge test ($F(1, 173) = 23.373$, $p < 0.001$) confirmed serial autocorrelation, and Pesaran's *CD* test ($CD = 6.305$, $p < 0.001$) indicated significant cross-sectional dependence across municipalities. Hence, to correct for these issues simultaneously, the present study additionally estimated the model with Driscoll–Kraay (DK) standard errors. Model (4) was selected as the final model, and the following discussion of results centers primarily on this model. Notably, in the DK model, the *METRO* variable could not be estimated because time-invariant variables are absorbed by the fixed effects transformation. To recover the coefficient of the time-invariant *METRO* variable, the present study separately estimated a Hausman–Taylor (HT) model. For more efficient estimators, the HT model was extended to the Amemiya and MaCurdy (AM) model, which strengthens the instrumental variable conditions. The HT-AM specification—the HT estimator with its AM extension—is reported as Model (5).

First, the estimated coefficients of the key variables in the DK model were all consistent with the expected theoretical directions. The within R^2 of 13.0% signified reasonable explanatory power [62]. The significance tests revealed that *TOUR*, *FOREIGN*, *RESIDENT*, *BURDEN*, *SPECIAL*, *COMPLEX*, and *COVID19* were statistically significant at the 1% level, while *CLEAN* and the overtourism-related variables $TOUR^2$ and TXM^2 were significant at the 5% level. In contrast, the interaction term *TXM* and the *METRO* variable estimated in Model (5) were not statistically significant.

Specifically, a one-unit (one-million-visitor) increase in *TOUR* corresponded to an approximately 6.6% rise in recycling volume—used as a proxy for residents' ERB—under the semi-log functional form. A one-unit increase in the proportion of inbound visitors (*FOREIGN*) was associated with an estimated 2.8% rise in recycling output, while an additional 10,000 residents (*RESIDENT*) corresponded to an estimated 3.6% gain. Furthermore, the fiscal self-reliance ratio (*CLEAN*) and the resident cost-sharing ratio (*BURDEN*) had statistically significant but relatively modest effects. A one-percentage-point increase in *CLEAN* was linked to an estimated 0.1% decrease in recycling volume, whereas a one-percentage-point increase in *BURDEN* produced an estimated 0.4% rise. Regarding tourism development variables, each additional tourism complex (*COMPLEX*) led to an estimated 19.2% uplift in recycling volume. In the case of tourism special zones (*SPECIAL*), recycling volumes were estimated to be approximately 1.45 times the levels in non-designated areas (dummy variable effects: $\%\Delta Y = (e\hat{}\beta - 1) \times 100$). The COVID-19 dummy (*COVID19*) likewise exerted a statistically significant positive effect on recycling volume, which during the pandemic period was approximately 1.30 times its pre-pandemic level.

Most importantly, overtourism—operationalized as the squared term of tourism demand ($TOUR^2$)—exhibited a statistically significant negative coefficient, indicating diminishing marginal effects: the positive impact of tourism demand on ERB gradually attenuates as tourism pressure accumulates. Furthermore, the interaction analysis indicated that the moderating role of metropolitan status was not significant for tourism demand (*TXM*) but significantly negative for overtourism (TXM^2). This finding suggests that the overtourism-driven decline in ERB is more pronounced in metropolitan areas. Figure 2 illustrates the moderating effect of metropolitan status on the overtourism–ERB relationship. To locate the policy-relevant threshold implied by the quadratic specification, the turning points were calculated separately for the non-metropolitan and metropolitan subsamples. Among non-metropolitan municipalities, the marginal effect of tourism demand turns from positive to negative at approximately 11.06 million annual visitors

(95% CI [5.59, 16.53]). Within the metropolitan subsample, this reversal occurs much earlier, at 6.95 million (95% CI [4.75, 9.15]). A more detailed discussion of these estimation results is provided in the Discussion section.

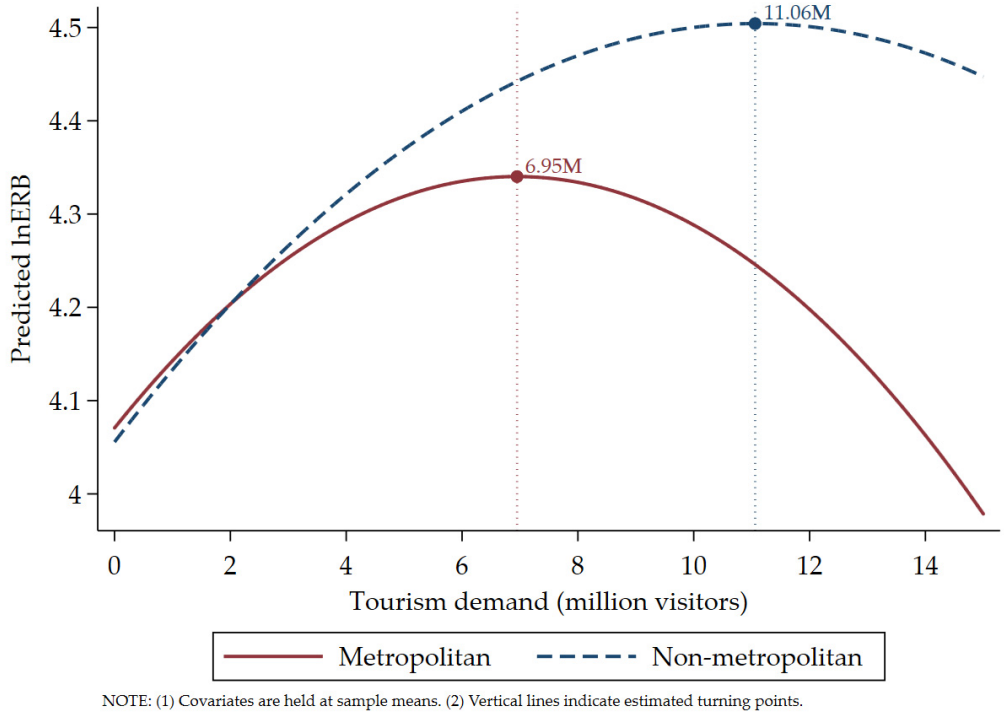


Figure 2. Interaction effect of metropolitan status on the overtourism–ERB relationship.

5. Discussion

This section interprets the main estimates from the Driscoll–Kraay model and discusses their implications for the tourism–ERB relationship. The results indicated that tourism demand had a statistically significant positive influence on ERB. Specifically, a one-unit (one-million-visitor) increase in tourism demand was associated with an approximately 6.6% rise in recycling volume, suggesting that in the early stages of tourism growth, expanding visitor demand may stimulate local environmental management activities or strengthen resource circulation systems, at least in part. In contrast, overtourism—captured by the quadratic tourism-demand term—produced a significant negative coefficient. This pattern revealed a nonlinear structure in which the upward impact of tourism demand on ERB gradually weakens beyond a certain threshold. Taken together, these findings empirically confirm that ERB do not simply respond linearly with growing tourism demand; rather, the initial positive effect may decline or diminish as excessive demand intensifies. The decline beyond the turning point is hard to explain by scale alone, since more arrivals would, by themselves, only add to the recorded volume; it instead points to a weakening of residents' sorting effort and cooperative norms as visitor pressure mounts.

The moderation analysis further reinforced the same structure. While the interaction between tourism demand and metropolitan status was not significant, that involving overtourism was significantly negative. The dampening influence of overtourism on ERB may thus be more pronounced in metropolitan areas when tourism demand reaches high levels. That is, during the initial phase of tourism demand growth, differences between metropolitan and non-metropolitan areas are not clearly evident. However, under overtourism conditions, the structural context of metropolitan areas may amplify the vulnerability of ERB. This pattern indicates that the Capital Region's distinctive features bear on the tourism–ERB link only past a nonlinear threshold. At low to moderate demand, its admin-

istrative capacity and waste-management infrastructure accommodate additional visitors, so metropolitan and non-metropolitan municipalities behave alike in the ordinary effect, consistent with the non-significant $TOUR \times METRO$. Once demand exceeds this range, however, those same features—dense settlement, overlapping residential and tourism space, high baseline waste-management loads, and intensifying congestion [19]—shift from buffer to saturation constraint, eroding residents' routine recycling more rapidly, as shown by the significant negative $TOUR^2 \times METRO$. The estimated turning points make this divergence concrete: at 6.95 versus 11.06 million annual visitors, the region reverses far earlier, near the 90th percentile of its own demand distribution, whereas the non-metropolitan turning point falls in the upper 1% tail of its own distribution, so that few municipalities ever reach it. Metropolitan status thus deepens the susceptibility of the over-tourism stage rather than reshaping the ordinary linear effect, in line with threshold and carrying-capacity arguments in urban tourism [11,70,71]. The control-variable estimates also imply that ERB are closely tied to regional structural and institutional conditions. The proportion of inbound visitors displayed a significant positive relationship with ERB. In quantitative terms, each one-unit increase brought about an estimated 2.8% rise in recycling volume. Regional population size likewise exerted a positive and significant effect on ERB; each additional ten thousand residents translated into a 3.6% gain in recycling output.

The control-variable results further underscore that population size and visitor composition, together with the scale characteristics of the dependent variable (recycling volume), may be closely connected with changes in local environmental management behavior. With respect to environmental finance, the fiscal self-reliance ratio of the sanitation budget was weakly but significantly negative, whereas the resident cost-sharing ratio was significantly positive. Such patterns suggest that the financial basis of environmental management systems and cost-sharing arrangements may directly inform municipal-level environmental governance practices. Significant effects also emerged for tourism development variables. Tourism special zones had recycling volumes approximately 1.45 times those of non-designated areas, while each additional tourism complex corresponded to an estimated 19.2% rise in recycling volume. Environmental management outcomes thus appear to differ systematically in areas where tourism activities are institutionally organized and spatially concentrated. Lastly, the COVID-19 dummy exhibited a significant positive association with ERB; recycling volumes during the pandemic period reached approximately 1.30 times their pre-pandemic level. This positive association, however, should not be read solely as evidence of heightened hygiene awareness or reorganized waste management. During the pandemic, longer time at home, mobility restrictions, and expanded home-based and delivery consumption may have mechanically raised household waste and recyclable materials, independently of any change in environmental attitudes. The COVID-19 effect is therefore better understood as a composite pandemic effect combining home-based consumption growth, shifts in waste-stream composition, hygiene-related awareness, and municipal administrative responses. At the same time, because recycling volume in South Korea is recorded only after source separation and collection, the additional materials still had to be sorted and discharged by residents and businesses before they entered the recorded total, so a behavioral component remains within the composite effect.

Situating these results in the literature, the current study shares certain commonalities with previous research on the relationship between tourism and local environmental management, while also offering several distinct contributions. In particular, the positive influence of tourism demand on ERB is broadly consistent with earlier studies suggesting that increased tourism activity can expand the demand for environmental stewardship and potentially enhance municipal environmental administration systems. Furthermore, the observed weakening of tourism demand's positive effect on ERB at higher demand inten-

sities aligns with discussions in the overtourism literature [11,38,40,44] regarding rising environmental pressures and the limits of ecological carrying capacity. Prior work [5–8,18] has likewise pointed out that increasing visitor numbers can heighten host environmental burdens and potentially weaken residents' pro-environmental behaviors. However, whereas much of the existing research [2,9,10,41,55] has focused primarily on the physical environmental consequences of tourism—such as waste generation or environmental degradation—the present study extends this discussion by empirically demonstrating that the relationship between tourism demand and ERB may follow a nonlinear pattern. Such a threshold structure echoes similar findings reported for urban livability and tourism carrying capacity [70,71], yet, unlike those studies, the present analysis locates the turning point empirically and shows that it shifts with metropolitan status. In addition, how tourism demand influences ERB is found to vary according to regional tourism intensity. Notably, the stronger negative impact of overtourism on ERB in metropolitan areas suggests that tourism's effects may interact with area-level structural conditions [29,32,35,56,57], including population density, infrastructure capacity, and administrative resources. In this respect, the result corroborates the broader literature [2,29,32–34,47,67] emphasizing that tourism's outcomes are shaped by local context and place-specific absorptive limits.

6. Conclusions

6.1. Summary

This study empirically examined how increasing tourism demand affects residents' ERB at the municipal level, focusing on heterogeneity between metropolitan and non-metropolitan areas. Using a balanced panel of 174 municipalities in South Korea over the period 2015–2023, the analysis adopted a semi-log specification with a quadratic tourism-demand term to account for potential nonlinear overtourism effects, alongside interaction terms with metropolitan status to test the moderating role. The model selection procedure validated the use of panel estimation: the Chow and LM tests favored FE and RE, respectively, over the pooled OLS model, while the Hausman test further supported FE over RE. Subsequent diagnostics detected heteroskedasticity, autocorrelation, and cross-sectional dependence; to ensure robust inference, the DK estimator was ultimately adopted as the preferred model.

The key results can be summarized as follows. Tourism demand was found to raise residents' ERB—by about 6.6% in recycling volume per million visitors—up to a turning point, beyond which its influence reversed, tracing an inverted U-shape under overtourism. This threshold fell at roughly 11.06 million visitors in non-metropolitan municipalities but only 6.95 million in metropolitan ones, and the negative interaction with the squared tourism-demand term confirmed that the downturn was sharper in the Capital Region. Among the controls, inbound visitor share (+2.8%), regional population (+3.6% per ten thousand residents), the resident cost-sharing ratio (+0.4%), tourism special zones (≈1.45 times non-designated areas), tourism complexes (+19.2%), and the COVID-19 period (≈1.30 times pre-pandemic) were positive, whereas the fiscal self-reliance ratio carried a small adverse weight (−0.1%).

6.2. Contributions and Implications

Several distinctive approaches set the current analysis apart from prior studies examining the relationship between overtourism and ERB. Notably, while much of the available scholarship has emphasized the visible environmental burdens of tourism—including waste accumulation and ecological degradation—overtourism is approached here through the lens of residents' ERB. In doing so, the focus extends to how increasing tourism demand

may shape local environmental management systems and residents' everyday environmental practices from a behavioral standpoint.

More importantly, the nexus between tourism demand and ERB is framed in this study as one that may not follow a simple linear pattern. A nonlinear specification including a squared tourism-demand term is applied, and the analysis reveals that tourism demand initially strengthens ERB but, beyond a certain threshold, its positive contribution tapers off—indicating diminishing marginal effects under conditions of overtourism. Relatedly, tourism intensity is proxied by metropolitan status as a structural attribute, and regional heterogeneity in tourism demand effects is tested through a moderation analysis. Such an empirical examination provides evidence that tourism demand's influence may vary across regional contexts, highlighting the importance of place-based factors in shaping the environmental consequences of tourism expansion.

These findings carry several important policy implications, particularly given that the link observed between rising tourism demand and local environmental management departs from a simple linear structure. First, while tourism demand may bolster municipal waste-management operations and resource circulation systems up to a certain point, excessive accumulation may gradually erode its positive contribution to ERB. Tourism policy should therefore move beyond a growth-oriented approach and be designed to also account for the environmental management capability and carrying capacity of local communities. Second, the nonlinearity that connects tourism demand and ERB implies that tourism policy should attend to the density and management of tourism demand rather than the sheer volume of visitors. Once tourism demand exceeds a certain threshold, this system may come under increasing strain, signaling the centrality of demand-management policy.

Third, the significant association identified between institutional tourism development arrangements—such as tourism special zones and tourism complexes—and ERB also carries direct policy relevance. Accordingly, tourism development policy should not be confined to expanding tourism infrastructure but should instead be integrated with environmental management policies, including waste management systems and resource circulation strategies. Fourth, the sharper erosion of ERB under overtourism in metropolitan areas suggests that tourism policy should reflect regional structural differences. These regulatory strategies may need to adopt tailored measures that align with regional disparities in visitor flows and infrastructure conditions. Finally, the interplay between tourism activities and the local sanitation system is intertwined with residents' day-to-day environmental conduct, indicating that tourism policy should extend beyond crowd management to encompass community-based environmental management frameworks and resident participation. These implications apply most directly where municipal governments hold substantial responsibility for managing household-type waste and tourism demand, administrative environmental data are systematically compiled, and visitor pressure is spatially concentrated—as in South Korea. They should therefore be transferred only cautiously to countries whose waste-management institutions or administrative structures differ substantially.

6.3. Limitations and Future Research

Although this study empirically investigated the overtourism–ERB nexus, several limitations should be acknowledged. Crucially, recycling volume was employed as a proxy indicator for ERB. The measure is widely accepted in earlier work but does not directly represent residents' ecological awareness or the broader spectrum of pro-environmental behaviors, warranting cautious interpretation. Future studies may benefit from drawing on survey-based instruments or behavioral data that more closely tap into residents' attitudes and practices in this area. Because fixed effects absorb only time-invariant hetero-

geneity, year-to-year variation in how completely separated recyclables are collected and recorded—rather than in residents' sorting itself—may remain in the residual. Moreover, data were obtained from municipalities in South Korea alone, which may limit external validity—the generalizability of the findings. In addition, South Korea's waste-management system operates within a relatively centralized and institutionally specific administrative structure, so the findings should be extended with caution beyond similar institutional settings. Since tourism demand profiles and environmental administration differ across countries and regions, future research could undertake comparative studies spanning multiple geographic contexts.

Further, tourism demand was measured primarily using visitor counts at major tourist attractions. Although the indicator is useful for gauging tourism scale, it may not fully convey the finer features of visitor behavior, such as length of stay, mobility patterns, or spending. Future work could leverage mobility data or spatially detailed datasets to better trace the dynamics of tourism activities. As a binary marker of Capital Region membership, *METRO* also cannot resolve micro-spatial heterogeneity within the region—for instance, between central Seoul, Incheon, and the Gyeonggi periphery. Lastly, the focus rested on quantitatively assessing the empirical association between tourism demand and ERB. Consequently, this study did not fully address the underlying social and behavioral mechanisms. Subsequent research could pursue more micro-level explanations by considering elements such as residents' perceptions, community norms, and environmental governance systems—and could disentangle the multiple pandemic-related pathways bundled within the COVID-19 period dummy, which the present model cannot separately identify.

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