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From Linear to Circular: Empirical Evidence of Circular Economy Adoption and Willingness to Pay in an Indonesian Coastal City

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Abstract: This study aims to: (1) estimate WTP and aggregate waste fee revenue potential; (2) evaluate community preferences for six CE strategies and their fiscal feasibility; (3) identify determinants of WTP using binary logistic regression; and (4) formulate an evidence-based policy portfolio to close the financing gap in Tarakan City's waste management system. Using CVM and binary logistic regression on 350 households (2024): (1) mean WTP of IDR 174,500/household/year yields IDR 3.93 billion/year aggregate (95% CI: IDR 3.60–4.26 billion) or 71% cost recovery; (2) CE strategy BCR hierarchy: reduce (∞) > reuse/recovery/sorting (1.46) > recycle (0.73) > repair (0.29); (3) Income (OR=2.14; p<0.05) and Education (OR=1.87; p<0.05) are the only significant WTP determinants — confirming the value-action gap and falsifying the information deficit model; (4) a three-level policy portfolio achieves near-full fiscal self-sufficiency (≈99.8% cost recovery) through progressive tariffs and recycling monetization.

Keywords: WTP, CVM, logistic regression, circular economy, financing gap

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INTRODUCTION

Urban waste management systems in developing countries face an acute and persistent fiscal paradox. On one hand, local governments allocate 20–50% of the public budget to the waste management sector; on the other hand, 80–95% of that budget is absorbed by collection and transportation operations, leaving almost no room for advanced processing capacity recycling, composting, and energy recovery to develop (Guerrero et al., 2013). As a result, only 50–80% of waste is successfully collected, while the rest becomes a latent threat to public health and the quality of urban ecosystems (Ferronato & Torretta, 2019). Indonesia faces this challenge with greater intensity. The 2024 National Waste Management Information System (SIPSN) data recorded national waste generation reaching 35 million tons per year, but only 39.89% was managed properly (KLHK, 2025). Households are the largest contributors, accounting for 54% of the total volume, making active participation and the willingness to pay by the community determinant variables in the success of the urban waste management system.

Beyond operational inefficiencies, a critical structural issue lies in the financing gap defined as the difference between total operational costs and user fee revenues which represents a universal fiscal challenge in urban waste services. In Indonesia, the average cost recovery rate remains relatively low at around 40–50% (Suryawan & Lee, 2023; Permatasari & Firda, 2023), far below the international efficiency benchmark of 80–100%. This condition reflects not only fiscal constraints but also inefficiencies in tariff design. In this context, Ramsey pricing where tariffs are set based on demand elasticity and ability to pay offers a theoretically grounded solution to simultaneously improve cost recovery while maintaining affordability for vulnerable groups (Ramsey, 1927; Li et al., 2023; Komives et al., 2005).

Amidst this pressure, the circular economy (CE) framework offers a transformative path: turning waste from a fiscal burden into a valuable economic resource through a hierarchy of strategies reduce, reuse, recycle, recover, and repair (Ellen MacArthur Foundation, 2013). However, the success of the transition to a CE system is heavily determined by empirical understanding of three critical questions that remain unanswered in the context of Indonesian medium-sized cities: (1) How much are people willing to pay for CE-based services, and what is the potential revenue from these services? (2) Which CE strategies are fiscally feasible to implement, and which require market failure corrections? and (3) what statistically significant factors determine the probability of a household being willing to pay and does environmental knowledge really predict WTP in the context of developing countries?

The third question has fundamental policy implications. The dominant policy model in Indonesia tends to assume that low community participation stems from an information deficit; thus, the proposed solution relies on socialization and environmental education campaigns. This assumption needs to be tested econometrically. Logistic regression was chosen as the method to identify the determinants of WTP in this study because the dependent variable is binary willing to pay (WTP > 0) vs. not willing (WTP = 0) and it produces a more intuitive interpretation of the odds ratio (OR) for policy intervention design compared to linear regression coefficients (Hosmer & Lemeshow, 2000; Greene, 2012).

Tarakan City, as a developing coastal city in North Kalimantan, represents a typical medium-sized city outside Java that faces acute fiscal limitations in waste management. Based on this context, this research is formulated with four complementary objectives: (1) Estimating the willingness to pay (WTP) and the aggregate potential revenue for circular economy-based waste management services in Tarakan City; (2) Evaluating community preferences for six circular economy strategies along with their fiscal feasibility through benefit-cost ratio (BCR) analysis; (3) Identifying socio-economic factors that significantly influence the probability of a positive WTP using binary logistic regression; (4) Formulating an evidence-based policy portfolio that is fiscally sustainable to close the financing gap of Tarakan City's waste management system.

METHOD

This study integrates three complementary analytical methods according to four research objectives. First, the Contingent Valuation Method (CVM) with a payment card format to estimate the WTP value and aggregate the economic value of environmental services to the population level. Second, benefit-cost ratio (BCR) analysis per CE strategy to classify strategies into tiers of fiscal feasibility. Third, binary logistic regression to identify determinants of positive WTP probability. Fourth, multi-instrument fiscal portfolio simulation to formulate policy combinations that optimally close the financing gap [Objective 4]. Primary data were obtained through direct interviews using structured questionnaires with heads of households in six sub-districts of the central area of Tarakan City (2024).

The study was conducted in six sub-districts of the central area of Tarakan City: Karang Anyar and Karang Anyar Pantai (West Tarakan District); Pamusian, Sebengkok, and Selumit Pantai (Central Tarakan District); and Lingkas Ujung (East Tarakan District). The unit of analysis is households as collective decision-makers in waste management (Afroz & Masud, 2011). The sample size was determined using the Slovin formula:

$$n = N / (1 + N \cdot e^2) = 101.334 / (1 + 101.334 \times 0{,}0534^2) \approx 350 \text{ households}$$

The proportionate stratified random sampling technique (Cochran, 1977) with the allocation $n_i = n \times N_i/N$ per sub-district ensures proportional representation of all segments of the population. This sample size meets the minimum requirements for logistic regression: an observation-to-predictor ratio of 50:1 (350/7) exceeds the minimum standard of 10:1 (Hosmer & Lemeshow, 2000) while also being consistent with the NOAA Panel standards for CVM (Arrow et al., 1993). The estimated binary logistic regression model is:

$$logit[P(WTP_i > 0)] = ln[P/(1-P)] = \alpha_0 + \alpha_1 INC_i + \alpha_2 EDU_i + \alpha_3 OWN_i + \alpha_4 YARD_i + \alpha_5 MAN_i + \alpha_6 CE_i$$

Hypothesis testing is conducted at two levels: (1) simultaneous test—likelihood ratio test (LRT): H_0: $\alpha_1=\alpha_2=...=\alpha_6=0$; reject H_0 if $p < 0.05$; (2) partial test—Wald test: H_0: $\alpha_j = 0$; reject H_0 if $p < 0.05$. The model's feasibility is evaluated through: (i) (i) Nagelkerke R^2 as a measure of goodness of fit; (ii) Hosmer-Lemeshow test for model calibration (not significant = good fit); (iii) classification accuracy from the confusion matrix; and (iv) Area Under Curve (AUC-ROC) as a measure of model discrimination (Long & Freese, 2014; Hosmer & Lemeshow, 2000).

BCR per CE strategy is calculated using the formula: BCR = WTP-average² / Estimated-cost-per-RT-per-month, with WTP-average² = Rp14,583/month. The fiscal portfolio simulation evaluates a combination of three revenue sources: (i) progressive tariffs (Ramsey pricing); (ii) monetization of recycling revenue; and (iii) public-private partnerships (PPP). Cost recovery is calculated as the ratio of total revenue to total operating costs (Rp5.55 billion/year).

RESULTS AND DISCUSSION

Research Result

The sample reflects a typical urban socio-economic structure in Indonesia, with 75% of respondents earning above Rp1,100,000 per month and 46% approaching the 2024 minimum wage of Tarakan City (Rp4,188,174). This pattern is consistent with the *urban wage premium*, where agglomeration effects lead to higher nominal wages, though not necessarily higher real welfare due to elevated living costs. At the same time, the presence of 25% low-income respondents underscores the need for equity-oriented tariff design, as flat tariffs can be regressive and disproportionately burden vulnerable groups (Baumol & Oates, 1988; Switzer & Teodoro, 2025).

In terms of demographics, the sample is relatively young (88% under 55), highly educated (81% holding at least a bachelor's degree), and dominated by civil servants (38%), followed by private employees and entrepreneurs (BPS, 2025). The high education level supports the internal validity of the CVM approach, as more educated respondents are better able to process hypothetical scenarios (Diamond & Hausman, 1994). However, it may also introduce upward bias in WTP estimates, making sensitivity analysis with sample weighting important (Wooldridge, 2010). The prominence of civil servants suggests relatively stable income and longer planning horizons, as well as potential demonstration effects in adopting retribution policies (Frey & Torgler, 2007; Rogers, 2003).

Estimation of WTP and Aggregate Potential of Retribution

The WTP distribution shows a bimodal pattern reflecting the heterogeneity of community preferences: 48% are willing to pay more than Rp15,000/month, while 8% prefer the status quo. The proportion of zero WTP (8%) must be interpreted with caution in the CVM literature, zero WTP can represent a protest response (a normative objection that waste management is the government's responsibility) or free-rider behavior (Mitchell & Carson, 1989; Brouwer & Martín-Ortega, 2012). Distinguishing true zeros from protest zeros is crucial to avoid distortion in aggregate estimates (Mavrodi et al., 2021). Concentration on certain price points also indicates an inherent focal point bias in the payment card format (Herriges & Shogren, 1996).

Table 1. Distribution of Respondents WTP Preference (n=350)

WTP Value (Rp/month)	Median Value (Rp/year)	Respondents (n)	Proportion (%)	Interpretation
Rp0 (status quo)	0	28	8	True zero / protest response
Rp5,000	60,000	67	19	WTP low
Rp7,500	90,000	88	25	WTP medium
> Rp15,000	> 180,000	167	48	WTP high
Total	—	**350**	**100**	—

Source: Processed Primary Data

The mean WTP estimate is calculated using the arithmetic mean (Carson & Mitchell, 1993):

$$\text{Mean WTP} = \Sigma\, WTP_i / n = \text{Rp } 61{,}025{,}000 / 350 \approx \text{Rp } 174{,}500 \text{ per household per year } (\equiv \text{Rp } 14{,}583 \text{ per month})$$

This value represents the Hicksian compensating variation (Freeman, 2003; Johnston et al., 2018). The WTP/median income ratio of 0.57% very close to the global median of 0.6% in the meta-analysis by Johnston et al. (2017) confirms the absence of excessive hypothetical bias, making the estimate valid as a basis for formulating the retribution tariff. Aggregation to the population level (22,520 households):

$$\text{Total WTP} = \text{Rp } 174{,}500 \times 22{,}520 \approx \text{Rp } 3.93 \text{ billion/year } CI_{95}\% = \text{Rp } 3.93 \text{ M} \pm \text{Rp } 329 \text{ million} = [\text{Rp } 3.60 \text{ M; Rp } 4.26 \text{ M}] \text{ (bootstrapping 1,000 iterations). Cost Recovery Rate} = \text{Rp } 3.93 \text{ M} / \text{Rp } 5.55 \text{ M} \times 100\% = 71\%$$

The cost recovery rate of 71% is considered high compared to the national average of 40–50% (Suryawan & Lee, 2023; Permatasari & Firda, 2023), but it still leaves a financing gap of Rp 1.62 billion/year (29%). In the framework of fiscal federalism, this gap serves as a valid economic justification for local government subsidies, considering that waste management possesses the characteristics of merit goods with extensive positive externalities, such as improved public health and environmental sustainability, which benefit the entire community (Musgrave & Musgrave, 1989; Samuelson, 1954). Thus, the first research objective is answered: WTP

Rp174,500/RT/year, aggregate potential Rp3.93 billion/year, and financing gap Rp1.62 billion/year.

CE Strategy Preference and Fiscal Feasibility

Table 2. Preference for CE Strategy, BCR, and Tier Classification Policy

CE Strategy	WTP Dominan (Rupiah/year)	Proportion (%)	Cost Estimation (Rp/month)	BCR	Tier
Reduce	> Rp250.000	14	Rp0	inf	Tier 1
Reuse	Rp100,000-150,000	26	Rp10,000	1.46	Tier 1
Recovery	Rp100,000-150,000	12	Rp10,000	1.46	Tier 1
Sorting	Rp150,000-200,000	7	Rp10,000	1.46	Tier 1
Recycle	Rp150,000-200,000	15	Rp20,000	0.73	Tier 2
Repair	> Rp250,000	21	Rp50,000	0.29	Tier 3
Status Quo	Rp0	4	—	—	—

Notes: BCR = Average WTP (Rp14,583/month) divided by estimated implementation cost per month per household
Source: *Processed Primary Data*

The benefit–cost analysis (BCR) reveals a clear and actionable hierarchy of circular economy (CE) strategies. The *reduce*strategy yields an effectively infinite BCR, as it involves no direct financial cost, meaning that the entire willingness to pay (WTP) translates into pure net benefit. Its aggregate net benefit reaches approximately Rp3.94 billion per year, representing the highest social return across all strategies and aligning with the international waste hierarchy that prioritizes waste prevention (Pires et al., 2011; Hariyani et al., 2025). Similarly, *reuse, recovery,* and *sorting* (BCR = 1.46) generate a positive net benefit of around Rp4,583 per household per month, or Rp1.24 billion annually in aggregate. These strategies are behavior-intensive but not capital-intensive, allowing them to operate sustainably through user fees (Wilson et al., 2006). However, the low preference for sorting (7%) despite its high BCR reflects behavioral constraints, including high opportunity costs of time (Bruvoll et al., 2002), institutional trust deficits in downstream waste processing (Saphores et al., 2006), and effort aversion due to suboptimal framing (Zhang, 2023), underscoring the need for policy design based on choice architecture that makes sorting the default behavior.

In contrast, the *recycle* strategy (BCR = 0.73) indicates a classic market failure rather than a lack of viability. Its positive externalities such as greenhouse gas emission reduction, energy savings, and resource conservation are not fully captured in private WTP (Samuelson, 1954; Arrow et al., 1993). Once the carbon value (approximately Rp1.73 billion per year) is internalized, the social BCR increases to 1.05, confirming its social feasibility. This justifies policy interventions such as Pigouvian subsidies (around Rp1.46 billion per year), implementation of Extended Producer Responsibility (EPR) schemes in line with PermenLHK P.75/2019, and the modernization of material recovery facilities alongside the development of recycling markets (Fullerton & Kinnaman, 1995). Meanwhile, the *repair* strategy (BCR = 0.29) shows a substantial deficit (Rp35,417 per household per month), driven by its labor-intensive nature, planned obsolescence in consumer goods, and the absence of a supportive institutional ecosystem (Lundberg et al., 2024; Singhal et al., 2020). Despite its low short-term private returns, repair remains valuable as a long-term social investment through job creation, skill development, reduction of electronic waste, and enhanced community economic resilience.

Determinants of WTP: Results of Binary Logistic Regression

Table 3. Result of Binary Logistic Regression Estimation – Determinants of The Probability WTP > 0 (n=350)

Variabel	Coefisien (α)	Wald Statistic	Significance	Exp (α) = OR	Marginal Effect
Constant (β_0)	-4,821	18,34	0,000*	0,008	—
Income— INC	**0,761**	**12,47**	**0,001**	**2,141**	**+0,053**
Education — EDU	**0,626**	**9,83**	**0,002**	**1,870**	**+0,044**
Ownership — OWN	0,214	1,29	0,256 n.s.	1,239	—
Yard — YARD	-0,087	0,43	0,511 n.s.	0,917	—
Waste Management — MAN	0,183	1,88	0,170 n.s.	1,201	—
Knowledge — CE	0,312	2,21	0,137 n.s.	1,366	—

Notes:** = significant α=5%; n.s. = not significant;Nagelkerke R^2 = 0.387; Hosmer Lemeshow $\chi^2(8)$ = 6.83, p = 0.554 (good fit);Classification accuracy = 91.4%; AUC-ROC = 0.823
Source: *Processed Primary Data*

The logistic regression model demonstrates satisfactory goodness of fit and predictive performance. The Nagelkerke R^2 of 0.387 indicates that the model explains 38.7% of the variation in the probability of a positive willingness to pay (WTP), which is considered adequate for behavioral models using socio-economic predictors. The Hosmer–Lemeshow test ($\chi^2(8)$ = 6.83; p = 0.554) confirms good calibration between predicted and observed probabilities. In addition, the model achieves 91.4% classification accuracy with an AUC-ROC of 0.823, indicating excellent discriminatory power (Hosmer & Lemeshow, 2000).

Among the explanatory variables, income (INC) emerges as the most influential determinant (α = 0.761; p = 0.001; OR = 2.141), implying that households with higher income are more than twice as likely to express a positive WTP compared to lower-income households. Education (EDU) also shows a positive and significant effect (α = 0.626; p = 0.002; OR = 1.870), suggesting that higher educational attainment increases the likelihood of supporting environmental service financing. These findings are consistent with economic theory that treats environmental quality as a normal good, where higher income increases the ability to pay (Kristrom & Riera, 1996; Afroz & Masud, 2011; Suryawan & Lee, 2023), while education strengthens both economic capacity and cognitive understanding of long-term environmental risks (Becker, 1964; Schultz, 1961; Viscusi et al., 2008; Tianyu & Meng, 2020).

In contrast, home ownership, yard ownership, waste management practices, and circular economy (CE) knowledge do not show statistically significant effects. The insignificance of CE knowledge challenges the information deficit model, indicating that greater awareness alone does not necessarily translate into financial commitment (Steg & Vlek, 2009). This pattern reflects the well-documented value–action gap, where pro-environmental attitudes do not automatically lead to willingness to pay when budget constraints are binding (Blake, 1999; Kollmuss & Agyeman, 2002).

Similarly, the absence of a significant relationship between existing waste management practices and WTP suggests weak complementarity between individual behavior and collective service provision, possibly due to limited downstream waste management infrastructure in Tarakan. The non-significance of home ownership is also noteworthy, as it contrasts with predictions from hedonic pricing theory, where environmental quality is capitalized into property values (Rosen, 1974; Chay & Greenstone, 2005). This discrepancy likely reflects the Indonesian context, where property markets are less formalized and such capitalization mechanisms operate more weakly.

Overall, the results indicate that economic capacity—particularly income—plays a more decisive role than informational factors, implying that economic incentives such as progressive tariffs are likely to be more effective than purely awareness-based interventions in supporting the financial sustainability of waste management services (Komives et al., 2005; Whittington, 1998).

External Validation: Comparation with Similar Studies

Table 4. Cross-Study WTP Comparation

Study	Location	WTP (USD/year)	Method	WTP Rasio/Income
Pratiwi, dkk. (Studi ini, 2024)	Tarakan	11,6	CVM – Payment Card	0,57%
Suryawan & Lee (2023)	Jakarta	10,1 – 13,5	Choice Experiment	~0,50%
Saptutyningsih & Amalia (2024)	Tasikmalaya	13,2	CVM	~0,60%
Afroz & Masud (2011)	Kuala Lumpur	82,7 *	CVM	~0,40% *

Notes: *the absolut difference in Malaysia reflects differences in per capita income and service standars, not preference anomalies

The WTP estimate for Tarakan (USD 11.6/year) is in the middle of the national and regional empirical range. The WTP/income ratio of 0.57% is close to the global median of 0.6% (Johnston et al., 2017; Ojea & Loureiro, 2007), confirming the external validity of the CVM. More importantly, theoretically, the consistency of significant determinants across studies—income and education always emerge as strong predictors of WTP, while environment-specific variables (knowledge and practices) consistently remain insignificant—indicating the structural reliability of the logistic regression findings of this study and its ability to be generalized to the context of medium-sized Indonesian cities.

Multi-Instrument Policy Portfolio: Closing The Financial Gap

Building on the synthesis of the previous findings, this section proposes an evidence-based policy portfolio to address the financing gap of Rp1.62 billion per year. Results from the WTP estimation establish the fiscal gap, the BCR analysis identifies priority circular economy (CE) strategies, and the regression results confirm that income-based instruments—rather than information campaigns—are the most effective policy lever. Accordingly, the portfolio is structured into three complementary layers. First, Tier 1 (BCR > 1) focuses on immediately implementable, high-return interventions, including *reduce* policies (e.g., single-use plastic restrictions and Pigouvian incentives), expansion of reuse/recovery systems through community-based waste banks, and household-level sorting supported by behavioral incentives (Pigou, 1920). These measures are low-cost, behavior-driven, and largely self-sustaining through user participation and revenue generation. Second, Tier 2 (recycling) addresses market failure through vian subsidies (~Rp1.46 billion/year), implementation of Extended Producer Responsibility (EPR), and investment in material recovery infrastructure and market creation via public procurement. Third, Tier 3 (repair) is positioned as a long-term social investment, focusing on workforce training, institutional ecosystem development, and digital market integration to support repair and refurbishment activities (Lundberg et al., 2024; Singhal et al., 2020).

To ensure equity and revenue optimization, the portfolio is anchored by a progressive tariff (pricing) aligned with income distribution. The proposed tariff structure generates an average of Rp17,100 per household per month, yielding approximately Rp4.62 billion per year and increasing cost recovery from 71% to 83.3%, while maintaining affordability for low-income households (Komives et al., 2005; Whittington, 1998). This design also functions as a fiscal automatic stabilizer, as revenue increases endogenously with income growth in higher brackets (Li et al., 2023).

A fiscal simulation confirms the feasibility of achieving near-full cost recovery through the integration of progressive tariff revenue (Rp4.62 billion/year) and net recycling revenue (Rp0.92 billion/year), resulting in total revenues of Rp5.54 billion per year, nearly matching operational costs of Rp5.55 billion. The remaining marginal gap (~Rp10 million) can be closed through efficiency gains or limited public–private partnerships (Lohri et al., 2014; Bharadwaj et al., 2020). Importantly, this configuration enables a strategic reallocation of public funds: rather than covering operational deficits, subsidies can be redirected toward correcting market failures in recycling and financing long-term investments in the repair ecosystem. Overall, the proposed three-tier portfolio represents a fundamental fiscal redesign, shifting from cost-heavy, collection-oriented systems toward a financially self-sustaining and structurally transformative waste management model.

Discussion

This study estimates an average willingness to pay (WTP) of Rp174,500 per household per year, with an aggregate revenue potential of approximately Rp3.93 billion annually (95% CI: Rp3.60–4.26 billion), covering about 71% of total operational costs. The WTP-to-income ratio of 0.57%, which is close to the global median, indicates that the estimated value is realistic and can serve as a reliable basis for tariff setting.

The benefit–cost analysis (BCR) establishes a clear prioritization of circular economy (CE) strategies: reduce and reuse/recovery/sorting are financially feasible, while recycling requires policy support and repair remains a long-term social investment. In addition, the regression results confirm that income and education are the only significant determinants of WTP, highlighting the importance of socio-economic factors in shaping payment capacity.

Finally, the fiscal simulation demonstrates that combining progressive tariffs with recycling revenue can nearly close the financing gap without heavy reliance on public subsidies. Based on these findings, this study proposes a tier-based policy portfolio aligned with fiscal feasibility and equity considerations. Future research should extend the analysis using alternative valuation methods, examine long-term policy impacts, and test the model's applicability in other urban contexts.

CONCLUSIONS

This research produces findings that directly address four research objectives while also providing theoretical and policy implications. The estimated willingness to pay (WTP) shows an average of Rp174,500 per household per year with an aggregate revenue potential of around Rp3.93 billion per year (95% CI: Rp3.60–4.26 billion). This value can cover approximately 71% of the operational costs of waste management, amounting to Rp5.55 billion per year. The WTP-to-income ratio of 0.57%, which is close to the global median (0.6%), also indicates that the CVM estimate is quite realistic and can serve as a basis for setting the retribution tariff.

Evaluation of the circular economy (CE) strategy through BCR analysis shows clear policy priorities: the reduce strategy is the most efficient choice (BCR = ∞), followed by reuse/recovery/sorting (BCR = 1.46), which has sustainable potential through user fees. Meanwhile, recycling (BCR = 0.73) still requires Pigouvian subsidies, and repair (BCR = 0.29) is more of a long-term social investment. Logistic regression analysis shows that only income and education significantly influence the probability of a positive WTP, while knowledge about CE is not significant. These findings indicate the presence of a value–action gap, where economic constraints are the primary factor compared to a lack of information.

Fiscal simulations show that a combination of progressive tariffs based on the Ramsey principle with the monetization of recycling results almost completely closes the operational financing gap without relying on regional government subsidies. These findings support the design of a three-tiered policy portfolio that adjusts instruments according to BCR value and considers equity aspects through progressive tariffs. Further research is recommended to explore community preferences through choice experiments, analyze the dynamic impacts of tariff policies in the long term, and replicate the model in other coastal cities to test the generalizability of the results.

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