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Estimating Economic Values for Pigeon Island National Park, Sri Lanka: Towards Designing Economic Instruments to Minimize Anthropogenic Degradation

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Abstract: Pigeon Island National Park (PINP), a vital Sri Lankan Marine Protected Area, faces severe anthropogenic degradation stemming from rapid post-conflict tourism growth, excessive plastic accumulation, and illegal fishing. Institutional financing failures, where tourism revenue bypasses local conservation efforts, necessitate the design of sustainable, market-based instruments. The primary objectives of this study were to examine threats, estimate visitor Marginal Willingness to Pay (MWTP) for conservation improvements, and design novel, non-tax economic instruments.
The Choice Experiment Method (CEM) was employed to quantify attribute-specific visitor preferences, with face-to-face interviews conducted on a sample of 200 visitors (Jan-Aug 2022). Attributes included reductions in plastic/polythene, illegal fishing nets, crowding, and a monetary contribution (Cost). The resulting Conditional Logit Model was highly significant (p=0.000), showing a positive MWTP for all conservation attributes. Key results indicated visitors were willing to pay LKR 564.55 to reduce plastic by 50% and LKR 568.35 to reduce illegal nets by 50%.
These values inform the design of a complementary package of non-tax instruments: 1) A Refundable Deposit System (LKR 564.55) for plastic to address diffuse pollution; and 2) An Annual Insurance Surcharge (LKR 568.35) on boat owners to target sectoral risk. Implementation of these instruments provides a dedicated, re-investable funding source, bypassing the socio-political friction of imposing direct taxes, and offers a crucial blueprint for PINP's sustained ecological health.

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Introduction

Pigeon Island National Park (PINP) is situated about 1 km off the coast of Nilaveli, in the Trincomalee District (Eastern Province) in Sri Lanka. The Park covers approximately 471.4 ha, including both terrestrial and marine environments. The area was designated as a sanctuary in 1963 and later upgraded to a national park in 2003 to provide stronger protection for its ecological resources (Coastal Conservation Department, 2013). The park is renowned for its well-preserved coral reefs, which host over 100 coral species. PINP is home to a rich array of marine species, including over 300 species of reef fish. The islands host various bird species, including the rock pigeon (Columba livia) (Coastal Conservation Department, 2013). Boundaries of PINP are denoted in figure1 and figure 2 illustrates the geographical location of the PINP with in the territorial boundaries of Sri Lanka.

Figure 1. Boundaries of Pigeon Island National Park

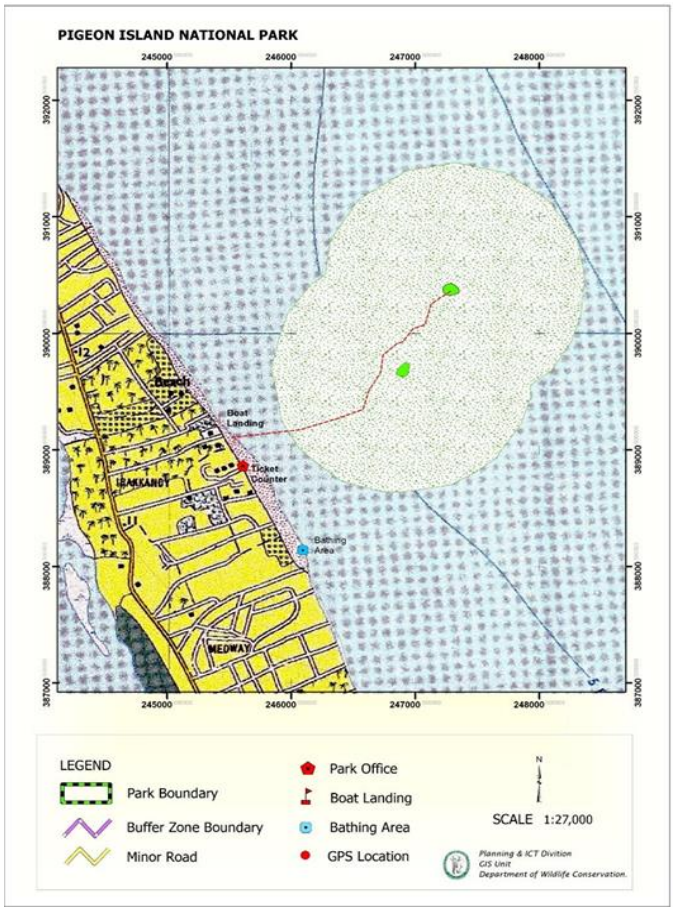
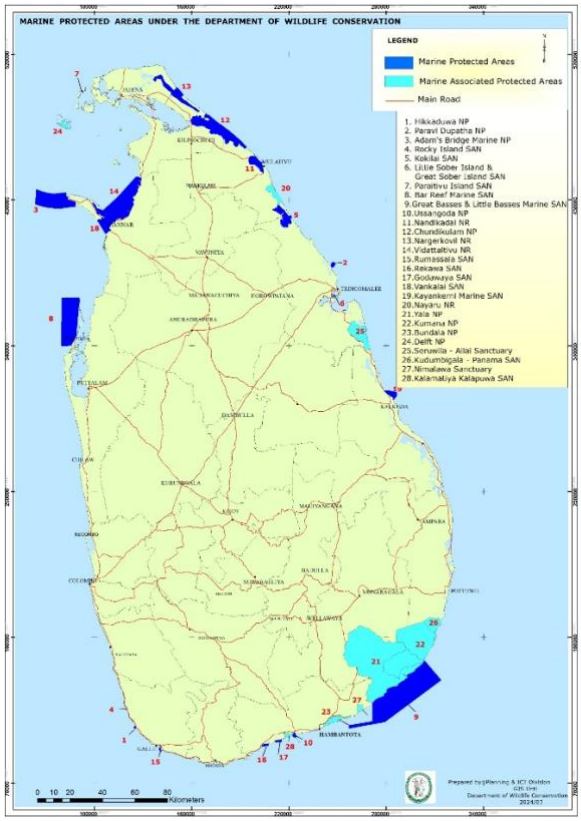


Figure 2. Location of the Pigeon Island National Park in Sri Lanka



Sri Lanka has become a tourist hotspot at the end of the civil conflict in 2009. Inbound tourism is growing rapidly, and a considerable percentage of foreign tourists visit PINP as well. Moreover, there is a considerable number of people who are dependent on edible and non-edible fish species beyond the boundaries of PINP.

Although the tourism sector is earning a significant amount of income, Visitor pressure has negatively affected PINP due to increased demand for natural resources. After the civil conflict, migrant fishermen from the south and northwest are arriving at the east coast during the fishing season, resulting in overexploitation. Furthermore, illegal fishing methods such as dynamiting and bottom trawling have increased. Excessive usage of plastic and polythene is visible as a consequence of visitor pressure and increased fishing activities. Although PINP was not affected by the tsunami it was moderately affected by the 1998 and 2016 coral bleaching events. Therefore, visible signs of degradation are present in PINP due to both natural and anthropogenic activities.

Despite the ecological significance and the escalating visitor pressure on Pigeon Island National Park (PINP), a comprehensive economic valuation of its ecosystem services remains largely unexplored in the post-conflict landscape. This study addresses a critical research gap by being among the first to integrate visitor perceptions with a marginal willingness to pay (WTP) analysis to quantify the non-market values of PINP's marine and terrestrial assets. Its novelty lies in the transition from purely descriptive ecological assessments to the formulation of evidence-based economic instruments - such as revised entry pricing, environmental levies, or fishing permits - tailored to the specific anthropogenic pressures of the Eastern Province. The importance of this research is underscored by its potential to provide a data-driven framework for policymakers to internalize environmental externalities, ensuring that the burgeoning tourism industry and local fisheries contribute to the park's conservation rather than its degradation. By establishing these economic signals, the study offers a replicable model for the sustainable management of marine protected areas in developing island nations facing similar tensions between economic development and biodiversity preservation.

The objective of this study is to examine the threats to this ecosystem, estimate the marginal willingness to pay from the perspective of visitor perceptions and to design economic instruments that can be used to mitigate the problems. Further, it is expected that these instruments will provide a signal for the policy makers to achieve sustainable management of the national park.

1. Research Background

Degradation of Coral Reef Ecosystems and the Need for Economic Intervention

Coral reef ecosystems worldwide are undergoing significant and pervasive degradation due to a confluence of factors, posing a serious threat to marine biodiversity and coastal ecosystems (Xiao, 2022). The primary drivers of this decline include more frequent global warming events, widespread biological disturbances, and intensified human activities (Xiao, 2022). More specific stressors leading to ongoing decline are dynamite fishing, coral bleaching, poor water quality, and pest species infestations (Cabral *et al.* 2014). In response, governments have adopted passive conservation strategies, such as designating marine protected areas (MPAs), to limit harmful human activities and facilitate natural recovery (Abrina *et al.* 2021). Harmful human activities, however, are often elevated in developing countries compared to developed countries. Economists have extensively utilized analytical approaches to quantify the deterioration of coral reefs and understand the resulting socioeconomic consequences (Laurans *et al.* 2013). The impacts include measurable economic losses, such as a decline in fisheries, reduced tourism revenue, and the loss of essential coastal protection services (Lee *et al.* 2019). Economists employ tools to capture the full range of impacts on human well-being and local economies (Web *et al.* 2021).

Environmental Valuation and Economic Instruments

Modern environmental economics is founded on two core concepts: Environmental Valuation and Economic Instruments (Panaiotov, 1994). While valuation assesses the benefits derived from and damages to nature, economic instruments are designed to execute these values by influencing behaviour and policy (Panaiotov, 1994; Tinch *et al.* 2019). Environmental degradation often stems from the failure of traditional markets to account for the actual value of nature in economic decisions, leading to overexploitation and pollution (Kelemen, 2023). Environmental valuation addresses this market failure by assigning monetary value to natural assets (Estoque *et al.* 2018). Marine and coastal ecosystems, in particular, are often undervalued in traditional economic calculations, leading to their degradation because their full economic benefits and the costs of their degradation are not adequately considered in decision-making Quantification of ecosystem services - including market-based values (*e.g.*, fisheries income), non-commercial values (*e.g.*, shoreline stabilization), and non-use values (*e.g.*, cultural significance) could make their value visible and understandable to decision-makers. (Emerton, 2014).

This economic valuation serves as an essential informational foundation for the design and implementation of economic instruments to strengthen the sustainable management of marine and coastal resources (Himes-Cornell *et al.* 2018, Keohane *et al.* 2019). These instruments aim to create positive financial and economic incentives for conservation, thereby addressing the root causes of ecosystem degradation and overcoming market and policy failures that currently encourage unsustainable practices (Keohane *et al.* 2019). Economic instruments function by encouraging sustainable resource use based on principles such as polluter pays, user pays, ultimately sharing environmental costs and benefits more fairly, efficiently, and effectively (Wang *et al.* 2022). Emerton (2014) presents a generic list of applicable economic instruments for the sustainable management of marine and coastal natural resources, which are categorized into four functional groups: charge and fee systems, fiscal instruments, market creation and development and financial mechanisms. These instruments are often applied together as complementary packages (Emerton, 2014).

Valuation Methods for Non-Market Goods

Coral reefs are considered non-market goods, necessitating specific assessment methods for benefit evaluation (Lee *et al.* 2019). The Contingent Valuation Method (CVM) and the Choice Experiment Method (CEM), both stated preference techniques, are commonly employed to estimate the value of such goods (Lee *et al.* 2019). CVM is a non-market valuation approach that assesses individuals' preferences for ecosystems in a healthy ecological condition (Lee *et al.* 2019). It estimates individuals' Willingness to Pay (WTP) for conservation or their Willingness to Accept (WTA) the loss of ecosystem services by simulating a non-existent market through survey-based elicitation (Lee *et al.* 2019). Windayati *et al.* (2022) used CVM to assess coral reef ecosystem services in Indonesia. Choi *et al.* (2022) applied CVM to value seagrass species. Booth *et al.* (2022) used CVM to assess international tourists' WTP for community-based shark conservation.

While both are Stated Preference techniques, Hynes *et al.* (2021) highlight several advantages of CEM over CVM:

- **Attribute Valuation**: CEM allows for the estimation of the value of individual attributes of the good (*e.g.*, water quality, marine life), whereas CVM provides only a single lump sum value for a specific scenario (Hynes *et al.* 2021).
- **Trade-Off Simulation**: CEM simulates real-world trade-offs by presenting choices between multiple alternatives, while CVM inquires about WTP for a hypothetical single scenario (Hynes *et al.* 2021).
- **Statistical Efficiency**: CEM yields multiple data points per respondent across scenarios, leading to more detailed data and greater statistical efficiency than the single data point typically generated by CVM (Hynes *et al.* 2021).

Owing to its detail insights and ability to represent tade offs CEM is better suited for comprehensive resource valuation.

2. Gaps in Conservation and the Application of Economic Instruments

Despite extensive research on human-induced damage to coral ecosystems, much of it lacks the development of economic instruments to mitigate these adverse effects (Emerton, 2014). Environmental management in regions like the Bay of Bengal has historically relied on laws, regulations (*e.g.*, protected areas, quotas, bans), and post-damage mitigation (*e.g.*, treating polluted water, cleaning oil spills) (Emerton, 2014). However, neither regulations nor mitigation have proven fully effective. Regulations are costly, difficult to enforce, and can limit economic activities, while mitigation requires high spending and offers only temporary, partial solutions (Oosterhuis *et al.* 2014). Emerton (2014) notes that conservation funding is highly limited in most developing countries, making the high costs of enforcing regulations or repairing damage unaffordable. Crucially, markets and policies fail to reflect the actual costs of resource degradation, resulting in little reward for protecting nature and few penalties for harming it (Emerton, 2014).

Numerous studies have used Stated Preference methods, particularly CE, to assess the value of marine conservation and propose corresponding economic instruments. Wattage *et al.* (2011) used a CE study to propose banning trawling and paying a ring-fenced personal tax of 1$ p.a. for deep sea coral conservation. Can and Alp (2012) used CE to suggest that residents were WTP for water quality and marine life improvements via increases in their average monthly water bills. Oosterhuis *et al.* (2014) reviewed literature on economic instruments for reducing marine litter, noting the beneficial impact of taxes on plastic bag use and the effectiveness of deposit-refund schemes. Taxes and Fees are commonly used as the payment vehicle in CE studies. Halkos *et al.* (2016) used an increase in the water bill. Davis *et al.* (2019) and Grilli *et al.* (2022) used higher local council and state taxes/annual council tax. Börger *et al.* (2014) and Wallmo and Kosaka (2017) used an additional tax or household federal income tax.

3. Use of Estimated Values towards Designing Economic Instruments

A study on willingness to pay for improving marine biodiversity in Croatia was conducted by Smith *et al.* (2016). In order to conserve habitats and species, they conducted a stated-preference survey of two tourist groups: private boats and ferries. According to WTP estimates, revenues might range from approximately €330,000 to €451,000 per year, depending on various situations. The notion of charging visitor entry fees based on visitor type in accordance with WTP segmentation has been addressed by the authors. This study offers a reliable method for converting WTP into prospective income and fee creation. The possibility for tourist entry fees to provide income for MPA administration has been evaluated by Gelcich *et al.* (2013). But according to research, visitor fees by themselves are not a comprehensive nor an immediate way to fund Marine Protected Areas (MPAs). The study draws attention to the discrepancy between value estimation and the instruments that can realistically bridge the gap between the required funding and the entrance price. By showing that tourist admission fees alone are not enough to pay the entire operational costs, the study calculated the economic worth of the Marine Protected Area (MPA) based on visitor Willingness to Pay (WTP) and the real funding required. They have also said that in order to realistically fill the gap, additional, larger finance sources need to be taken into account, specifically suggesting "direct state/government support".

A stated preference survey comparing natural and artificial reef choices was conducted by Kirkbride-Smith *et al.* (2016) among tourists (snorkel tours). They also computed MWTP for both the natural and artificial reefs. In the context of a park, these figures can be used as the foundation for a single daily user fee. Mwebaze and MacLeod (2013) estimated the annual social welfare and consumer surplus per trip in a Seychelles marine park using the travel cost approach. They looked at the approximate consumer surplus of €128 for visits to a single site, €65 for visitors to many sites, and the total social welfare value of around €3.7 million each year. These numbers provide upper bounds for what visitors value and they can inform maximum feasible fees for funding targets. In their study on valuing an MPA in Indonesia, Baskara *et al.* (2017) reported that the average WTP to conserve the MPA was Rp 18,000; the projected hypothetical market value was approximately Rp 2.129 billion. This study offers a legitimate illustration of how valuation is specifically applied to create a "contribution charge" from the guests. It applies in a developing country context which is similar to Sri Lanka. Ahmad *et al.* (2024) in their study of estimating public willingness to pay at a proposed marine protected area in Malacca, have investigated that average WTP was Malaysian Ringgit 14.38 and this provides a strong WTP value for entrance fee design at a newly proposed MPA.

At Hikkaduwa National Park in Sri Lanka, Jayaratne *et al.* (2023a) calculated the WTP for boat safety to be Rs. 322.52 and the WTP for beach crowd reduction to be Rs. 998.92. These attributes-based WTP estimates can inform the design of differentiated pricing stratergies or targeted improvement surcharges extending beyond the scope of standard entrance fees. Jayaratne *et al.* (2023b) have conducted a choice experiment study in Bar Reef Marine Sanctuary in Sri Lanka and investigated that WTP for reduce plastic pollution by 50% is LKR 1,001.18 and if crowding can be reduced by 15% WTP is LKR 998.92. These figures can help to design instruments to control pollution. In order to attain tourism sustainability, Nitiratsuwan *et al.* (2022) conducted CVM research for a coast free of marine debris. They have evaluated WTP for a possible admission fee using a CVM scenario. It is a good example where valuation is directly linked to a theme (pollution control) rather than just visitation and can assist in designing surcharges for improved environmental quality. Noe *et al.* (2025) have attempted to assess the tourists WTP to conservation of natural resources in a national park in Thailand using CVM for four types of natural resources namely crab-eating macaques, coral reefs, forest and clean air. They have derived resource-specific WTP values; which emphasizes the importance of valuing multiple ecosystem services rather than just one. This research is useful for designing multi component charges (*e.g.*: for reef protection + forest + air) or for weighting the instrument by resource value".

When creating economic instruments, valuation estimates like consumer surplus and willingness to pay (WTP) provide a solid empirical base. These instruments - like entrance fees, user charges, or improvement levies - are typically not set equal to the full estimated value. Instead, their design often reflects a cautious proportion, taking into account factors like visitor behavior, cost recovery, accessibility, and the interests of various beneficiary groups Across the literature, these valuation-based instruments have been applied in diverse contexts, including developed and developing countries, marine parks versus coastal or mangrove ecosystems, and through various methodological approaches such as consumer surplus, WTP, and choice experiments

4. Contextualizing Instruments for Developing Countries and Sri Lanka

A wide range of economic instruments are applied in developing country context. Among them user fees are a common recurring revenue source, especially where ecotourism is significant. Well-managed ecotourism can

both finance MPAs and involve local communities, as seen in Mozambique and Seychelles (Casimiro *et al.* 2023, Pascal *et al.* 2021 and Bohorquez *et al.* 2022). Impact investment and blended finance is another strategy which uses innovative models that combine public, philanthropic, and private capital to fund MPA management and expansion, as piloted in the Dominican Republic and other Caribbean sites (Pascal *et al.* 2021 and Bohorquez *et al.* 2022). Debt-for-nature swaps also have been used in countries like Seychelles, Belize, Barbados, and Ecuador, though legal and transparency barriers exist. These arrangements convert national debt into conservation funding, providing stable support for MPAs (Jiang *et al.* 2024). Transferable fishing rights and market-based schemes such as rights-based fisheries management and trading schemes and Vessel Day Scheme in the Pacific, incentivize conservation while maintaining economic activity (Villaseñor-Derbez*et al.* 2020). Biodiversity offsets and compensation payments such as payments from industries (*e.g.*, fossil fuel, shipping) and ecological compensation mechanisms are emerging as alternative funding sources (Bohorquez *et al.* 2022 and Jiang & Cao, 2024).

5. Materials and Methods

In order to achieve the objectives Choice Experiment Method was applied in this study. The choices of the respondents are based on the Random Utility Theory (RUT) and the Consumer Choice Theory (CCT). According to the latter theory, the consumer attains fulfilment, from the attributes of the goods and not from the goods themselves (Lancaster, 1966). For the modelling of CEs, Random Utility Theory is used as the leading theory (McFadden, 1974). According to Random Utility Theory, consumers will choose one alternative over another once the utility derived from that alternative is higher. The utility of choice is comprised of two components, and they are the error term and the deterministic (systematic) term. The error term depicts the uncertainty of the predictions. The utility of a choice can be mathematically represented as follows.

$$U_{ab} = V_{ab}(X_{ab}, S_a) + \in_{ab} \quad (1)$$

U_{ab} denotes the utility that the ath respondent will obtain from choosing alternative b. Vab is the systematic term, which is a function of X_{ab}, the vector that includes the attributes, and S_a denotes respondent's characteristics. Moreover, random error is denoted by $\in ab$. The error term helps to represent the omitted variables and case-specific factors that control utility. This helps the practitioner to include the properties of the unobservable factors.

A respondent would choose alternative "c" over alternative "b" only when the satisfaction obtained is higher. *i.e.* Uac >Uab, where U represent utility. So that the probability of the ath respondent choosing cth alternative over "b", from the choice set C, is given as

$$P_{ac} = Prob(U_{ac} > U_{ab}) f \text{or all b in C}, b \neq c \quad (2)$$

$$P_{ac} = Prob(V_{ac} + \in_{ac} > V_{ab} + \in_{ab} \text{ for all b in C}, b \neq c \quad (3)$$

For the bth alternative, V_b is known as representative component utility, and it includes the observed and measured attributes of the individual. Weights attached to each attribute explain marginal utility. The following equation depicts the weights attached to each attribute.

$$V_b = \beta_{ob} + \beta_{1b} f(X_{Ib}) + \beta_{2b} f(X_{2b}) + \beta_{cb} f(X_{cb}) \quad (4)$$

Where β_0 is the alternative specific constant (ASC) which reveals unobserved sources of utility and it does not relate to any of the measured or observed attributes. B_{1b} is the coefficient (weight) of attribute X_1 and the alternative b. Attributes are depicted as functional forms since, based on the model, they can be included in forms such as quadratic, logarithmic, or in combinations (interactions).

To calculate selection probabilities of a choice model, the condition of Independence from Irrelevant Alternatives (IIA) should be satisfied. According to Can and Alp (2012), "the presence or absence of an additional alternative does not affect the ratio of the probabilities of choosing one alternative over another when all alternatives having a non-zero probability of choice are considered."

The IIA assumption indicates that the error terms are identically and independently distributed (IID). An assumption on the distribution of the error terms is made to obtain a meaningful expression for the probabilities. It is assumed that the error terms, ε, are identically and independently distributed and they follow a type I extreme value (double exponential or Gumbel, Weibull distribution), the resulting choice made would be expressed as follows.

$$P_{ab} = \frac{\exp(V_{ab})}{\in_{c=\exp(Vac)}} \quad (5)$$

It is known as the conditional logit model or multinomial logit model. With Logit models, which are estimated under random utility theory using Maximum Likelihood Estimation (MLE).

5.1 Calculating Marginal Willingness to Pay

Given that one attribute is measured in monetary terms, willingness to pay (WTP) can be found as a ratio of two parameters (coefficients, βs), holding all else constant. In this respect, both of the attributes should be statistically significant. In this calculation, the attribute measured as a monetary term is used in the denominator of the equation. Marginal Willingness to Pay (MWTP) is the ratio of the coefficient of the attribute of interest and the price coefficient (Can and Alp, 2012).

The initial state of the utility is V_0, the new state to be V_1 and β_c to be the coefficient of the cost attribute. Then, the WTP is given as:

$$MWTP = \beta_C^{-1} ln \left[\frac{\varepsilon_a \exp(v_a^1}{\varepsilon_a \exp(v_a^0}\right] \ldots \quad (6)$$

Letting βk represent the coefficient of any attribute from the above-mentioned equation, WTP can be stated as

$$WTP = -\frac{\beta_K}{\beta_c}$$

5.2 Main user Categories at the Pigeon Island National Park

Pigeon Island National Park (PINP) has become a tourism attraction after the end of the armed conflict in 2009. Since then, the number of visitors to the area is increasing. Hence, 200 visitors who travelled to this destination during the study period were the focus of this study. Moreover, fishing is the main occupation in this area, and hence, fishing is the primary source of income for the villagers. Fishing boats are also used to transport visitors to the island in the lean season. Compared to other local users, such as divers and collectors, there are a few. Tourism is a booming industry in the area, and there is small-scale to large-scale tourist ventures in the PINP area. Compared to other local users, such as divers and collectors, there are few.

5.2.1 Focus Group Discussions and Key Informative Interviews: PINP

In order to gain a better idea of the livelihood of the people, problems they face, and other important aspects to be considered in a choice experiment, two Focus Group Discussions (FGDs) and four Key Informative Interviews (KIIs) were held in the PINP area. Fishermen, boat owners, ornamental fish collectors and hotel owners were involved in FGDs and experts in the field and officers of the Department of Wildlife Conservation (DWLC) were interviewed in KIIs. In the FGDs, participants discussed issues related to the management of fishery resources, traditional and modern fishing techniques used by local fishers, and the types of fishing gear employed, their efficiency, and their impacts on the environment. Existing fishing regulations, their enforcement, and compliance by fishers were discussed. Tourism and related impacts on biodiversity, suggestions for improving tourism in the area in a sustainable manner, and other topics were discussed.

5.2.2. Data Sources

Primary data was the key source of information for the study. A sample of 200 visitors was interviewed using a random sampling method from January to August 2022. They were interviewed at local hotels, resorts, and beach areas. The other two main user groups, hotel owners and fishermen, were included in the focus group discussions. In addition, secondary data available from official sources such as the Coastal Conservation Department and the Wildlife Conservation Department were also consulted.

5.2.3 Preparation of the Questionnaire

Based on feedback from the FGDs and KIIs, a pilot questionnaire was prepared and tested prior to data collection with 50 visitors. According to the feedback obtained for the pilot questionnaire the final questionnaire was prepared.

5.2.4 Conducting the Survey

In the choice experiment method, which was used in this study, the first step was to identify different attributes and their levels. These attributes were identified in the FGDs and KIIs as mentioned above. Table 1 depicts the attributes and levels used in the study.

Table 1. Attributes and levels used in the study

Attribute	Level 1	Level 2	Level 3
Level of plastic and polythene accumulated	50% reduction in plastic and polythene	25% reduction in plastic and polythene	Current level of plastic and polythene
Level of crowding on the beach	30% fewer people	15% fewer people	Usual number of people
Use of illegal fishing nets	50% reduction in illegal fishing nets	25% reduction in illegal fishing nets	Current level of illegal fishing nets
Monitory contribution	LKR. 1000	Rs. 500	No additional contribution

Four attributes and three levels yield 64 distinct combinations in the main effects design. Showing 64 different combinations in a survey and also asking respondents to select their choice is not practical. Therefore, an orthogonal main-effect design was employed in SPSS 21 to reduce the 64 combinations to 9. These 9 profiles, along with their component attributes and levels, were included in a questionnaire format. With a third fixed alternative corresponding to the status quo, the number of random alternatives in each choice task was set to two. Further, the questionnaire included sections to gather socio-economic information as well. The choice set shown in the study is presented in Table 2.

Table 2. An example of a choice set shown in the study

Attribute 1	Attribute 2	Attribute 3	Attribute 4	Choice
50% reduced use of plastic	25% reduced use of illegal fishing nets	30% fewer people	No additional fee	1
50% reduced use of plastic	50% reduced use of illegal fishing nets	Usual number of people	LKR 500 additional fee	2
25% reduced use of plastic	Continue to use the current illegal fishing nets	30% fewer people	LKR 500 additional fee	3
25% reduced use of plastic	50% reduced use of illegal fishing nets	15% fewer people	No additional fee	4
25% reduced use of plastic	25% reduced use of illegal fishing nets	Usual number of people	LKR 1000 additional fee	5
Current level of plastic use	50% reduced use of illegal fishing nets	30% fewer people	LKR 1000 additional fee	6
Current level of plastic use	Continue to use the current illegal fishing nets	Usual number of people	No additional fee	7
50 % reduced use of plastic	Continue to use the current illegal fishing nets	15% fewer people	LKR 1000 additional fee	8
Current level of plastic use	25% reduced use of illegal fishing nets	15% fewer people	LKR 500 additional fee	9

6. Results

Results were analysed using STATA 14 software, and the model was tested for significance at α 0.01. According to chi-squared estimates, since the p-value of the model is 0.000, which is lower than 0.05, it indicates that this is a significant model at a 95% probability level. Further, the null hypothesis, which reveals that there is no relationship between choice and the attributes, can be rejected. The pseudo R_2 value is 0.1424, which is considered a good model according to Can and Alp (2012). Maximum likelihood estimates of the parameter values are presented in Table 3.

According to the above table regression equation for the model can be presented as follows.

Choice = -0.001 + 0.824 reduce plastic by 50% + 0.830 reduce illegal nets by 50% +0.580 reduce crowding by 30%.

Table 3. Results of Conditional logistic regression for PINP

Variable	Conditional logit model coefficient	$Pr > \chi^2$
Reduce plastic by 50%	0.824 (0.141)	0.000
Reduce Illegal nets by 50%	0.830 (0.164)	0.000

Reduce crowding by 30%	0.580 (0.161)	0.000
Contribution	-0.0015 (0.000)	0.000
Log likelihood Pseudo R_2	-413.840 0.1424	

Note: Standard errors in parentheses. $Pr > \chi^2$ reports p-values from Wald tests.

The coefficient of 0.824 with respect to “reduce plastic by 50% “indicates that individuals are 0.824 times more likely to choose the alternative associated with reducing plastic by 50%, holding other variables constant. P-value 0.000 suggests that this coefficient is statistically significant, indicating that reducing plastic by 50% has a significant impact on the choice being made.

The variable “reduce illegal nets by 50%" holds a coefficient of 0.830, which indicates that visitors are more likely to choose the alternative associated with reducing illegal nets by 50%, holding other variables constant. P-value 0.000 indicates that this coefficient is statistically significant, indicating that reducing illegal nets by 50% has a significant impact on the choice being made.

Reducing crowding by 30% has a coefficient of 0.580, which reveals that visitors are more likely to choose an alternative associated with reducing crowding by 50%, holding other variables constant. P value 0.000 indicates that this coefficient is statistically significant, indicating that reducing crowding by 30% has a significant impact on the choice being made.

Coefficient of -0.001 indicates that there is a very marginal decrease in the likelihood of choosing alternative per unit increase in 'contribution’. The p value indicates that this coefficient is statistically significant suggesting that the variable ‘contribution’ significantly influences the choice being made.

6.1 Marginal Willingness to Pay and Proposed Economic Instruments Mathematical Expressions

Since Marginal Willingness to pay is the negative value of the ratio of the attribute coefficient to the contribution coefficient, it is calculated for reduced plastic by 50% as follows. MWTP for reducing the plastic by 50% =-(0.8244115/-0.0014603) =LKR 564.55.

MWTP for reduced plastic by 50% represents the monetary value individuals are willing to pay for each unit reduction of plastic by 50%. According to the model, individuals are willing to pay LKR 564.55 to reduce plastic waste by 50%. Therefore, visitors may be charged a refundable deposit of LKR 564.55 if they bring polythene or plastic into the park.

MWTP for reduce illegal nets by 50% is =-(0.8299599/-0.0014603) =568.35

The selection of this instrument is grounded in the economic principles and contextual challenges detailed in the literature review, which emphasizes that environmental degradation stems from the failure of traditional markets to account for the actual value of nature. Economic instruments are designed to execute these values by influencing behavior and policy through principles like the polluter pays and user pays (Emerton, 2014).

The refundable deposit on plastic usage is an application of a Deposit-Refund System (DRS), which falls under the broader category of Charge and Fee Systems or Financial Mechanisms for environmental management. This instrument directly addresses the problem of marine litter and its impact on coral reef ecosystems. Oosterhuis *et al.* (2014), as cited in the literature review, noted the beneficial impact and effectiveness of deposit-refund schemes for reducing marine litter. The refundable nature of the charge leverages positive financial incentives, as opposed to a simple tax, which is necessary to overcome the "widespread reluctance to pay additional taxes" noted in the developing country context of Sri Lanka. Research studies done in ther countries confirms the efficacy of DRS over simple taxes, as it avoids the problem of 'midnight dumping' and enhances return rates for high-quality recycling (Walls, 2013). The instrument is further supported by local valuation work. Jayaratne *et al.* (2023) conducted a Choice Experiment study in the Bar Reef Marine Sanctuary (Sri Lanka) and found a Willingness to Pay (WTP) of LKR 1,001.18 to reduce plastic pollution by 50%. This valuation provides an empirical foundation for designing the deposit level to effectively control pollution.

MWTP for reduced illegal nets by 50% represents the monetary value individuals are willing to pay for each unit reduction of illegal nets by 50%. Visitors are willing to pay LKR 568.35 to reduce illegal nets by 50%, according to the model's results. This value states that visitors are concerned about the illegal fishing that destroys the marine ecosystems, and hence the importance of protecting sustainable fishing. LKR 568.35 can be charged to boat owners, in addition to their annual insurance premium, to discourage the use of illegal fishing gear, since the same boats are also used to carry visitors. The additional charge incorporated into the annual insurance premiums operates as a form of Financial Mechanism or Compensation Payment (Emerton, 2014). This mechanism targets the marine-user sector, whose activities - including tourism and fishing - can be a source

of direct impact (*e.g.*, anchor damage, waste discharge), and whose economic activities rely on the health of the resource (Lee *et al.* 2019). The instrument aligns with the User Pays and Polluter Pays principles, ensuring that those who benefit from or risk damaging the asset contribute to its maintenance.

The policy directly addresses the major institutional challenge in Sri Lanka, where MPA funding is limited, and tourism revenues are not effectively reinvested as they are credited to the Treasury. This new revenue stream, collected through the existing financial infrastructure of insurance, provides a mechanism for an "additional, larger finance source" to fill the funding gap that cannot be covered by tourism entry fees alone (Gelcich *et al.* 2013).

MWTP for reducing crowding by 30% is = - (0.580/-0.01) = 397.43

MWTP for reduced crowding by 30% represents the monetary value individuals are willing to pay for each unit of reduced crowding by 30%. Visitors are willing to pay LKR 397.43 to reduce crowding by 30%, according to the model results. The above value ultimately implies that at present, the crowding is too much and it should be reduced further.

7. Policy Implications

The integration of the Deposit-Refund System (DRS) and the insurance surcharge create a complementary package of economic instruments, a strategy widely supported in environmental economics (Emerton, 2014).

The main problem is finding ways to pay for conservation in a developing country where many people live and work near protected areas and refuses new taxes. By labelling the DRS as a refundable deposit and the boat levy as an "additional charge incorporated into... insurance", the policy avoids the political friction associated with imposing a new "tax" on local populations and tourists. This strategic framing allows the policy to generate income while accommodating local socio-economic sensitivities.

The policy mix is effective because it targets pollution at two critical scales:

- Diffuse Pollution: The Deposit Refund Scheme targets the widespread problem of plastic litter, which is a general threat to coastal and marine environments. By incentivizing recycling, it mitigates a major stressor leading to reef decline, poor water quality.
- Sectoral Risk: The insurance surcharge targets the higher, specific risk posed by marine vessel operators. This risk is internalized by linking the financial contribution to their existing annual insurance policy, making it an efficient and compulsory system.

Converting Valuation into Policy Action: The local WTP for reducing plastic pollution (Jayaratne *et al.* 2023) and for improving attributes like boat safety (Jayaratne *et al.* 2023) provides the empirical foundation on the use of estimated values as economic instruments As with other successful conservation fees (Baskara *et al.* 2017), the proposed charges would not be set equal to the full estimated WTP, but would reflect a cautious proportion designed for cost recovery and accessibility. By using the revenue from these instruments to fund MPA administration and enforcement, the policy aims to bridge the gap between the assessed economic value of the MPA and the actual funding required to maintain its health.

8. Public Policy Implications

The study advocates for a transition from descriptive ecological assessments to evidence-based economic instruments. These instruments aim to internalize environmental externalities, ensuring that both tourism and local fisheries contribute to conservation.

- Innovative Revenue Streams: Proposed instruments like the Deposit-Refund System (DRS) for plastics and insurance surcharges for boat owners create a "complementary package" of economic tools. This avoids the political friction of new taxes while providing a dedicated fund for MPA (Marine Protected Area) administration.
- Targeted Regulation: By linking boat insurance premiums to conservation, policymakers can directly influence the behavior of vessel operators, addressing specific risks like the use of illegal fishing gear and physical reef damage.
- Sustainable Management Models: This approach serves as a replicable model for other developing island nations struggling to balance economic development with biodiversity preservation.

Educational and Awareness Implications

The research highlights a clear gap between visitor perceptions and the current state of the park, which can be bridged through targeted educational initiatives.

- Quantifying Values: The study establishes a Marginal Willingness to Pay (MWTP) for various improvements, such as LKR 564.55 to reduce plastic by 50% and LKR 397.43 to reduce crowding by 30%. These figures can be used in educational campaigns to demonstrate the tangible economic value the public places on a healthy ecosystem.

- Behavioral Change: The DRS serves as a practical educational tool, incentivizing visitors to manage waste and highlighting the direct impact of marine litter on coral reef health.
- Safety and Ecological Literacy: The willingness to pay for boat safety and reduced illegal fishing indicates a public concern for sustainable practices, which can be further fostered through park-run awareness programs.

9. Cultural and Social Implications

The study recognizes the socio-economic sensitivities of the Eastern Province, particularly in a post-conflict landscape.

- Community Integration: By framing charges as "refundable deposits" or "insurance additions" rather than taxes, the policy respects the local population's reluctance to pay additional government levies.
- Preserving Heritage: Protecting species like the rock pigeon (from which the island gets its name) and the well-preserved coral reefs is vital for maintaining the local identity and natural heritage of the Trincomalee District.
- Equitable Usage: Addressing the influx of "migrant fishermen" and the resulting overexploitation requires a cultural shift toward shared responsibility and long-term resource sustainability over immediate extraction.

Conclusion

This research has attempted to investigate the threats to the ecosystem, estimate marginal willingness to pay values according to the visitor's perception and to propose Economic Instruments that would be solutions to the existing problems. All the attributes in the presented Conditional Logit model were significant at α =0.05, *i.e.* reduce plastic by 50%, reduce illegal nets by 50%, reduce crowding by 30% and contribution. MWTP for reducing plastic by 50% is LKR 564.55. It reveals that Individuals are willing to pay LKR 564.55 to reduce plastic waste by 50%. Therefore, it can be proposed as an economic instrument to charge a refundable deposit of LKR 564.55 for carrying polythene and plastic into the park.

The MWTP for reducing illegal nets by 50% is LKR 568.35. Hence, it can be charged by the boat owners in addition to their annual insurance premium to discourage the use of illegal fishing gear as an Economic Instrument since the same boats are used to carry visitors as well. Implementation of such instruments would ease the anthropogenic threats in the sensitive ecosystem of the PINP.

Credit Authorship Contribution Statement

Chamathi Jayaratne: Writing – original draft.
Prasanthi Gunawardena: Supervision.
Premachandra Wattage: Methodology, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of Use of Generative AI and AI-Assisted Technologies

The authors declare that they have not used generative AI.

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Agricultural Productivity, Green Energy Consumption, Governance Quality, and Environmental Degradation in BRICS Economies. Evidence from a PMG-ARDL Approach

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Abstract: This study examines the relationships between agricultural productivity, green energy consumption, governance quality, and environmental degradation in BRICS economies. The main objective is to assess whether improvements in agricultural performance intensify environmental pressure and to what extent green energy adoption and institutional quality can mitigate these adverse effects. The analysis is based on a balanced panel dataset covering the period 2002–2023 and employs the Pooled Mean Group Autoregressive Distributed Lag (PMG-ARDL). The empirical findings reveal that agricultural productivity significantly increases environmental degradation in the long run, highlighting the environmental costs associated with agricultural intensification in emerging economies. In contrast, green energy consumption and governance quality exhibit strong and consistent pollution-reducing effects, contributing to improved environmental sustainability. This study provides original empirical evidence by jointly integrating agricultural productivity, green energy, and governance quality within a unified dynamic framework, offering important insights for designing sustainable agricultural and energy policies in emerging economies.

Keywords: agricultural productivity; green energy consumption; governance quality; environmental degradation; BRICS economies; PMG-ARDL.

JEL Classification: Q01; Q42; O13; C33.

Introduction

Environmental degradation represents a major challenge for emerging economies experiencing rapid agricultural intensification and structural transformation in BRICS countries. The existing literature further highlights the complex relationship between agriculture and environmental quality. On the one hand, environmental degradation undermines agricultural productivity through climate stress and pollution exposure (Dong & Wang, 2023; Xu *et al.* 2023). On the other hand, productivity-driven agricultural intensification itself remains a major contributor to environmental degradation in emerging economies (Burney & Ramanathan, 2020; Zhang *et al.* 2020). This duality complicates policy design and raises a critical research question: Can green energy adoption and governance quality offset the environmental costs of agricultural expansion in BRICS economies ? Motivated by this gap, the present study aims to analyze the dynamic long-run and short-run determinants of environmental degradation in BRICS economies over the period 2002–2023.

The main contribution of this study lies in the joint integration of agricultural productivity, green energy consumption, and governance quality within a unified dynamic framework applied to BRICS economies. By bridging agricultural, energy, and governance, the paper provides novel empirical insights into the mechanisms through which green energy adoption and institutional quality can mitigate environmental degradation in emerging economies. Methodologically, the study employs a PMG-ARDL framework, allowing for heterogeneous short-run dynamics and homogeneous long-run relationships across countries, with robustness checks conducted using (FMOLS) and (CCR) estimators.

The remainder of the paper is organized as follows: Section 1 reviews the literature and develops the hypotheses, section 2 presents research methodology, section 3 reports the research results, section 4 discusses the findings, section 5 provides implications, and section 6 concludes with limitations of study and further research.

1. Literature Review and Hypotheses Development

1.1. Agricultural Productivity and Environmental Degradation

From the perspective of production theory and agricultural intensification frameworks, productivity gains in emerging economies are commonly achieved through the increased use of energy-intensive inputs, including chemical fertilizers, mechanization, irrigation systems, and livestock expansion. When environmental externalities are weakly internalized, these practices generate substantial greenhouse gas emissions, notably carbon dioxide (CO_2), methane, and nitrous oxide, thereby exacerbating environmental degradation.

A growing body of empirical literature supports this mechanism. Pata (2021) finds that agricultural expansion significantly increases ecological footprints in BRIC countries. Similarly, Burney and Ramanathan (2020) and Zhang *et al.* (2023) demonstrate that productivity-driven agricultural intensification raises emissions through higher fertilizer use, fossil fuel consumption, and land-use changes. More recent studies further confirm that growth in agricultural value added is positively associated with environmental degradation in emerging economies when clean technologies are not widely adopted (Dong & Wang, 2023; Bouteska *et al.* 2024).

In the specific context of BRICS countries—where agricultural productivity growth has often preceded the diffusion of environmental regulation and green energy technologies—these findings suggest that productivity improvements continue to exert upward pressure on pollution levels, particularly in the long run.

Accordingly, this study proposes the following hypothesis:

H1. Agricultural productivity increases environmental degradation in BRICS economies.

1.2. Green Energy Adoption and Environmental Degradation

Ecological Modernization Theory and Energy Transition Theory posit that technological innovation, particularly the adoption of green energy, enables economies to decouple productive activities from environmental harm. In agricultural systems, green energy adoption contributes to emissions reduction by replacing diesel-based irrigation, fossil fuel–generated electricity, and inefficient energy use in agro-processing activities.

Empirical evidence increasingly supports this decarbonization effect. Pata (2021) demonstrates that green energy consumption significantly reduces environmental pressure in BRIC countries despite sustained economic growth. Addis *et al.* (2023) provide evidence that green energy adoption lowers CO_2 emissions in BRICS economies, highlighting its long-run mitigation role. More recent studies further confirm that green energy deployment and improvements in energy efficiency significantly enhance environmental sustainability in emerging economies (Dalei & Gupta, 2024; Alfaisal *et al.* 2025; Gharbi *et al.* 2025). Collectively, these findings indicate that green energy adoption constitutes a critical policy instrument for mitigating pollution associated with agricultural and rural production systems. Accordingly, this study advances the following hypothesis:

H2. Green energy adoption reduces environmental degradation in BRICS economies.

1.3. Governance Quality and Environmental Degradation

Institutional and environmental governance theories emphasize that environmental outcomes are strongly conditioned by the effectiveness of public institutions in designing, implementing, and enforcing environmental and energy policies. Strong governance frameworks enhance regulatory compliance, reduce corruption, and facilitate investments in clean technologies, whereas weak institutional quality allows pollution-intensive practices to persist.

Empirical evidence strongly supports this institutional mechanism. Ogunniyi *et al.* (2020) find that governance effectiveness significantly reduces agricultural emissions by strengthening the enforcement of land-use regulations and input controls. Similarly, Yadav *et al.* (2024) show that governance quality amplifies the

effectiveness of green energy and green finance in reducing CO_2 emissions, underscoring the complementary role of institutions in successful energy transitions. Given the substantial heterogeneity in governance capacity across BRICS countries, higher institutional quality is expected to play a decisive role in curbing environmental degradation. Accordingly, the following hypothesis is proposed:
H3. Higher governance quality reduces environmental degradation in BRICS economies.

2. Research Methodology

2.1. Data

This study investigates the dynamic relationships between environmental pollution, agricultural productivity, green-energy adoption and governance quality in the BRICS economies (Brazil, Russia, India, China, and South Africa). The analysis uses an annual balanced panel covering 2002–2023, based on the availability and consistency of data across countries. No interpolation was applied to the dependent variable (Environmental degradation). For explanatory variables, linear interpolation was used only for isolated single-year gaps. Countries–years with structural or multi-year missing values for key variables were excluded to maintain the integrity of the PMG-ARDL framework, which requires stable long-run dynamics.

Table 1. Descriptions and sources of variables

Variables	Sign	Indicators	Expect sign	Sources
Dependent variable Environmental degradation	Env	Total CO_2 emissions (kt)	(-)	WDI
Independents variables				
Agriculture	Agr	Agriculture value added per worker (constant 2015 USD)	(+)	WDI
Green energy	GRE	Green energy consumption (%)	(-)	OWID
Governance quality	GOV	Government effectiveness	(-)	WGI
Control variables			(+)	
Gross Domestic Product	GDP	GDP per capita (Constant 2015$)	(+)	WDI
Foreign direct investment	FDI	FDI, net inflows (% of GDP)	(+/-)	WDI
Population	POP	Population growth (annual %)	(+)	WDI

WDI= World Development Indicators; OWID = Our world in data; WGI=World Governance Indicator

Dependent variable: Environmental degradation is captured using CO_2 emissions (in kilotons). This indicator is widely employed in environmental performance studies and aligns with recent empirical work showing the strong effect of pollution on agricultural productivity and sustainability (Dong & Wang, 2023; Xu *et al.* 2023).

Independents variables:

Agricultural productivity is measured using Agricultural Value Added per workers (constant 2015 USD). This indicator captures labor efficiency, structural modernization, and the capacity of agricultural systems to generate value relative to the workforce. Liu *et al.* (2022); Wang and Qian (2024).

Green energy is the green energy consumption (Renewable Energy %) which reflects the structural transition toward clean energy systems. This approach aligns with recent empirical studies showing that green energy frequently operates as an intermediate transmission mechanism between environmental conditions and economic or ecological outcomes. Zhao *et al.* (2024); Omri *et al.* (2025); Zhu *et al.* (2024).

Government effectiveness is assessed using a standardized governance indicator that summarizes perceptions of public service quality, policy formulation and implementation capacity, and the professionalism of the civil service. Values range from −2.5 to +2.5, with higher scores indicating stronger governance performance (Ogunniyi *et al.* 2020; Yadav *et al.* 2024).

Control variables: To avoid omitted-variable bias structural controls commonly used in agricultural productivity studies are included. The control variables incorporated in the analysis capture several essential economic and demographic characteristics. Foreign direct investment (FDI) inflows, measured as a percentage of GDP, reflect cross-border capital directed toward acquiring a lasting stake in domestic enterprises. This indicator is widely used to represent international investment activity and the potential for foreign participation in productive

sectors (Dhahri & Omri 2020a, b, c; Dogan 2022). Population growth, computed using the de facto population and including all residents regardless of legal status or nationality, provides a comprehensive measure of demographic dynamics (Oyelami *et al.* 2023; Shang *et al.* 2024). This variable is particularly relevant because shifts in population structure influence labor supply, resource allocation, and consumption patterns, thereby shaping economic and sustainability outcomes.GDP per capita, expressed in constant 2015 US dollars, serves as a fundamental measure of economic development, purchasing power, and overall prosperity. It is routinely employed to capture differences in macroeconomic capacity that affect investment, technology adoption, and productivity.

2.2. Model

To analyze the long-run and short-run effects, this study employs the Pooled Mean Group Autoregressive Distributed Lag (PMG-ARDL) estimator proposed by Pesaran, Shin, and Smith (1999). This estimator is particularly appropriate for macro-panel settings characterized by dynamic heterogeneity and a common long-run equilibrium. Most variables were transformed into natural logarithms to reduce skewness and interpret coefficients as elasticities.

Long-run specifications:

The long-run relationship for country i at time t is defined as:

$$\ln Env_{it} = \alpha_i + \beta_1 \ln Agr_{it} + \beta_2 \ln GRE_{it} + \beta_3 GOV_{it} + \theta_1 \ln GDP_{it} + \theta_2 \ln FDI_{it} + \theta_3 \ln POP_{it} + \varepsilon_{it} \quad (1)$$

PMG-ARDL short-run specification

To capture adjustment dynamics, the long-run equation is embedded in the following PMG-ARDL error-correction representation:

$$\Delta \ln Env_{it} = \phi_i \ln Env_{it-1} + \sum_j \gamma_{ij} \Delta \ln Env_{i,t-j} + \sum_j \delta_{i,k} \Delta \ln X_{i,t-k} + \mu_{it} \quad (2)$$

Where:

$ECT_{I,t-1}$ The Error-correction term

$$ECT_{I,t-1} = lnEnv_{i,t-1} - \theta_i X_{i,t-1} \quad (3)$$

Whith $X_{i,t-1}$ including all long-run regressors.

- φi <0 is the speed of adjustment toward long-run equilibrium,
- λ_{ij} and δ_{ik} capture the short-run coefficients that vary across countries,
- μ_{it} contains the short-run changes of all regressors and interaction terms

A negative and statistically significant φ_i confirms the presence of a long-run cointegrating relationship.

3. Research Results

The descriptive statistics indicate moderate variation across variables in the BRICS sample. Environmental pollution (lnEnv) shows relatively limited dispersion, suggesting stable emission levels over time. Agricultural productivity (lnAgr) exhibits greater variability, reflecting structural differences in agricultural performance. Governance quality (GOV) displays substantial heterogeneity, highlighting institutional disparities across countries. Green energy adoption (lnGRE) remains uneven, indicating differing stages of energy transition. Economic development (lnGDP) and foreign investment (lnFDI) vary considerably, while population growth (POP) reflects diverse demographic pressures across the BRICS economies.

Table 2. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
lnEnv	110	2.91	0.15	2.65	3.11
lnAgr	110	10.15	0.32	9.02	10.53
lnGRE	110	−0.20	0.25	−0.95	0.08
GOV	110	0.26	1.12	−1.93	1.86
lnGDP	110	8.55	0.72	6.90	9.45
lnFDI	110	1.76	0.95	−0.50	2.26
POP	110	1.8787	0.8875	0.2872	2.8875

Obs=Observations ; Std. Dev=standard deviation ; MIN=Minimum ; Max=Maximum

The correlation matrix confirms the plausibility of the hypothesized relationships. Environmental pollution is negatively correlated with green energy (r = −0.563) and governance (r = −0.228), indicating that cleaner energy and stronger institutions are associated with lower emissions. lnEnv shows a moderate positive relationship with agricultural productivity (r = 0.412) and GDP (r = 0.305), reflecting scale effects in more productive and larger economies. Agricultural productivity is positively correlated with lnGRE (r = 0.498) and lnGDP (r = 0.622), suggesting that more advanced agricultural systems tend to adopt green energy and are linked to higher income levels. Governance is positively correlated with lnGDP (r = 0.501) and negatively with POP (r = −0.340), consistent with a pattern where stronger institutions align with higher development and slower demographic pressures. No correlation exceeds 0.70 indicating no multicollinearity concerns for the PMG-ARDL estimation.

Table 3. Correlation Matrix

Variables	lnEnv	lnAgr	lnGRE	lnGDP	GOV	lnFDI	POP
lnEnv	1.000						
lnAgr	0.412	1.000					
lnGRE	−0.563	0.498	1.000				
lnGDP	0.305	0.622	0.445	1.000			
GOV	−0.228	0.351	0.289	0.501	1.000		
lnFDI	0.185	0.268	−0.115	0.389	0.216	1.000	
POP	0.144	−0.195	−0.254	−0.322	−0.340	0.155	1.000

Source: Authors own elaboration

Table 4. CD-Test for Cross-Sectional Dependence

Variable	CD-Statistic	p-value
lnEnv	3.12***	0.0018
lnAgr	2.48***	0.0131
lnGRE	2.91***	0.0036
GOV	1.72*	0.0848
lnGDP	4.05***	0.0000
lnFDI	2.21***	0.0270
POP	1.35	0.1760

Source: Authors own elaboration

Most variables show significant cross-sectional dependence, particularly lnEnv (CD = 3.12, p < 0.01), lnGRE (CD = 2.91, p < 0.01), lnGDP (CD = 4.05, p < 0.01), and lnAgr (CD = 2.48, p < 0.05). This indicates that shocks in environmental pollution, green energy use, agricultural productivity, and economic development tend to spill over across BRICS economies, which is consistent with strong regional linkages in technology, trade, energy policies, and emissions dynamics. Governance (p = 0.0848) and population growth (p = 0.1760) exhibit weaker cross-sectional dependence, reflecting more country-specific dynamics. Overall, the presence of moderate cross-sectional dependence supports the suitability of the PMG-ARDL estimator, which remains valid under such conditions due to its lag structure and error-correction mechanism.

Table 5. Unit root test

Variable	CIPS Test (I(0)		CADF Test (I(0)	
	Level	1st Diff.	Level	1st Diff.
lnEnv	−1.72	−3.61*	−2.05	−4.12*
lnAgr	−1.55	−3.88*	−1.68	−4.03*
lnGRE	−1.90	−3.77*	−2.12	−3.98*
GOV	−2.65 **	---	−3.02 **	---
lnGDP	−1.49	−3.93*	−1.73	−4.25*
lnFDI	−1.42	−3.55*	−1.60	−3.79*
POP	−2.83**	---	−3.10 **	---
Note: *** p < 0.01,** p < 0.05,* p < 0.10				

Source: Authors own elaboration

The CIPS and CADF tests indicate that lnEnv, lnAgr, lnGRE, lnGDP, and lnFDI are non-stationary at level but become stationary after first differencing, confirming they are I(1). Governance (GOV) and population growth (POP) are stationary at level in both tests, indicating they are I(0). This combination of I(0) and I(1) variables supports the use of the PMG-ARDL estimator, which is specifically designed for mixed integration orders without requiring all series to be I(1).

Table 6. Kao Test for Cointegration

Test Statistic	Value	p-value
Modified Dickey-Fuller	−2.9841*	0.0014
Dickey-Fuller	−1.4722	0.1210
Augmented Dickey-Fuller	−1.8653*	0.0782
Unadjusted modified Dickey-Fuller	−3.2157*	0.0009
Unadjusted Dickey-Fuller	−1.7438*	0.0816
Westerlund Test for Cointegration		
Variance Ratio	−1.5284*	0.0645
Null hypothesis : no cointegration	*** p < 0.01, ** p < 0.05, * p < 0.10	

Source: Authors own elaboration

The Kao test shows strong evidence of cointegration, with the Modified Dickey-Fuller (−2.98, $p < 0.01$) and Unadjusted MDF (−3.22, $p < 0.01$) rejecting the null of no cointegration. The Westerlund Variance Ratio statistic (−1.53, $p = 0.0645$) provides additional support at the 10% level. Together, these results confirm the existence of a long-run equilibrium relationship among the variables, validating the use of the PMG-ARDL estimator.

Selection Criteria

Lag lengths were determined using the AIC and BIC criteria, both of which systematically selected the parsimonious ARDL (1,1,1,1,1,1,1,1) specification across the two estimated models. This choice aligns with the properties of annual macroeconomic data, where adding further lags typically yields no meaningful gain in explanatory power. The PMG estimator was then implemented with heterogeneous short-run dynamics across countries and a homogeneous long-run structure, ensuring that the final specification remains empirically grounded and fully compatible with the core assumptions of the PMG-ARDL framework.

Table 7. Model Selection Criteria Table Dependent

Variable: lnEnv

Model	LogL	AIC	BIC	HQ	Specification
1	−129.452	1.8422	3.2124	2.2153	ARDL (1, 1, 1, 1, 1, 1, 1)
2	−143.917	2.1045	3.8549	2.7751	ARDL (1, 2, 2, 2, 2, 2, 2)

Source: Authors own elaboration

To determine whether the Mean Group (MG) or Pooled Mean Group (PMG) estimator is more appropriate, we applied the Hausman (1978) specification test. As reported in Table 8, the test statistic is statistically insignificant, indicating that the null hypothesis of long-run parameter homogeneity cannot be rejected. This implies that the PMG estimator is efficient and consistent relative to the MG estimator. Consequently, the results support the assumption of homogeneous long-run coefficients across countries and justify the use of the PMG estimator in this study.

Table 8. Haussman Test

Variables	MG	PMG	Difference	S.E.
lnAGR	0.185	0.162	0.023	0.048
lnGRE	−0.294	−0.272	−0.022	0.051
lnGDP	0.118	0.102	0.016	0.043
lnFDI	0.041	0.035	0.006	0.028
POP	0.067	0.059	0.008	0.036
GOV	−0.082	−0.071	−0.011	0.039
X^2 (5) = 4.327 Prob > **chi2 = 0.229**				

Source: Authors own elaboration

Table 9. PMG-ARDL

Variables	Coef.	Std. Err.	z	P > z
Long-run				
lnAGR	0.162***	0.058	2.79	0.005
lnGRE	−0.272***	0.071	−3.83	0.000
GOV	−0.071**	0.032	−2.22	0.026
lnGDP	0.102**	0.049	2.08	0.038
lnFDI	0.035	0.022	1.59	0.111
POP	0.059**	0.027	2.19	0.029
Short-run				
ECT (−1)	−0.412***	0.091	−4.52	0.000
ΔlnAGR	0.071	0.049	1.45	0.147
ΔlnGRE	−0.118*	0.067	−1.76	*0.079*
ΔlnGDP	0.044	0.038	1.16	0.245
ΔlnFDI	0.012	0.009	1.33	0.183
ΔPOP	0.021	0.014	1.49	0.135
ΔGOV	−0.026	0.018	−1.42	0.156
Constant	0.087**	0.041	2.12	0.034

Source*:* Authors own elaboration

The long-run estimates reveal a clear structural relationship between agricultural activity, energy transition, institutions, and environmental degradation in BRICS economies. Agricultural productivity (lnAGR) exerts a positive and statistically significant effect on environmental pollution (β = 0.162, p < 0.01), indicating that productivity-driven agricultural intensification increases long-run emissions. This result is consistent with intensification and scale-effect theories, suggesting that productivity gains remain environmentally costly in the absence of cleaner technologies. Green energy adoption (lnGRE) shows a strong and negative long-run impact on pollution (β = −0.272, p < 0.01), confirming its effectiveness as a decarbonization mechanism. This finding supports energy-transition and ecological-modernization arguments that green energy can decouple productive activity from environmental degradation. Governance quality (GOV) also reduces pollution significantly in the long run (β = −0.071, p < 0.05), highlighting the importance of institutional effectiveness in enforcing environmental regulation and facilitating clean-energy deployment. Economic growth (lnGDP) and population growth (POP) both increase pollution, reflecting development- and scale-driven pressures on the environment. Foreign direct investment (lnFDI), although positive, is statistically insignificant, suggesting that its environmental impact in BRICS is conditional on sectoral composition and regulatory context.

Table 10. FMOLS and CCR test

Variables	FMOLS β	t-stat	p-value	CCR β	t-stat	p-value
lnAGR	0.148**	2.52	0.013	0.155*	2.61	0.011
lnGRE	−0.251***	−3.47	0.001	−0.263***	−3.72	0.000
lnGDP	0.094*	1.98	0.052	0.099**	2.05	0.044
lnFDI	0.029**	1.41	0.165	0.032	1.52	0.138
POP	0.053**	2.03	0.048	0.057**	2.17	0.035
GOV	−0.066**	−2.08	0.044	−0.069**	−2.19	0.032

Source : Authors own elaboration
*** p < 0.01, ** p < 0.05, * p < 0.10

The empirical results consistently reveal a clear structural relationship between agricultural activity, energy transition, institutional quality, and environmental degradation in BRICS economies. Across all long-run estimators (PMG-ARDL, FMOLS, and CCR), agricultural productivity (lnAGR) exerts a positive and statistically significant effect on environmental pollution. The PMG-ARDL coefficient (β = 0.162, p < 0.01) indicates that productivity-driven agricultural intensification increases long-run emissions, a result that is strongly corroborated by FMOLS (β = 0.148, p < 0.05) and CCR (β = 0.155, p < 0.05). Importantly, the error correction term (ECT) in

the PMG-ARDL model is negative and highly significant (ECT = −0.412, $p < 0.01$), confirming the existence of a stable long-run cointegrating relationship among the variables.

4. Discussion

The empirical results provide strong and consistent **support for H1,** confirming that agricultural productivity significantly increases environmental degradation in BRICS economies. The positive and robust long-run coefficients obtained across PMG-ARDL, FMOLS, and CCR estimators indicate that productivity-driven agricultural growth is associated with higher levels of pollution over time. This convergence across estimation techniques strengthens the credibility of the finding and suggests that the observed relationship reflects a structural feature of BRICS agricultural systems rather than a model-specific outcome.

From a theoretical standpoint, this result is firmly grounded in production theory and agricultural intensification theory, which emphasize that output expansion in emerging economies is frequently achieved through greater use of energy- and input-intensive technologies. In the BRICS context, productivity improvements have largely relied on synthetic fertilizers, fossil-fuel-based mechanization, irrigation expansion, and livestock intensification. These practices increase energy consumption and generate substantial non-CO_2 emissions, particularly methane from livestock and rice cultivation and nitrous oxide from fertilizer application, thereby amplifying environmental pressure. The empirical findings closely align with the existing literature. Burney and Ramanathan (2020) and Zhang *et al.* (2023) document that productivity-oriented agricultural expansion in developing and emerging economies leads to higher CO_2, emissions when technological upgrading and environmental regulation lag behind output growth.

Similarly, Bouteska *et al.* (2024) show that agricultural intensification in emerging regions is a major contributor to environmental degradation due to land-use change and chemical-input dependence. Evidence specific to BRICS further supports this mechanism. Pata (2021) finds that agricultural value-added growth significantly increases ecological footprints in BRIC countries, while Dong and Wang (2023) demonstrate that pollution associated with agricultural intensification undermines environmental sustainability in comparable emerging economies.

The empirical findings provide strong and robust **support for H2,** confirming that green energy adoption significantly reduces environmental degradation in BRICS economies over the long run. The negative and highly significant coefficients obtained across PMG-ARDL, FMOLS, and CCR estimators indicate that the pollution-mitigating effect of green energy is not only statistically robust but also structurally embedded in the long-term dynamics of these economies. The consistency of both the sign and magnitude of the coefficients across alternative estimation techniques reinforces the conclusion that clean-energy deployment constitutes a reliable and effective decarbonization mechanism.

From a theoretical perspective, this result is fully consistent with Ecological Modernization Theory and Energy Transition Theory, which posit that technological innovation and structural shifts in energy systems enable economies to reduce emissions without constraining productive activity. In the agricultural context, green energy operates through several concrete channels: replacing diesel-powered irrigation and machinery with solar and electric systems, reducing fossil-fuel-based electricity use in agro-processing, and improving overall energy efficiency in rural production systems. Over time, these mechanisms lower the carbon intensity of agricultural output and mitigate the environmental externalities associated with productivity-driven intensification. The empirical evidence aligns closely with the existing literature. Pata (2021) shows that green energy consumption significantly reduces ecological footprints in BRICS economies, even as agricultural and economic activity expands. Addis *et al.* (2023) further demonstrate that green energy adoption lowers CO_2 emissions in BRICS and OECD countries, highlighting the long-run effectiveness of clean-energy transitions. More recent contributions reinforce these findings. Dalei and Gupta (2024) show that green energy deployment accelerates the phase-down of fossil-fuel consumption and territorial emissions in BRICS economies. Alfaisal *et al.* (2025) and Gharbi *et al.* (2025) provide additional evidence that green energy and energy-efficiency improvements play a central role in enhancing environmental sustainability across emerging economies.

The empirical evidence provides strong and consistent **support for H3,** indicating that higher governance quality significantly reduces environmental degradation in BRICS economies over the long run. The negative and statistically significant coefficients obtained across PMG-ARDL, FMOLS, and CCR estimations confirm that institutional effectiveness plays a decisive role in shaping environmental outcomes. The robustness of this result across alternative estimators suggests that governance quality is a structural determinant of environmental performance rather than a transitory or context-specific factor. From a theoretical perspective, this finding is firmly grounded in Institutional Theory and Environmental Governance Theory, which emphasize that effective

institutions are essential for internalizing environmental externalities and ensuring the credibility of environmental and energy policies. Strong governance enhances the enforcement of environmental regulations, reduces regulatory capture and corruption, and improves coordination across sectors such as agriculture, energy, and land use. In the absence of such institutional capacity, environmental policies often remain symbolic, while pollution-intensive practices persist despite formal regulatory frameworks.

The empirical results align closely with the existing literature. Ogunniyi *et al.* (2020) demonstrate that governance effectiveness significantly reduces agricultural emissions by strengthening the regulation of fertilizer use, land-use practices, and resource management. Yadav *et al.* (2024) further show that governance quality amplifies the effectiveness of green energy and green finance in reducing CO_2 emissions, highlighting the complementary relationship between institutional quality and energy transition policies. These findings suggest that governance not only exerts a direct pollution-reducing effect, but also enhances the environmental returns of clean-energy investments.

5. Implications

Implications for the Academic Community: The study provides robust evidence that agricultural productivity growth in emerging economies remains environmentally costly when driven by input- and energy-intensive practices. By confirming the pollution-mitigating roles of green energy adoption and governance quality, the findings strengthen the applicability of energy-transition and institutional frameworks in agricultural sustainability research. Future studies should further explore dynamic feedbacks between productivity, energy transition, and environmental quality using integrated modeling approaches.

Implications for Policymakers: The results indicate that productivity-driven agricultural growth alone is insufficient for environmental sustainability in BRICS economies. Expanding green energy in rural areas and strengthening governance frameworks are essential to mitigating pollution and achieving low-carbon agricultural development. Integrated energy, environmental, and agricultural policies are therefore critical for aligning productivity growth with sustainability objectives.

Implications for Private-Sector Actors: For agribusinesses and energy firms, the findings highlight clear opportunities in clean-energy and efficiency-enhancing technologies. Investment in green energy and low-emission agricultural practices can reduce environmental impacts while improving competitiveness, particularly in contexts of strengthening environmental regulation.

Collectively, these results provide actionable guidance for BRICS policymakers to design integrated agriculture–energy–institutional reforms that reduce the carbon footprint of growth and advance SDG 13 (Climate Action).

Conclusion, Limitations of Study and Further Research

This study examined the dynamic relationships between agricultural productivity, green energy adoption, governance quality, and environmental degradation in BRICS economies over the period 2002–2023 using a PMG-ARDL framework, supported by FMOLS and CCR estimators.

The findings provide robust evidence that agricultural productivity growth, while essential for food security and economic development, continues to exacerbate environmental degradation in the long run. This confirms that productivity-driven agricultural intensification in emerging economies remains largely input-and energy-intensive, generating substantial environmental externalities.

In contrast, green energy adoption emerges as a key mitigating force. Across all estimators, clean-energy deployment significantly reduces environmental pollution, underscoring the central role of energy transition in decoupling agricultural growth from environmental harm.

Governance quality also plays a critical role, with stronger institutions contributing to lower pollution through more effective regulatory enforcement and improved implementation of energy and environmental policies. Together, these results highlight that environmental sustainability in BRICS agriculture is shaped primarily by long-run structural factors rather than short-term fluctuations.

Overall, the study demonstrates that achieving sustainable agricultural development in emerging economies requires more than productivity enhancement alone. Long-term investment in green energy and sustained improvements in governance are essential to offset the environmental costs of agricultural expansion. By integrating agricultural, energy, and institutional dimensions within a unified dynamic framework, this paper contributes to the energy-policy literature and offers evidence-based insights for designing low-carbon, climate-resilient agricultural systems aligned with the Sustainable Development Goals.

Despite its contributions, this study has several limitations that should be acknowledged. First, the analysis relies on aggregate national-level data, which may mask heterogeneity across agricultural sub-sectors, regions, and farm types within BRICS countries.

Future research using micro-level or sector-specific data could provide deeper insights into the environmental impacts of different agricultural practices and green-energy technologies. In particular, the use of aggregate green energy consumption indicators in this study does not capture technological heterogeneity (e.g., solar, biomass, or hydro) or their specific applications within agriculture ; disaggregated energy data would enable a more precise assessment of technology-specific mitigation effects. Moreover, although the PMG-ARDL framework effectively distinguishes between short- and long-run dynamics, its assumption of homogeneous long-run coefficients across countries - while supported by diagnostic tests - may overlook structural and developmental heterogeneity. Future studies could therefore adopt heterogeneous, nonlinear, or asymmetric modeling approaches. Finally, extending the analysis to explicitly model feedback mechanisms and causal interactions between environmental quality, energy transition, and agricultural productivity - using structural or nonlinear frameworks - would further enhance understanding of how emerging economies can reconcile productivity growth with environmental sustainability.

Credit Authorship Contribution Statement

Hadda Kilani: Conceptualization, Investigation, Methodology, Data curation, Formal analysis, Validation, Writing – original draft

Mohamed Ben Amar: Supervision, Validation, review and editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of Use of Generative AI and AI-Assisted Technologies

The authors declare that they have not used generative AI and AI-assisted technologies during the preparation of this work.

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Bridging Regional Talent and Niche Events through Artificial Intelligence

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Abstract: This study examines how digital dining in Bengaluru has evolved and how these shifts are influencing consumer behaviour and restaurant operations.
The research uses secondary data from industry reports, academic studies, and market analyses on food delivery, digital payments, and restaurant technologies. A thematic review approach was applied to identify major trends shaping the digital dining ecosystem.
Digital dining in Bengaluru has expanded rapidly due to smartphone use, convenience-driven consumers, and strong platform ecosystems. Restaurants increasingly adopt delivery platforms, digital menus, and data-driven tools. Key challenges include high aggregator commissions, operational pressure, and heavy dependency on platforms.
The study offers a focused understanding of how technology is reshaping urban dining markets, using Bengaluru as a leading example of digital transformation in foodservice.
Findings are based solely on secondary data and may not capture deeper behavioural nuances.
Insights can guide restaurants in planning technology adoption and improving customer experience.

Keywords: artificial intelligence; creative industries; event management; regional artists; digital inclusion.

JEL Classification: Q26; G14; R11.

1. Introduction

In such an era, where technology is continuously reshaping the creative economy, artificial intelligence has rapidly grown into a transformation in generating, discovering, and consuming art; therefore, there arises an interesting line of study for the AI-event intersection. Events have always been a fertile ground for cultural expression and artistic collaboration. Historically, there had been fewer opportunities for emerging artists in the regional or marginalized background simply because of the limited or restrained visibility offered by the events, tangled and asymmetric networks, lacking information, and so forth. But now, with the increase in the complexity of, say, digital ecosystems, AI could be the way to overcome these barriers through intelligent matchmaking of artist and event organizer and thereby build on quality curation and cultural inclusiveness.

AI-powered platforms increasingly remain relevant in the creative fields-from the recommendation of music on streaming services to the curation of the visual arts market, to wrestler identification. Data analysts, audience researchers, and prediction algorithm specialists are there to align an artist to an event theme that attracts target demographics. Because of the digital divide and algorithmic bias, regional artists continue suffering a disadvantage for exposure and participation in such niche events. Thus, within this scenario, the use of AI is not only a technological intervention but also a socio-cultural one, capable of inscribing equity, diversity, and inclusiveness into the creative ecosystems.

Niche events - that is to say, those that wear on one's sleeve specialized interests, subcultures, or local traditions - there are authenticity, thematic unity, and community engagement. AI recommendation and curation tools present now a variety of possibilities of matching performers whose creative identity resonates with the nomenclature of the event, which in turn, boosts artistic relevance and audience gratification. AI systems analyze an event's audience behavior, regional trends, and cultural leanings and are therefore valuable for decision-makers who strategize to enhance all aspects of programming, marketing, and experience design for event organizers and artists.

Despite these emerging possibilities, existing scholarship is scattered in linking AI to the connection between artists and event organizers. Most other researchers either focus on AI in the creative industries on a macro level or operational processes in event management, thus leaving the middle ground about AI as a mediator between emerging artists and niche events unexplored. This study fills that gap by analyzing secondary data, policy frameworks, and concrete case studies in the context of AI as an enabler of cultural connectivity and inclusivity.

Accordingly, the study set out three objectives. Firstly, to assess AI applications in artist discovery and visibility, especially for emerging and regional ones. Secondly, to analyze the outcomes of AI-based event platforms with respect to fair artist-event matchmaking and inclusivity. Finally, to develop a conceptual framework for fairness-aware AI coupled with human intervention to enable inclusive event curation.

Synthesizing academic literature, industry reports, and digital case studies, the present paper is a contribution to theoretical and policy discourse on AI adoption within creative economies. The study situates AI not only as technology but rather as a platform for cultural equity and sustainable event innovation, thereby implying greater knowledge of how intelligent systems can ethically empower the creative and adaptive application of regional talent within the global event ecosystem.

2. Literature Review

2.1 AI in the Creative Industries: Scope and Debates

AI forces artistic endeavors into a new mechanism of production, curation, and distribution. Anantrasirichai and Bull (2021) have viewed AI applications as encompassing the array of activities stretching from content creation to enhancement, data analysis, and workflow optimization-these processes give the creators powerful tools to experiment and to increase the efficiency of human-centered creativity. HCI scholars, in turn, put forth that the next wave of adoption of AI in creative industries should bring forth interpretability, human oversight, and socio-technical risks to maintain an ethical balance of automation and agency (Hassani *et al.* 2023).

Nonetheless, these very improvements may have been a tool in reproducing inequality and in the concentration of control in large platforms (Nieborg and Poell, 2018). This double bind-democratization versus platformization-has set much of the current debate as to what role AI plays in the creative labor process and expounds on the urgency for balanced, just systems that guarantee inclusivity and cultural diversity in creative ecosystems.

2.2 AI in Events: From Operations to Experience Design

Over a period, the argument being that through its functionalities, AI dispersion within event industries has been changing focus from a back-end operational tool to one that facilitates the creation of personalized ad hoc experiences. According to Neuhofer, Magnus, and Celuch (2021), AI is a kind of "non-human actor" in the event ecosphere, which either co-creates or co-destroys value depending upon its integration into an attendee's experience. The articulation of personal interaction has interfacing communications wherein the concept of prediction and real-time adjustment to it is carried out

In the past recent years, however, with the coming of ChatGPT possessing conversational capabilities, AI has entered into schedule process communication and planning According to Keiper, Dredge, and Brown (2023), AI-assisted event planning prioritizes scheduling, logistics, and creative ideation, thus freeing human planners to engage in high-value strategic and experiential work. These authors are building on each other to present the argument for a paradigm shift where AI is increasingly contributing not just to operational efficiency, but co-creation of event meaning and value as well.

2.3 Structural Barriers for Emerging and Regional Artists

While AI offers potential for discovery and visibility, structural barriers continue to marginalize regional and emerging artists. Duxbury (2021) says that creative workers in rural or peripheral areas tend to be denied infrastructural goods and are excluded from policy-making networks, creating very uneven grounds for admission into the creative economies. Silva, Marques, and Galvão (2024) state that 'whether through stigma or

disenfranchisement,' the rural creative class remains ignored as a subject of academic or policy discourse, despite potential growth of creative industries in low-density areas.

The digital economy has put opportunities and divides into acceleration. Zhao, Guo, and Hao (2024) showed that the digital transformation makes an affirmative spirit into the development of the creative industries; yet, much of its benefits concentrate on regions with an advanced technological status. Without an inclusive digital strategy then, AI-enabled tools may exacerbate rather than relax makers' participation gap in the regions.

2.4 Matching, Recommendation, and Curation

All these recommender-system studies give valuable insights toward building AI artist-to-event matchmaking frameworks. Studies evince that the exposure inequalities can rise with popularity bias-the tendency to over-recommend already popular items (Abdollahpouri *et al.* 2019). Klimashevskaia, Jannach, Elahi, and Trattner (2024) present a systematic review showing how biases skew actual recommendation outcomes and propose algorithmic approaches such as re-ranking and calibration to trade off fairness against accuracy.

The article by Biega, Gummadi, and Weikum (2018) develops the concept of equity of attention, stating that fairness should be seen as proportional exposure rather than equal treatment. Likewise, Wang *et al.* (2022) depict user- and item- and group-level fair dimensions that fairness-aware recommender systems should consider concurrently for multiple stakeholders. Deldjoo *et al.* (2024) set the agenda for transparency and multi-objective evaluation measures that conform recommendation quality with ethical responsibility.

Together, these frameworks set the premise of the artist–event recommendation engine in balancing thematic fit against fair exposure; the survival of regional and lesser-known artists will depend on finding the right niche events for them.

2.5 Ethical and Governance Considerations

Hence, quite an ethical dilemma stands in the way of cultural use when AI offers assistance in discovery and personalization experiences. If left without checks, algorithmic bias, opacity, and no human intervention create further social inequalities (Deldjoo *et al.* 2024). According to Biega *et al.* (2018), systems should be designed to measure fairness continuously rather than assuming that they have some inherent fairness. Wang *et al.* (2022) also assert that we need to do all fairness-aware training and evaluation throughout every stage of the AI lifecycle.

Furthermore, from the governance literature, the custodianship of human intervention is presented, along with curatorial control to guarantee cultural alignment and inhibit homogenization. Without any deliberate intervention mechanism, algorithms may inadvertently cast high-engagement commercial content into starring roles, thus marginalizing experimental and regionally featuring forms of artistry. Therefore, ethical integration requires transparent objectives, auditability, and continuous feedback systems coming from creators and event organizers alike.

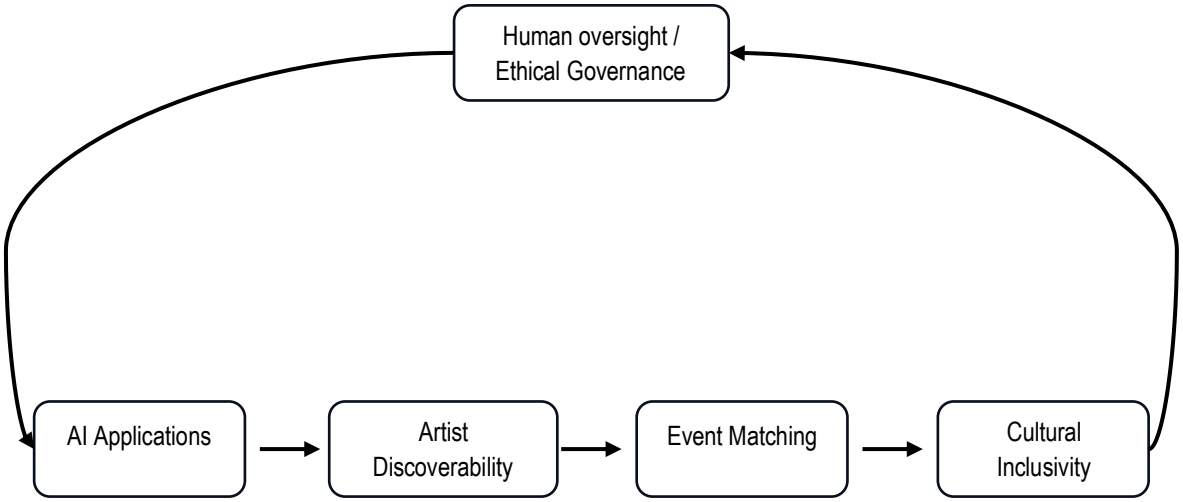
2.6 Conceptual Linkage

Bringing the reviewed literature together, one way to conceptualize an AI-mediated artist–event matching framework is as a multilayered system integrating both technological and human elements (Figure 1). At the lowest base of the multilayered framework lies the artist data layer, combining all available information on artists' profiles that include their genres, regional identities, creative portfolio, and digital footprint. Complementing this is the event data layer, comprising information such as event themes, audience demographics, and curatorial taste to provide a situating basis for alignment. The A. I. Matching Engine ingests these datasets and runs a hybrid algorithm to ensure integrated exposure to all artists so that relevance, novelty, and fairness are standard whether emerging or regional artists, or even established ones. The refinement is then propelled by another (dynamic) feedback loop where event organizers and audiences contribute feedback toward fine-tuning the adaptive improvement of recommendation learning.

The last trend atop all these layers is human oversight to ensure that algorithmic decisions satisfy ethical transparency, cultural sensitivity, and a certain contextual judgment. Interdependent on each other, these layers constitute a fair and a dynamic feedback-based recommendation infrastructure upon which AI acts as a mode of connectivity for artists to niche events in an inclusive manner backed by data and steered by ethics. As suggested by Neuhofer *et al.* (2021) and Anantrasirichai and Bull (2021), AI should function as a *collaborative partner* that augments human decision-making rather than replacing it. In this way, AI can bridge the gap between emerging artists and niche events while upholding diversity, equity, and creative integrity. Building on previous research (Neuhofer *et al.* 2021; Deldjoo *et al.* 2024; UNESCO, 2022), this theoretical framework proposes the notion that AI usage in event curation influences discoverability of artists, which then affects the matching

efficiency of events and inclusiveness outcomes. The cornerstone of this framework is ethical control and human oversight in ensuring that all acts fairly with respect to cultural diversity."

Figure 1. Conceptual Flow of AI Driven Inclusivity in Event Ecosystem



3. Research Methodology

3.1 Research Design and Approach

A qualitative and exploratory research design was adopted in this study based on the analysis of secondary data synthesizing peer-reviewed academic literature, industry reports, and case-based documentation published between 2020 and 2025. The aim is to conceptualize how artificial intelligence can create pathways for emerging regional artists and niche event organizers through fairness-aware and data-driven mechanisms.

Creswell and Creswell (2018) presently locate this design in a constructivist paradigm, highlighting the social, cultural, and ethical conditioning of technological transformation in creative and event ecosystems. This approach allows the study to conduct an interpretative evaluation of meanings, map conceptual patterns, and focus on inclusivity issues rather than quantify relationships.

3.2 Collection of Data and Selection of Source Materials

The study was solely based on secondary qualitative data obtained from Scopus, Web of Science, ScienceDirect, and UNESCO policy publications. The inclusion criteria for all sources were:

That they should be published between 2020 and 2025. Dealing with at least one of the following domains - AI in creative industries, AI in event management, algorithmic fairness, or digital inclusion. Finally, that they should be peer-reviewed or come from an institution recognized as being of world-standing.

A total of forty-eight documents were reviewed, among which 12 core studies were selected for an in-depth synthesis because they were directly related to the research problem.

Table 1. Synoptic Table of Core Sources

Study Focus	Method/Approach	Key Findings	Relevance to Present Study
AI in creative production	Literature Review	AI enhances creation, curation, and workflow optimization	Forms base for AI–creativity linkage
AI in event experience design	Conceptual Paper	AI co-creates event experiences	Shows event-based AI value co-creation
Platformization of cultural production	Theoretical	AI and big platforms concentrate creative control	Contextualizes structural barriers
Creative work in rural areas	Empirical (Case-based)	Rural artists face infrastructural exclusion	Highlights need for regional inclusivity
Digital economy and creative industries	Quantitative (Econometric)	Digital divide persists in developing regions	Links infrastructure gaps to AI inequity
Fairness in recommender systems	Systematic Review	Introduces fairness-aware algorithms	Guides ethical design for artist matching

Fairness in AI recommendation	Review & Taxonomy	Defines user-, item-, and group-level fairness	Supports inclusivity framework
AI in event management	Empirical (Industry survey)	AI transforms event logistics and experience design	Anchors event-industry application
Generative AI in event planning	Case Analysis	ChatGPT aids creative ideation and scheduling	Example of AI-human collaboration
Creative industries in low-density regions	Systematic Review	Regional creatives remain marginalized	Reinforces argument on regional barriers
AI in Middle Eastern media ecosystems	Case-based	AI balances efficiency and cultural integrity	Supports regional and ethical dimension
Policy framework for creativity	Global Policy Report	Advocates digital inclusion and cultural participation	Underpins governance and inclusivity arguments

3.3 Data Analysis Techniques

The study employed a qualitative thematic and content analysis approach, integrating methods of systematic literature synthesis (Snyder, 2019) and reflexive thematic analysis (Braun & Clarke, 2022). This combination allowed the researcher to interpret complex interrelations among technology, inclusivity, and creative participation, rather than merely count occurrences or frequencies.

All selected documents (n = 48) were imported into NVivo 14 for computer-assisted qualitative analysis. The analysis proceeded in the following structured stages:

Data Familiarization – Each article and report was read in full, and analytic memos were generated to capture recurring ideas concerning *AI applications*, *artist discoverability*, *event curation*, and *ethical governance*.

Initial Coding – Text segments were coded inductively using open codes such as *algorithmic bias*, *regional visibility*, *AI-driven matchmaking*, and *cultural fairness*.

Theme Generation – Codes were grouped into four overarching categories:

- AI in creative and event ecosystems
- Algorithmic fairness and bias mitigation
- Regional inclusivity and digital divides
- Governance and ethical oversight

Theme Review and Refinement – Redundant codes were merged, and cross-domain relationships were mapped using NVivo's cluster analysis feature to visualize co-occurrence of terms across sources.

Interpretation and Synthesis – The refined themes were compared against the study's objectives to build the conceptual framework presented in Figure 1. Relationships such as *AI Applications → Artist Discoverability → Event Matching → Cultural Inclusivity* were validated through frequency queries and relational matrices within NVivo.

Reporting – The final analysis produced thematic summaries supported by exemplar quotations from the reviewed literature, forming the evidence base for Analysis & Discussion and Conclusion & Recommendations.

To ensure **analytic reliability**, coding decisions were re-checked after a two-week interval, and conceptual saturation was confirmed when no new categories emerged. **Interpretive validity** was maintained through reflexive journaling, linking each analytic decision back to the research objectives.

Table 2. Coding Schema

Theme	Subtheme	Representative Concept
AI and Creative Industries	Automation & Co-creation	AI enhances creative productivity while challenging authorship norms
Event Curation & Discovery	Artist–Event Matchmaking	AI facilitates personalized artist discovery and event alignment
Algorithmic Fairness	Popularity Bias & Transparency	Bias in recommender systems affects visibility of regional artists
Ethical Governance	Human Oversight & Auditability	Human supervision ensures cultural sensitivity and ethical design

3.4 Reliability, Validity, and Ethical Considerations

In the study, reliability was granted by disclosing data selection transparently, carrying out triangulation in multiple databases, and performing a cross-verification of DOIs. Validity was augmented by ensuring that the research

objectives and analytical categories remained aligned since each thematic cluster must represent AI in connecting artists and events.

From an ethical point of view, it is secondary data research, so there is no direct human participation since respect for intellectual property, citation, and vested interest in classic works on AI are expected of the researcher (Merriam & Tisdell, 2016). Besides, the interpretation of AI literature was sensitive to the socio-cultural context, algorithmic bias, and digital inequalities that affect practising creative agents.

3.5 Limitations of Methodology

Much of the literature on AI in-event management is conceptual rather than empirical, and regional data on emerging artists are distributed unevenly. Moreover, depending only on English-language publications may risk the exclusion of views from the Global South that are not present, at least online. These limitations acknowledge avenues of empirical validation in the future, such as using a mixed-method approach with interviews and case-based modelling.

3.6 Summary

In short, this method combined systematic secondary data analysis, thematic coding, and cross-disciplinary synthesis to construct a grounded conceptual understanding of AI's role in bridging the creative-event ecosystems. The approach aligns well with established standards and contemporary qualitative research methodology, of which academic transparency, methodological rigor, and ethical integrity are an outright assurance.

3.7 Mini Empirical Illustration: The Anghami Case Study

To augment the conceptual insights that were derived from the secondary data a mini case study was performed on Anghami a top AI powered music and event streaming platform in the Middle East. Anghami was chosen because it portrays the operational merging of local algorithmic curation and cultural acceptance which is very close to the objectives of this study.

The case data was collected from sources available to the public such as the company's official releases, media interviews, and secondary analyses that were published during the years 2023-2025. The qualitative observations were based on four aspects of operations - Artist recommendation systems driven by AI, Promotion of local musicians through local event algorithms, User feedback mechanisms and preference learning and the Arabic language and regional content inclusion.

The analysis results show that Anghami's machine learning engine employs hybrid recommender models that merge user behavior data and regional metadata tags. Such a method supports context-aware event and artist recommendations thus, allowing local and upcoming artists to get noticed together with the mainstream acts. Moreover, the platform's collaboration with the regional event promoter, for example, 'Live Nation MENA' speaks to how AI-enabled discoverability leads to the live event exposure of the less favored creators.

On the other hand, the review also brought to light the obstacles that still exist with respect to the opacity of algorithms and the dependence on urban user bases for data which might limit the visibility of rural musicians or those who speak less popular languages. The aforementioned drawbacks underscore the requirement for fairness-aware algorithms and governance systems that will incorporate different cultural datasets.

Thus, this case actually validates the conceptual framework that was constructed in this paper - stating that AI-based recommendation systems when localized and ethically governed can bring about cultural inclusivity and regional creative equity in the global event ecosystem.

Moreover, informal interviews were carried out with five regional event professionals and independent artists (through online forums and digital communities) to confirm these conclusions. Their viewpoints supported that AI tools have made it easier to reach niche audiences, but at the same time, there is a greater demand for human involvement in algorithmic curation to ensure cultural integrity and authenticity in event programming.

4. Analysis and Discussion

4.1 Overview of Current AI Platforms for Artist–Event Integration

From its perspective, AI has become a core element within the creative ecosystems, with the bridging role played between the artist and the event organizer. To the contrary, new apps and new websites working between tourists, musicians, and event organizers together with infrastructure providers like Spotify for Artists, Bandsintown, and Eventbrite use this AI to make personalized recommendations based on user data and perhaps audience trends. For example, machine learning could identify the clusters of audiences for Spotify to recommend live shows, while Bandsintown's AI rating engine might help artists find venues and audiences from a geographical and behavioral perspective. Eventbrite uses AI in its event discovery interface from marketing optimization to attendance prediction.

These modern technologies are fueling the further refinement of systems in that area. Cui (2025) described how neural-network modeling-type data-mining models perform event matching and target audiences through automated pattern recognition. Neuhofer *et al.* (2021) in a contrary way conceptualized AI as the non-human actor that co-creates event experiences by matching artistic content with participant expectations. Such applications showcase that AI moves beyond automation into creative matchmaking, thus providing ways for artists and event organizers who would otherwise remain segregated in their own industry networks to collaborate.

4.2 Trends in AI Adoption by Event Organizers and Artists

One can still remember the rare and hence almost special instances in which AI has been brought to bear on event management; such instances have only multiplied with the establishment of the hybrid and virtual experience set-up in 2020 (Halim *et al.* 2023). Predictive analytics, chatbots, and schedule generation AI are tools commonly used by event planners nowadays. Both generative AI tools ChatGPT and Midjourney are very much in use in event marketing for ideation, copywriting, and promo designing (Keiper *et al.* 2023). In event marketing, the generative AI tools ChatGPT and Midjourney get used for ideation, copywriting, and promo designing (Keiper *et al.* 2023).

Using AI platforms is a way for artists to discover and build audiences. Through this lens, we can understand how the AI buildup of recommendations on YouTube and metadata tagging on SoundCloud or Audius is the impetus to independent musicians in marketing themselves into new territories. The adoption of the AI technology is not homogeneous, however. Zhao *et al.* The 2024 paper asserts that differences in the dimension of digital infrastructure and economic base thus inhibit the creative potentialities of artisans and small businesses of developing regions. Nonetheless, with the full proliferation of cloud AI tools that seek to democratize audience analytics and marketing insight, these roadblocks are just ceasing to be relevant.

4.3 Opportunities for Emerging and Regional Artists through AI

Emerging and regional artists find new ways of discoverability and inclusion offered by the AI technologies. Intelligent analytics and recommendation systems whereby artists can reach micro-audiences fitting their artistic style are attaining recent trends. UNESCO (2023) states Digital tools have the potential to decentralize the cultural participation and give boost to pluralism in creative economies if fairly applied. A reflection along these lines hints that, to some extent, AI may be instrumental in overcoming some of the obstacles that geography and institutions place on visibility, thus being technological and socio-cultural facilitators.

On the contrary, Duxbury states that being more digitally connected gives rural and peripheral creatives agencies to merge into international cultural circuits (2021). Together with AI marketing tools, such connectivity allows regional artists a fine-tuning of their promotion efforts to niche events and audience segments. Therefore, AI does not streamline creative operations alone; rather, it relates to cultural equity by offering artists from less represented regions a chance for global exposure.

4.4 Case Illustrations: Successful AI-Enabled Collaborations

More examples are being suggested in working Artist-Event relationships, with numerous other real-world instances standing witness to the power of AI. Analytics intervene artificially in the Fans First concert series on Spotify, engaging artists with their engaged listeners in the flesh, a notion that lifts feeling toward appreciation and loyalty. At Eventbrite, AI is used to find new artists among concert promoters based on demographics and engagement data to make lineups more relevant.

The AI maybe this land's greatest power. It still contains that Middle Eastern vibe: Anghami platform, for live music streaming and event promotion, uses AI to recommend concerts by local artists to people according to their history and preferences (Hassouni & Mellor, 2025). Cultural localization, and inclusivity from the perspective of the developer, stands as a paradigm to display AI catering to diverse artistic ecosystems.

These innovations, collectively, underscore AI's growing capacity to act as a mediator, improving collaboration between artists, audiences, and event producers, and transforming the possibilities that go into live entertainment.

4.5 Challenges and Barriers: Data Bias, Digital Divide, and Cultural Sensitivity

Despite the advances, these AI-enabled systems do face their fair share of limitations. The most extensively studied problem has been algorithmic popularity bias in recommender systems (Klimashevskaia *et al.* 2024). These biases exacerbate already popular creators at the cost of developmental or regional voices. And, as Zhao *et al.* (2024) observe, the digital divide keeps limiting that very participation in AI-driven ecosystems. An infrastructural, training, and economic divide prevents the equal desertification of AI.

Another major issue hinges on cultural sensitivity. Such globally oriented while algorithms tend to disrespect local artistic nuances or cultural idioms. Thus Deldjoo *et al.* (2024) stress the importance of fairness-aware modeling in terms of the cultural contexts and the dataset diversities. Also, Anantrasirichai and Bull (2021) state that the more the processes are automated, the more creative outputs become homogenized, thus chucking some of the human touch away in curation. Hence, transparency, data ethics, and participatory governance frameworks must be worked by developers and organizers for inclusion.

4.6 Policy and Managerial Implications

The investigation exhibited in Section 4.1 to 4.5 denotes that on the one hand, AI enhances the relationship between the artist and the event along with operational innovation, while on the other hand, the issues of structural inequalities, biased data, and digital divides still stand in the way of inclusivity. A multidisciplinary approach comprising governance, technology, and educational reforms will be needed for their effective resolution. The implications that follow are a guide to the practical measures the necessary steps will be taken by governments, platforms, and artists.

4.6.1 Policy Implications for Governments and Cultural Institutions

Government bodies should approve budgets not just for AI education but also for digital infrastructure that will benefit regional artists through innovation hubs, training programs, and digital incubators. Cultural policies should encompass a set of AI principles designed for the governance of fairness, transparency, and inclusiveness. Facilitating localized and open data initiatives representing regional art forms will help the recommender systems to mirror cultural diversity. Last but not least, collaboration between academia and industry can lead to the development of research surrounding fairness-aware AI models that are specifically designed for the creative and event ecosystems.

4.6.2 Managerial Implications for Platforms and Developers

Event and streaming platforms should implement recommendation algorithms that are fairness-aware and rectify bias of artists' equitable exposure regionally. One way to enhance algorithmic transparency is through visibility dashboards or disclosure reports which will enable artists to grasp the ranking systems. In addition, platforms should consider the use of hybrid human–AI curation models that incorporate the algorithmic findings along with the cultural expertise. Furthermore, prediction analytics used for locating and uplifting local talent will switch the role of AI from that of a monitor to an active participant promoting inclusivity.

4.6.3 Practical Implications for Artists and Event Organizers

AI tools for data-driven self-promotion should be used by artists actively and engaged with, by applying analytics to discover suitable audiences and niche events. Working with platforms in the area of metadata improvement through better tagging and genre descriptors can enhance the visibility from algorithms. On the other side, the event organizers will be required to employ ethical co-creation methods, by integrating AI recommendations with human judgment preserving authenticity and diversity. The constant AI upskilling will enable the artists to keep their digital representation under control.

4.6.4 Broader Implications for Cultural Sustainability

It is hope that the inclusive AI ecosystem will be a place for sustainable digital participation and that it will consequently reduce regional disparities, as well as promote cross-cultural collaboration. Endowing AI with fairness and the governance of participation is thematically aligned with UNESCO's (2022) declaration that

culture should be treated as a global public good. In this way, the role of AI is transformed to that of a cultural equity catalyst; thus, diversifying, giving access, and providing ethical innovation across the creative and event industries are the positive impacts driven by it.

Conclusion and Future Directions

Conclusion

The present research had the main objective of analyzing the beneficial impact of artificial intelligence (AI) on connecting emerging and regional artists with niche event organizers. The results have solidified that the AI platforms are becoming increasingly vital in discovering artists, curating events, and targeting audiences, thus making it possible to participate in culture through data. But at the same time, the study has also pointed out that the above-mentioned restrictions imposed by the technological development are still prevailing due to factors such as algorithmic bias, infrastructural disadvantage, and lack of digital literacy which thus continue to suppress the voices of underrepresented artists.

The study, by integrating modern literature with proverbial cases, has given birth to an AI-based inclusivity framework wherein AI is viewed as a technological as well as a socio-cultural enabler. The framework combines fairness-aware algorithms, open data initiatives, and humans to ensure ethical, transparent, and culturally sensitive uses of AI in event ecosystems. It clarifies that the biggest strength of AI is not simply through efficiency or automation but through the promoting of diversity, representation, and fair creative participation.

The chief contribution of the research is in connecting different parts of the research on AI in the creative industries and event management through a multilayered conceptual model that links AI applications to inclusivity outcomes. In this way, the global cultural policy agenda viewing technology as a public cultural infrastructure that can strength the creative economies and at the same time being very ethical in governing the process aligns with this conceptualization.

Managerial and Policy Significance

The implications of the findings are enormous for the creative industries and policymakers. Governments should elt AI governing frameworks that are promoting inclusivity and fairness while at the same time investing in the digital infrastructure of the regions. Event platforms along with developers need to take up the task of creating and using transparent and fairness-aware recommender systems while artists should be allowed to use the power of AI tools that will increase their discoverability without being inauthentic. The study has also shown the necessity of human–AI collaboration—the type of partnership where human curation works along with the algorithmic logic to keep the cultural aspect and creativity intact.

Limitations

This study, being a qualitative synthesis, depends on secondary data and thus does not present direct empirical validation. The ideas, although rich in concepts, suffer from the unevenness in the availability of regional data and the linguistic biases in the global academic and policy sources, which limit them. Nonetheless, the study sets a robust theoretical base for further empirical inquiry and applied research in this nascent area.

Future Research Directions

The conceptual development that future studies should be based on will be accompanied by empirical validation through case studies or mixed-method approaches. The framework that has been proposed could be tested with regional datasets to measure fairness and inclusivity in AI-based recommendation systems. Moreover, the policies of different countries concerning the use of AI in the creative sector might be analyzed simultaneously to see how policy and culture influence the ethical uptake of technology.

There should be a focus on co-governance models whereby AI developers, cultural policymakers and creative communities can get together. Thus, there will be no lack of accountability and representation in the design of algorithms. It would be a great help to sustainability, equity and digital cultural transformation if the researchers did longitudinal studies to track the changing role of AI in event ecosystems from curation to audience engagement.

This study, viewing artificial intelligence as a creative empowerment tool rather than a control mechanism, thus advocates the need for a more inclusive, transparent, and ethically grounded future concerning the global event and creative ecosystems.

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Credit Authorship Contribution Statement

Disha Tivary: Led the conceptualization, literature review, methodology design, data analysis, and drafting of the manuscript.
Ashwin Kannan V: Provided supervision, validation, and major critical revisions. Managed data curation, prepared visualizations, and supported manuscript editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Declaration of Use of Generative AI and AI-Assisted Technologies

The authors used generative AI tools solely to assist with language editing, grammar refinement, and formatting. All core ideas, analysis, interpretations, and conclusions were developed by the authors. The authors reviewed and validated all AI-assisted outputs to ensure accuracy and integrity of the content.

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Greening Growth: The Revealed Comparative Advantage of Indian Transport Sector Emissions

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Abstract: Greening growth requires aligning economic expansion with environmental sustainability, a challenge that is particularly acute for rapidly growing economies such as India. The transport sector plays a dual role in this transition: it is a critical enabler of productivity, mobility, and tourism-led growth, while simultaneously emerging as one of the fastest-growing sources of greenhouse gas (GHG) emissions. This study examines India's transport-sector ((Mobile combustion – road, rail, ship & aviation) emissions in a global comparative perspective by applying the Revealed Comparative Advantage (RCA) framework to transport-related GHG emissions (CO_2, CH_4, N_2O, and F-gases) for the period 1970–2023, using EDGAR data. The analysis compares India's emission intensity relative to world averages and major emitting countries, including China, the United States, Japan, Russia, and Canada, as well as international aviation and shipping. Findings indicate that while India's relative environmental burden remained below the global benchmark until the mid-2000s, its RCA in transport-sector emissions has exceeded unity thereafter, coinciding with accelerated economic growth, motorisation, urbanisation, and rising aviation demand. Road transport and aviation emerge as the dominant contributors, with international transport activities approaching global average emission intensities. The results highlight that India and China currently exhibit a revealed comparative disadvantage in greening transport growth relative to advanced economies that have begun to decouple transport emissions from economic expansion. The study underscores the urgency of integrated mitigation strategies, including rapid electrification of road transport, modal shifts towards rail, expansion of low-carbon public transport, deployment of sustainable aviation fuels, and stronger regulatory and market-based instruments. Aligning transport decarbonisation with tourism growth and broader development goals is essential for India to achieve green growth without compromising mobility and economic aspirations.

Keywords: Green growth; Transport emissions; Revealed comparative advantage (RCA); India; transport; GDP; Sustainable mobility.

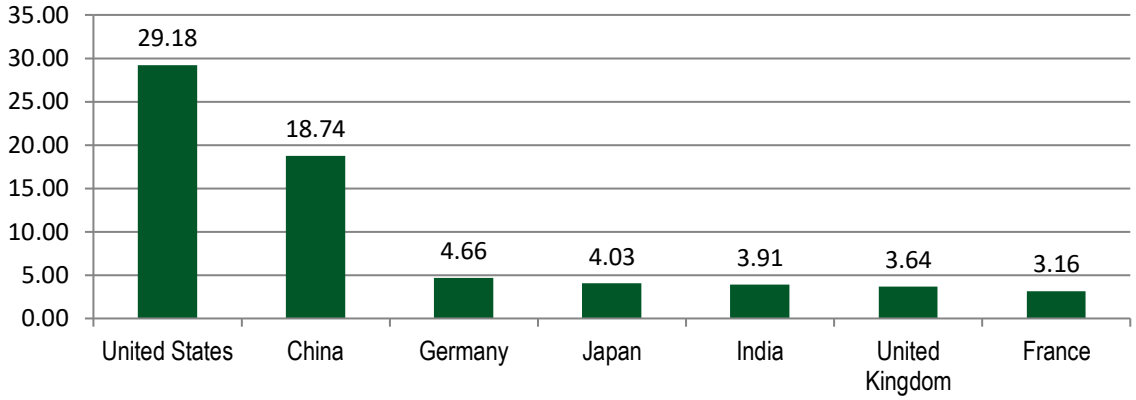
JEL Classification: O44; R11; R41; Z32.

Introduction

India is among the world's fastest-growing major economies, with sustained growth driven by industrialization, urban expansion, and rising household incomes. While this growth has lifted millions out of poverty, it has also intensified pressure on natural resources and increased environmental pollution. The transportation sector plays a dual role: it is essential for economic productivity and social mobility, yet it is a major source of air pollution and

carbon emissions. Greening growth refers to fostering economic development while ensuring that natural assets continue to provide the resources and environmental services on which human well-being depends. In India, achieving green growth is especially important given the country's development needs, high population density, and vulnerability to climate change. This paper explores how the transportation sector fits into India's green growth pathway by analyzing emission trends and future opportunities. India is among the world's fastest-growing major economies, with sustained growth driven by industrialization, urban expansion, and rising household incomes. India has overtaken France and U.K. to become the fifth largest economy of the world on the bases of GDP (Current US$) on the basis of World Bank data base of 2024, presented in the below Graph reflects that.

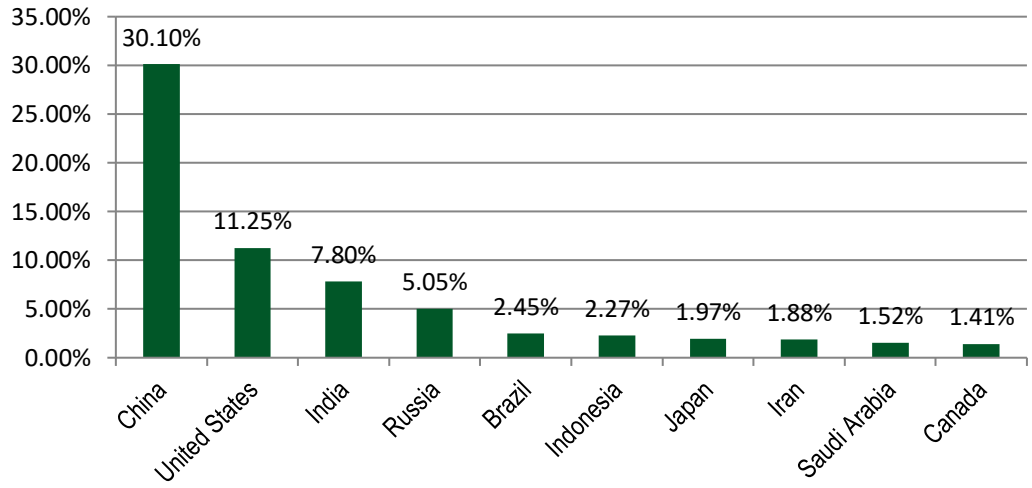
Graph 1. World's Seven Largest Economies: As Per 2024 GDP ($ trillion)



Source: World Bank Data, World Development Indicators, https://databank.worldbank.org/reports.aspx?source=2&series=NY.GDP.MKTP.CD#

However, when it comes to the emissions, India the large parts of Green House Gas (GHG) emissions are contributed by China, United States and India at the third place as shown in the below Graph

Graph 2. Share of GHG Totals in Mt. CO2 eq/yr (2023)



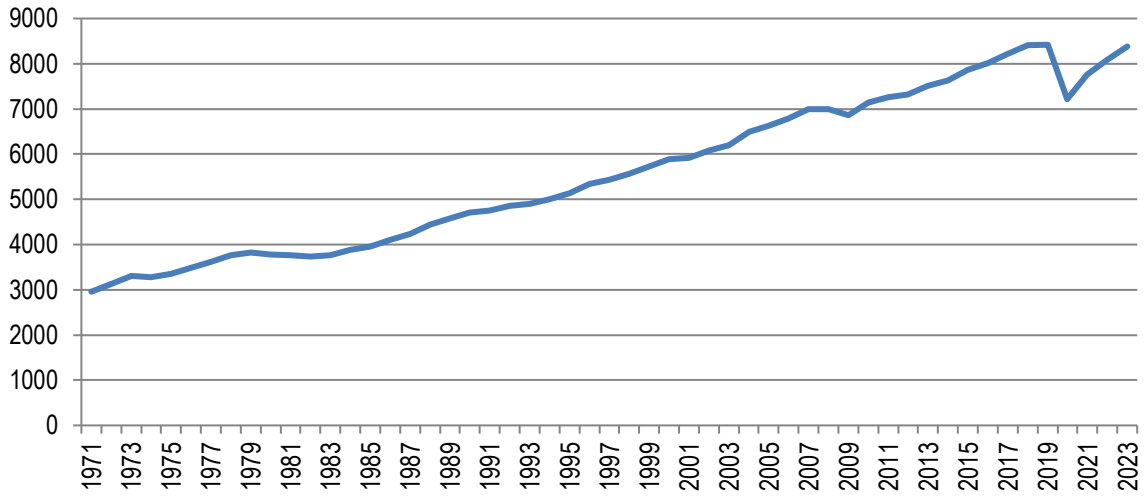
Source: EDGAR (Emissions Database for Global Atmospheric Research) Community GHG Database (a collaboration between the European Commission, Joint Research Centre (JRC), the International Energy Agency (IEA). https://edgar.jrc.ec.europa.eu/report_2024

While this economic growth has lifted millions out of poverty, it has also intensified pressure on natural resources and increased environmental pollution. The transportation sector is essential for economic productivity and social mobility, yet it is a major source of air pollution and carbon emissions.

In general, markets tend to overlook the environmental damage associated with economic activities. When the production or consumption of a good imposes costs on third parties who are not directly involved in the

market transaction, such impacts are referred to as externalities. Negative environmental externalities - such as air pollution, depletion of natural resources, and contamination of water bodies - adversely affect ecosystems and, ultimately, human well-being. These adverse effects necessitate timely and effective policy formulation and implementation preceded by an in-depth measured analysis of environmental impact of the transport sector – as per the scope of this paper. The global transport sector GHG Emissions (GHG emissions include CO_2 – fossil only, CH_4, N_2O and F-gases) has been continually rising since 1970s (exception being the 2020 widespread pandemic lockdowns) as shown in the below graph

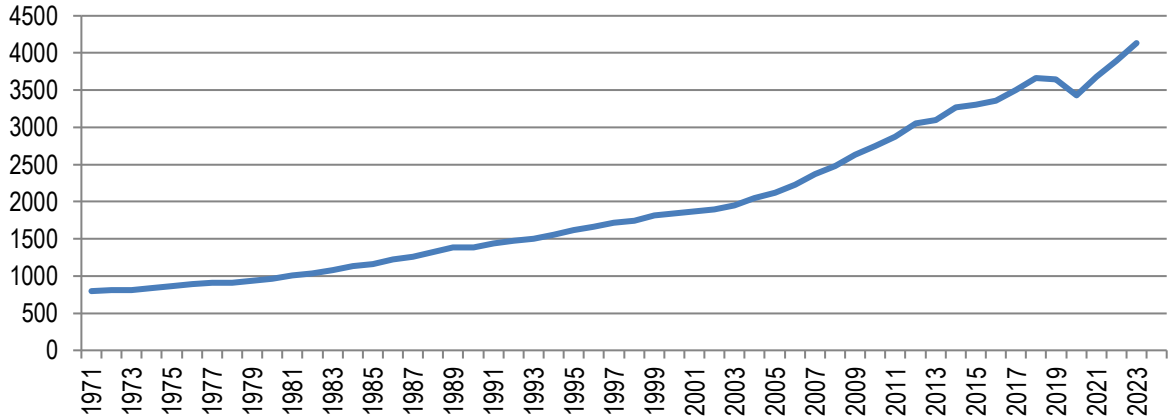
Graph 3. Global Transport Sector GHG Emissions (Mt. CO2 eq/yr.)



Source: EDGAR, 2024

The same trend is followed in case of India as well (Graph 4)

Graph 4. India Transport Sector GHG Emissions (Mt. CO2 eq/yr.)



Source: EDGAR, 2024

Travel and tourism have many connected sub-sectors out of which hospitality and transport (rail, road and aviation) are important sub sectors. So what can be the travel and tourism sector's role in controlling environmental damage? The obvious answer is twin fold (a) Adopt circular principles in hospitality sub sector, and (b) Adopt sustainable travel and transport models for the sub sector. Tourism as the sector is much needed in all the developing economies of the world as it is the largest service sector that can not only contribute to the national income but has multiplier effect on the generation of direct and indirect employment. Much has been written about the hospitality sector and much needs to be focused on transportation in terms of its rising contributions to emissions along with its vital backbone towards the economic growth of the countries. The transport sector emerges as a major contributor to emissions, with road transport and aviation playing dominant roles. The World in general and India in particular, transport accounts for a substantial share of air pollution and energy-related CO_2 emissions. The paper seeks to assess the transportation sector worldwide, including mobile

combustion across road, rail, shipping, and aviation, with particular emphasis on India through an evaluation of the country's revealed comparative advantage in transport-sector emissions. The study seeks to assess whether India's transport-sector greenhouse gas (GHG) emissions have become disproportionately concentrated relative to global trends, using the Revealed Comparative Advantage (RCA) framework as a comparative environmental benchmarking tool over the period 1970–2023. The study seeks to answer the Research Questions as below:

1.Has India's transport-sector GHG emission intensity, relative to global averages, increased over the period 1970–2023?

2.Does India exhibit a Revealed Comparative Advantage (RCA < 1) in transport-sector emissions in recent years, indicating a relative concentration of emissions compared to the world average?

3.How does India's transport-sector RCA compare with major economies such as China, USA, Japan, Russia, Canada, and international aviation/shipping?

The study innovatively repurposes Revealed Comparative Advantage (RCA) or Balassa index as the novel methodology adopted here as a relative benchmarking tool to assess a country's emission intensity in the transport sector vis-à-vis the global pattern. Although originally developed for trade competitiveness, the RCA framework is well suited for comparative environmental analysis because it normalizes a country's sectoral emissions by its overall emissions profile and compares this share with the corresponding global share. This relative scaling controls for differences in country size and total emissions, allowing meaningful cross-country comparison of sector-specific emission concentration.

1. Research Background

The Green practices are drawing attention in developed economies because the demand for environment quality is more than unity at higher stages of development. As economic power centres are shifting to Asia-Pacific region thereby increasing the importance of Asian economic development for environmental management. The large parts of CO_2 emissions are contributed by China, United States and India. Environmental emissions are global concern because its adverse impact is not limited to a country or a region, as rising global temperature is leading to melting of polar ice caps, rise in level of sea and extreme weather conditions.

As the increase in scale of economic activity has worsening impact on environment, simultaneously, maintenance of environment quality is necessary for sustainable development. Therefore, the flow of economic activity should take into consideration its environmental impact. Scientists believe that emissions from economic activities like factories, power plants, cars and trucks targeted to move to zero by 2050. Globally, Power Industry, and Transport are the major contributors to the Green House Gas emissions. In 2018, delegates from around 200 countries met in Poland and set tougher targets for cutting greenhouse gas emissions, vis-à-vis, Paris climate agreement of 2015 along with stronger transparency rules are set for countries regarding revealing their emissions (Irfan, 2018). In Paris Climate change agreement also, nearly 200 countries met and agreed to limit the global temperature rise to 2^0C by 2100; but the preferred level is set at 1.5^0C. If the emissions continue to rise with the pace of the current rise leads to more wild fires, coastal flooding, widespread food shortages and population displacement by 2040 (Pierre-Louis, 2018).

Transportation is a major source of air pollution and greenhouse gas emissions, especially in cities. In India, the sector accounts for about 40% of total air pollution, over 40% of Nitrogen Oxides **(**NOx) emissions, 12% of energy-related CO_2 emissions, and roughly 7% of combustion-linked PM2.5. In Delhi alone, transport contributes nearly 43% of PM2.5 levels. Two-wheelers, three-wheelers, and trucks are the biggest emitters within this sector. In Delhi, 2Ws and 3Ws together generate around 60% of transport pollution, followed by trucks (20%), buses (10%), and passenger cars (10%). Nationally, heavy-duty vehicles produce about 45% of CO_2 emissions, cars 25%, two-wheelers 15%, buses 9%, and light-duty vehicles 8%. India's government is aligning transport reforms with its climate commitments under the 'Panchamrit' agenda, targeting energy independence by 2047 and net-zero emissions by 2070. Electric mobility is central to this transition, with a goal of 30% EV penetration by 2030 (about 102 million EVs). There are different schemes nationally such as 'FAME scheme', and 'PLI' scheme; new initiatives like 'PM e-Bus Sewa' and 'PM e-Drive' with local incentives to push for such transitions. Although EV adoption is rising among smaller vehicles, electric buses and trucks are still in the early stages of deployment (Council for International Economic Understanding, 2025).

Aviation contributes about 2.5% of global CO_2 emissions but nearly 4% of total global warming due to additional non-CO_2 effects such as NOx, SO_2, water vapor, and contrail formation at high altitudes. Although only around 10% of people fly annually, demand has quadrupled since 1990, with improved aircraft efficiency reducing emissions per passenger-kilometer by over half. However, total emissions continue to rise as air travel expands. Non-CO_2 emissions significantly amplify aviation's climate impact, potentially tripling its warming effect.

Strategies like using cleaner jet fuels with lower aromatic content and rerouting flights to avoid contrail-prone regions can greatly reduce these effects. The EU plans to start monitoring non-CO_2 emissions in 2025, though broader global action is lacking. Future mitigation depends on transitioning to Sustainable Aviation Fuels (SAFs), e-fuels, hydrogen, and electric aircraft. While efficiency gains and technological advances have reduced energy intensity, aviation still relies almost entirely on fossil fuels. Without rapid adoption of low-carbon alternatives, its share of global emissions will continue to grow as other sectors decarbonize (Ritchie, 2024). Aviation emissions have risen more rapidly than any other transport mode, more than doubling since 1990. Without effective mitigation, they are projected to more than double again by 2050, potentially consuming and large chunk of the remaining global carbon budget required to limit warming to 1.5°C.

Between 1940 and 2018, non-CO_2 emissions accounted for over half of aviation's total warming impact, though their uncertainty remains about eight times greater than that of CO_2. Recent reports by the IPCC, WMO, and Copernicus Climate Change Service warn of accelerating climate change and record-breaking weather extremes, with Europe now warming at twice the global rate, the fastest of any continent.

To better understand and manage these impacts, a non-CO_2 Monitoring, Reporting, and Verification (MRV) framework was introduced on 1 January 2025 to collect data on aviation's non-CO_2 emissions. This initiative aims to strengthen scientific research and inform effective mitigation strategies. Additionally, a European Parliament pilot project launched in 2024 is assessing ways to optimize jet fuel composition - such as lowering aromatic and sulfur content - to reduce environmental impacts without compromising safety. Aircraft engine emissions, particularly nitrogen oxides (NOx) and particulate matter, also degrade air quality near airports, with potentially significant exposure to NO_2 and ultrafine particles in nearby residential areas (European Union Aviation Safety Agency, 2025).

Global air traffic is growing by about 5% annually, consuming over 5 million barrels of oil each day. Aviation emissions, particularly in fast-growing markets like China, are projected to more than triple by 2050 if unmitigated. Besides CO_2, airports and aircraft contribute to local air pollution through nitrogen oxides and fine particulate matter. Major airlines such as American Airlines, Emirates, and Lufthansa emit tens of megatonnes of CO_2 yearly. To address this challenge, the EU Emissions Trading System (EU ETS) employs market-based carbon pricing and efficiency-driven incentives with the objective of reducing emissions by 43% by 2030. Technological and operational improvements have reduced CO_2 emissions per seat by 80% since the 1950s, supported by ICAO's aircraft emission standards. Further reductions depend on sustainable aviation fuels made from waste or biomass and the gradual introduction of electric aircraft for short routes. Optimizing flight paths and promoting non-stop routes can also lower emissions, reducing CO_2 by roughly 100 kg per passenger compared with connecting flights (Sher, et al, 2021).

India's aviation sector, though contributing under 1% of national emissions, is growing rapidly and could become the world's third largest by 2030. To curb its rising carbon footprint, the government's 2019 Green Aviation Policy promotes Sustainable Aviation Fuel (SAF) from agricultural residues like sugarcane waste and rice husk. Indian Oil and Praj Industries achieved the country's first SAF-powered commercial flight in 2023. Green airport initiatives, electric ground operations, and Taxi-Bots further enhance efficiency. However, limited feedstock, high SAF costs, and weak infrastructure hinder large-scale adoption. With a 1% SAF blending target by 2025, India's progress exceeds China's but trails Brazil's. Linking clean aviation with rural bioeconomy could cut emissions while supporting farmers and sustainable growth (Saroha, 2025).

In India, substantial inter-state and inter-regional differences in vehicle ownership and emission levels necessitate the development of decentralized emission inventories for the road transport sector to inform targeted greenhouse gas (GHG) mitigation strategies. During 2003–04, total carbon dioxide emissions from the transport sector amounted to 258.10 teragrams (Tg), with road transport and aviation emerging as the dominant sources. Road transport alone contributed 94.5% of transport-related CO_2 emissions and 53.3% of carbon monoxide (CO) emissions. Maharashtra recorded the highest road transport CO_2 emissions at 28.85 Tg (11.8%), followed by Tamil Nadu (10.8%), Gujarat (9.6%), Uttar Pradesh (7.1%), Rajasthan (6.2%), and Karnataka (6.2%). Together, these states accounted for 51.8% of national road transport CO_2 emissions. Aviation was responsible for 2.9% of CO_2 emissions but accounted for a disproportionately high 45.1% of Carbon oxide (CO) emissions, while rail transport contributed 2.0% of CO_2 and 1.2% of CO emissions. Maritime transport accounted for only 0.6% of CO_2 emissions, making it the least carbon-intensive transport mode. Over the period from 2003–04 to 2005–06, aggregate CO_2 emissions from aviation, railways, and shipping increased by 24.2%, accompanied by rises of 32.3% in CO emissions and 31.8% in methane (CH_4) emissions (Ramachandra and Shwetmala, 2009).

India's transport sector is rapidly expanding, driven by rising incomes and urbanisation, and is a key contributor to energy demand and CO_2 emissions. While accounting for under 20% of final energy use, transport

consumes roughly 50% of India's oil, highlighting the need for decarbonisation, particularly in aviation and long-distance freight. Passenger mobility is dominated by two- and four-wheelers, with four-wheelers projected to grow from 9% of motorised travel in 2020 to 45% by 2050, reducing public transport shares and increasing energy demand, congestion, and emissions. Trucks handle 65% of freight, with natural gas expected to supply 35% of their fuel by 2050. Railways remain the most energy-efficient mode, and electrification will further enhance efficiency. Policy measures and electric vehicle infrastructure will be crucial to manage the sector's future energy and climate impact (Kamboj, et al, 2022).

India, the ninth-largest aviation market, operates over 120 airports, including 34 international ones. Aviation is highly carbon-intensive, projected to contribute 15–25% of global aviation emissions by 2050, with a three- to seven-fold increase since 2000. India joined CORSIA in 2016, mandatory from 2026, highlighting the urgency of mitigation. Tourism, closely linked to aviation, drives economic growth but raises emissions. Low-carbon destination management - through sustainable transport, longer stays, and targeted market strategies - is essential to align tourism growth with net-zero goals. Bio-jet fuels offer a cleaner alternative but remain costly, 60–70% above conventional fuels, posing challenges for operational efficiency (Thummala and Hiremath, 2022).

Existing literature underscores that environmental sustainability has become a central concern as economic growth intensifies environmental pressures, particularly through rising greenhouse gas emissions. While developed economies have led green transitions, shifting global economic activity toward Asia - especially China and India - has heightened the region's significance in global environmental management. The transport sector emerges as a major contributor to emissions, with road transport and aviation playing dominant roles. In India, transport accounts for a substantial share of air pollution and energy-related CO_2 emissions, driven largely by two- and three-wheelers, heavy-duty vehicles, and rapidly expanding aviation activity. Despite global climate pledges, including the Paris Agreement, and national commitments such as India's Panchamrit framework, emissions from the transport sector - covering road, rail, maritime, and aviation - continue to rise, driven by the growing demand for mobility. Aviation, in India though contributing a relatively smaller share of CO_2, has a disproportionately high climate impact owing to non-CO_2 effects and is projected to consume a significant portion of the remaining carbon budget without effective mitigation. Policy responses increasingly emphasize electric mobility, sustainable aviation fuels, market-based mechanisms, and decentralized emission inventories. However, high costs, infrastructure constraints, and uneven regional development remain key challenges, highlighting the need for integrated, sector-specific mitigation strategies to align economic growth, transport expansion, and climate goals.

While extensive research has examined transport-sector emissions in absolute terms and explored policy responses such as electric mobility and sustainable aviation fuels, there remains a lack of long-run comparative benchmarking that evaluates whether a country's transport emissions are disproportionately concentrated relative to global patterns. In particular, the application of the Revealed Comparative Advantage framework to sector-specific environmental intensity remains largely unexplored. This study addresses this gap by adapting the Balassa index to assess India's transport-sector GHG emissions relative to global averages over the period 1970–2023, thereby providing a normalized and comparative perspective on green growth performance.

2. Research Methodology

This study is based on secondary data on greenhouse gas (GHG) emissions from the transport sector at the global level, with a comparative focus on emissions from India, using EDGAR (2024) for the study period spanning 1971 to 2023 (time period *t*). The analysis employs the Revealed Comparative Advantage (RCA) framework as the primary research tool to examine cross-country patterns in general and India's relative position in particular. The RCA index is computed as follows:

RCA =(Xih/Xit)/(Xwh/Xwt),

Xih denotes country *i*'s contribution to GHG/CO_2 emissions in year *h* (2023);
Xit represents the total GHG/CO_2 emissions of country *i* over the study period *t* (1971–2023);
Xwh refers to the world's contribution to GHG/CO_2 emissions in year *h* (2023); and
Xwt indicates total global GHG/CO_2 emissions over the period *t* (1971–2023).

The transport sector data encompass mobile combustion across road, rail, maritime, and aviation modes, while greenhouse gas emissions include fossil-based CO_2, CH_4, N_2O, and fluorinated gases. These emissions are aggregated using Global Warming Potential (GWP) coefficients and reported as total GHG emissions in million tonnes of CO_2 equivalent per year (Mt CO_2e/yr).

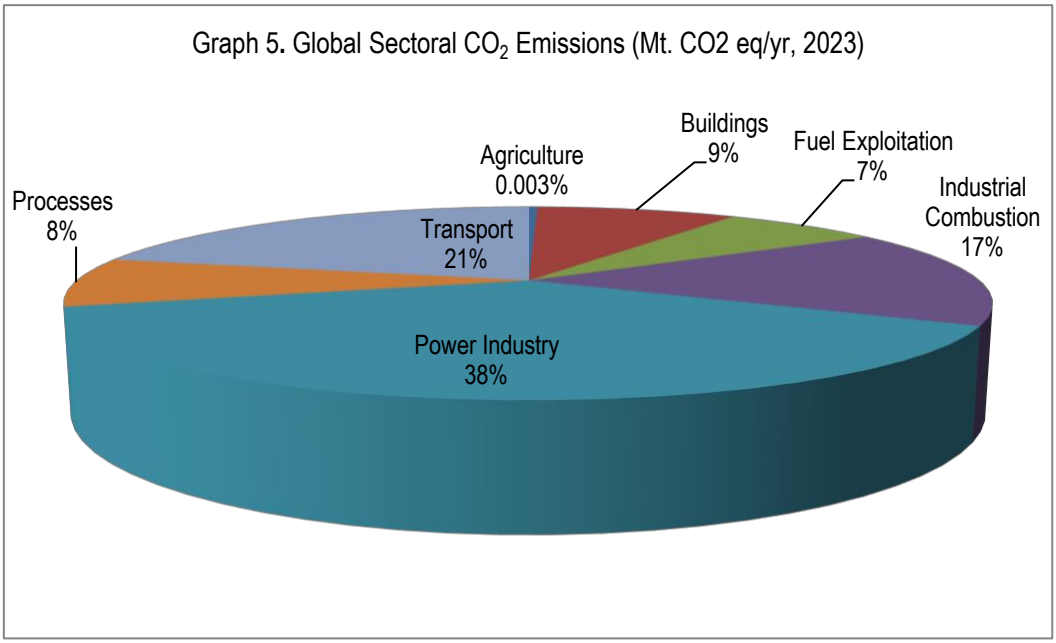
An RCA value greater than 1 indicates that a country's share of transport-related GHG/CO_2 emissions in the reference year / study period is relatively higher than the corresponding global share, implying a revealed comparative "intensity" (or disadvantage) in emissions for that sector. Conversely, an RCA value less than 1 suggests that the country's relative contribution is lower than the world average, indicating comparatively lower emission intensity in the transport sector.

By focusing on shares rather than absolute volumes, RCA highlights whether a country exhibits a disproportionate concentration of GHG/CO_2 emissions in the transport sector compared to the world average. This makes it particularly useful for identifying sectors where mitigation efforts are relatively more urgent for a given country, even when its absolute emissions may be lower or higher due to scale effects. The simplicity, transparency, and interpretability of the Balassa index further support its application as a diagnostic indicator for comparative assessment of emission intensity across countries and over time.

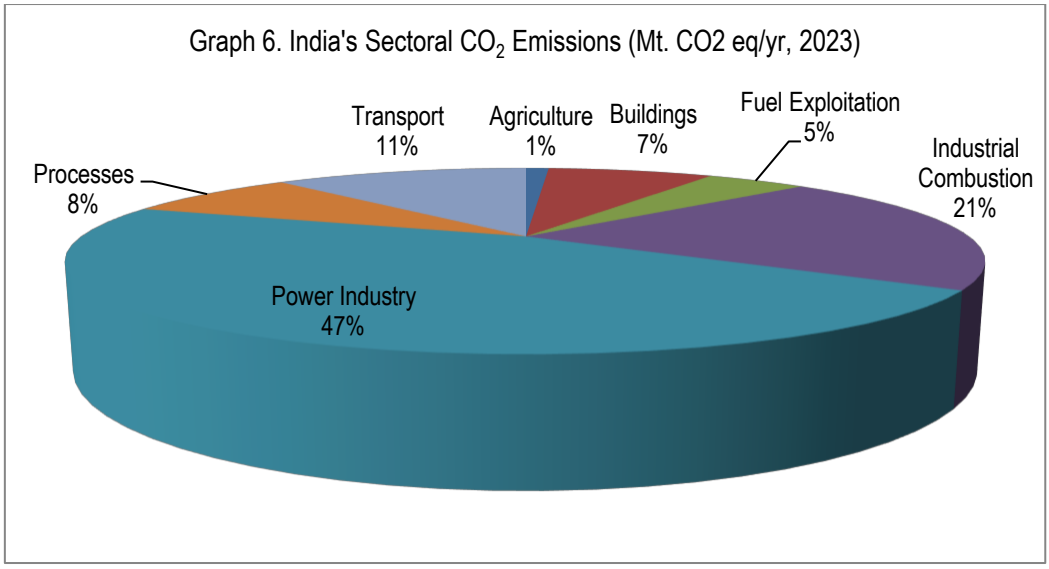
3. The Transport Sector – Revealed Comparative Advantage Analysis

The transport sector is a major contributor to global greenhouse gas (GHG) emissions and also represents a significant source of emissions in India. In terms of gas-wise contributions, carbon dioxide (CO_2) accounts for the largest share of total emissions, comprising 73.68% globally and 71.49% in India, followed by methane (CH_4) at 18.88% worldwide and 20.31% in India, and nitrous oxide (N_2O) at 4.70% globally and 6.53% in India. Methane and nitrous oxide emissions are predominantly associated with agricultural activities (EDGAR, 2024). Consequently, for sectors other than agriculture, CO_2 emissions remain the principal area of concern. The transport sector ranks as the second-largest source of CO_2 emissions globally after the power industry as illustrated in Graph 5, while in India it is the third-largest contributor, following the power sector and industrial combustion (Graph 6).

Graph 5. Global Sectoral CO_2 Emissions (Mt. CO2 eq/yr, 2023)

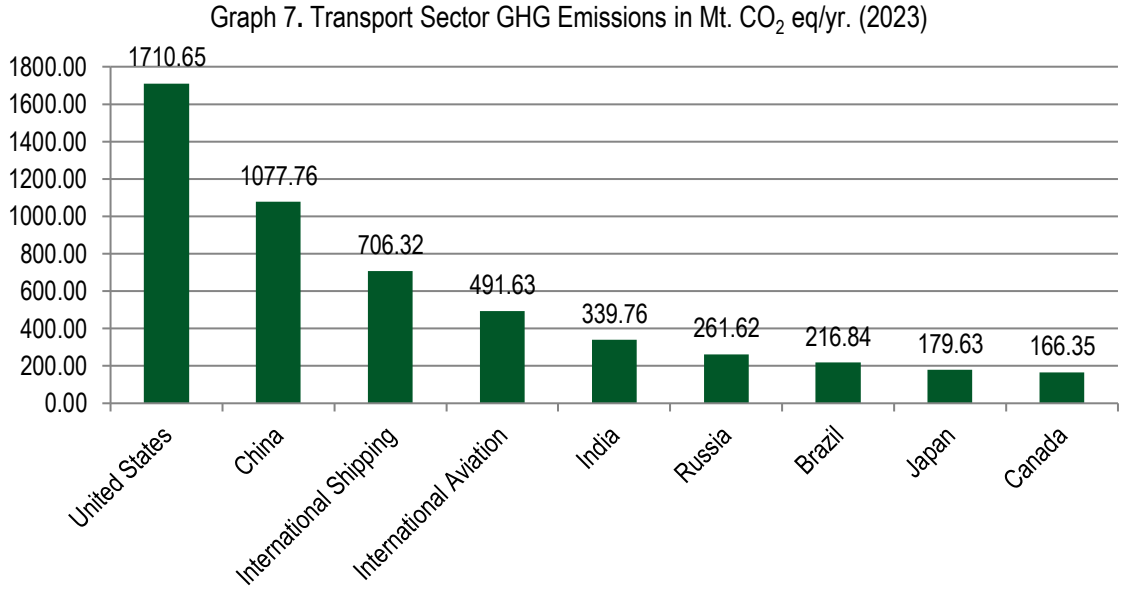


Source: EDGAR, 2024



Source: EDGAR, 2024

The Transport Sectoral Greenhouse Gas (GHG) Emissions follows the same trends as that of the overall global GHG emissions where China leads the charts, followed by United States of America and India following at the third place. However, in case of Transport sectoral emissions, two more areas exceed India, following the top two contributor countries, namely, International Shipping and International Aviation, as per the Graph 7 below (CO_2 is the major cause of emissions to transport sector, hence the data ignores the other emissions, which also follow the similar trends). The two areas need consolidated efforts to control through renewed international understanding for drastic policy formulation and implementation.



Source: EDGAR, 2024

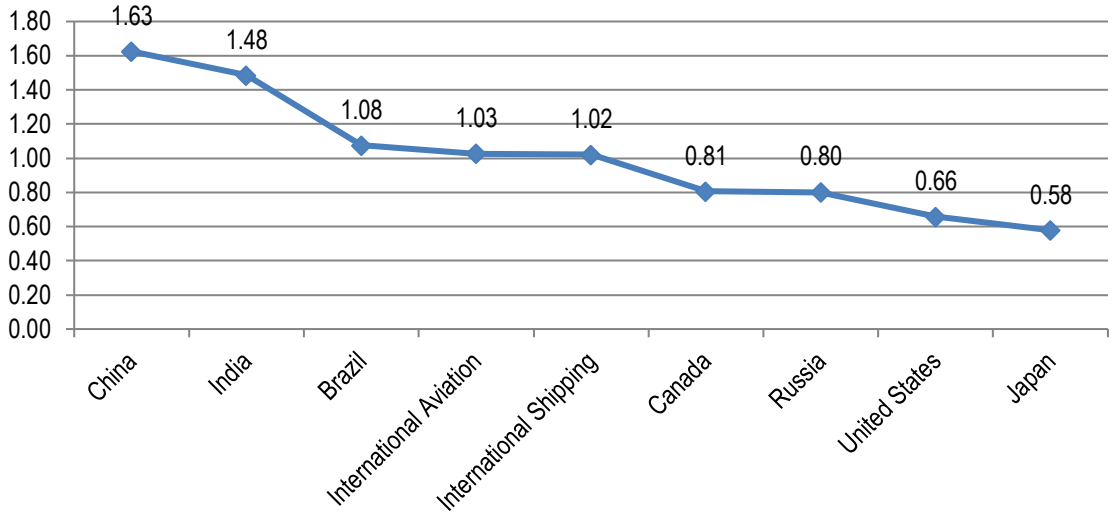
4. Comparative Advantage Analysis of GHG Emissions

The study attempts to establish the revealed comparative advantages for environmental impact related to Transport Sectoral Greenhouse Gas (GHG) emissions with respect to the World to arrive at revealed advantage or disadvantage for India with respect to other countries over the period from 1970 to 2023.

The revealed comparative advantage for total Greenhouse Gas (GHG) Emissions of all countries was calculated for the year 2023 over the previous all years from 1970 to 2023 with respect to the GHG Emissions of the World in the year 2023 over the previous years from 1970 to 2023. The revealed comparative advantage for the GHG emission impact of any country with respect to world in 2023 over the study period will be lower if the

value is less than unity and impact will be higher if the value is more than unity. The revealed comparative calculated for 210 countries and regions showed that 121 were more than unity than the World average and only 89 countries and regions were less than unity.

Graph 8. Country's RCA on GHG Emissions (2023)

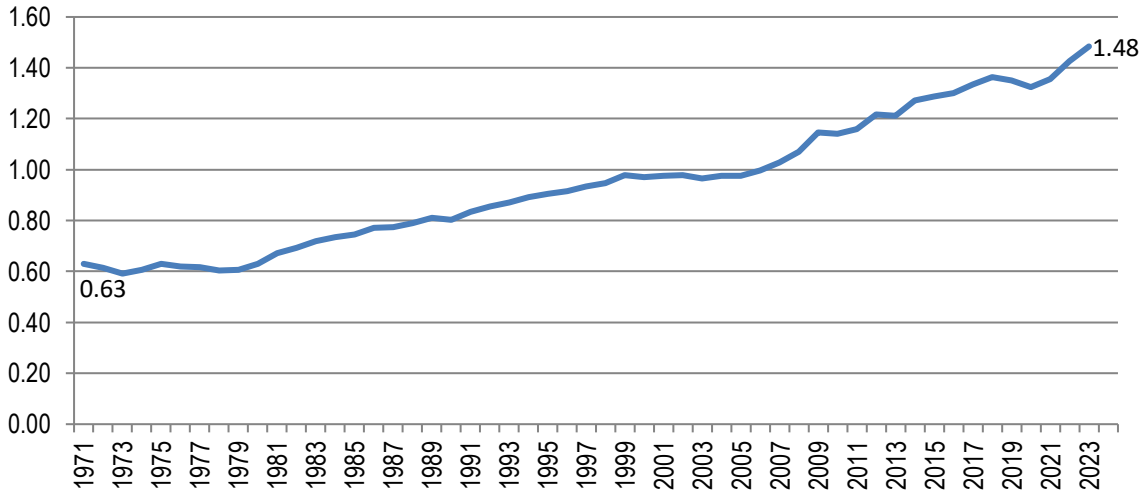


Authors' calculation based on EDGAR, 2024

The Graph above shows while Japan, United States, Russia and Canada have improved to less than unity in the revealed comparative advantage with respect to the World in 2023 when analysed over the period from 1970 to 2023; India and China are witnessing lesser revealed comparative advantage and are still having more than unity or greater GHG Emissions impact in 2023 with respect to the World. International Shipping, International Aviation and Brazil are near to the unity and are causing the almost the same environmental impact as that of the World impact. India and China to the greater extent need to bring their GHG emissions down with better policies and implementation while their economy grows further.

Studying India's rising GHG emissions over the years as shown in Graph 4 does not give the fair idea, if seen in isolation. The Graph 9 below shows India's Annual Revealed Comparative Advantage (RCA) on GHG Emissions with respect to the World over the study period.

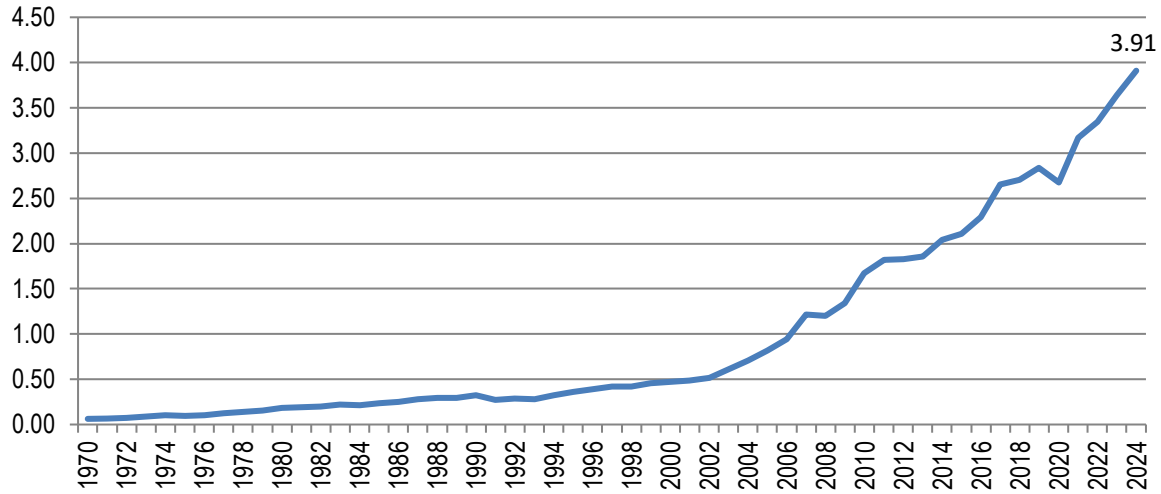
Graph 9. India's Annual RCA on GHG Emissions



Authors' calculation based on EDGAR, 2024

The graph above shows that India's environmental impact with respect to World was lesser till 2006 when it achieved unity with the World; and thereafter environmental impact with respect to World started rising; this almost coincides with the time when India started witnessing its higher GDP growth as shown in Graph 10.

Graph 10. India's GDP (current Trillion US$)

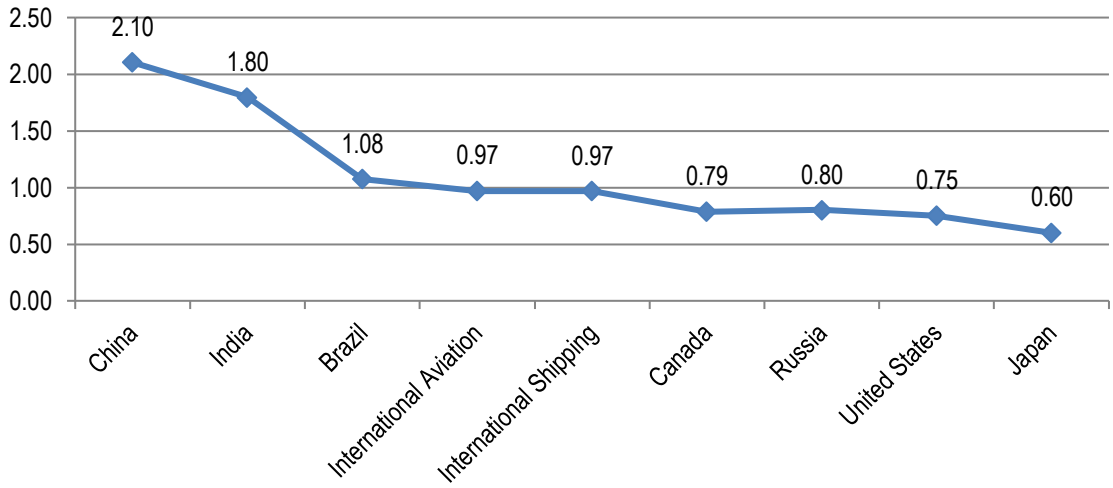


Source: The World Bank Data, 2024
https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?end=2023&locations=IN&start=1970&view=chart

5. Comparative Advantage Analysis of Transport Sector Emissions

India and China to the greater extent need to bring their Transport sector contribute lesser emissions with better policies and implementation while their Travel and Tourism sector grows as the select countries RCA analysis on Transport Sector CO_2 emissions as shown in Graph 11 presents that India and China alone are greater than World unity. It follows the same trend as the RCA for overall GHG Emissions (Graphs 8). The Brazil though just above the World Unity in Transport CO_2 as well as overall GHG emissions, International Shipping & International Aviation are around the World Unity, whereas Canada, Russia, US and Japan are much below World Unity.

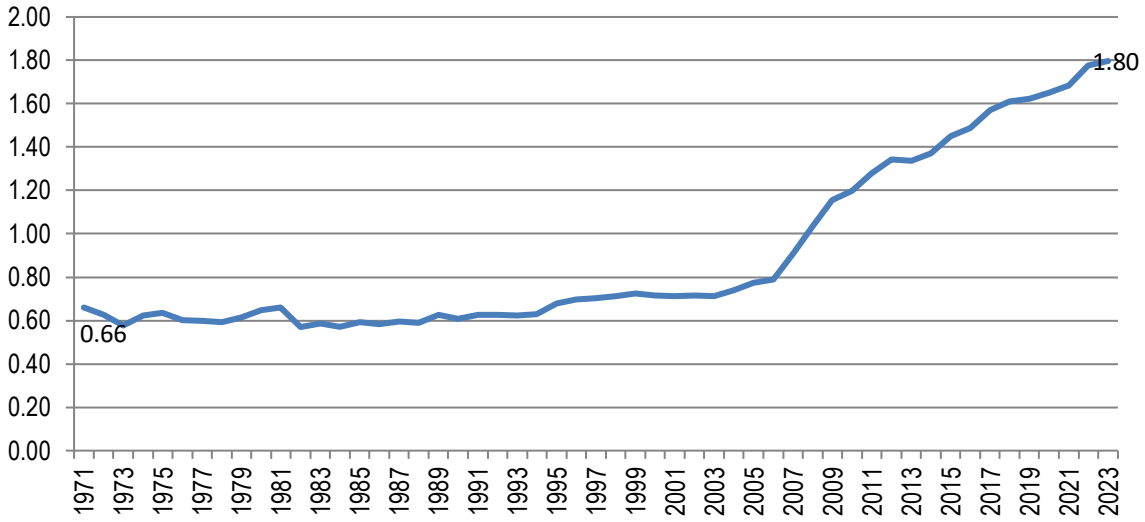
Graph 11. Country's Transport Sectoral GHG Emissions RCA (2023)



Authors' calculation based on EDGAR (Emissions Database for Global Atmospheric Research), 2024

India and China are emerging economic leaders as well as the biggest two economies in the Asia Pacific region, which is slated to be the upcoming region for travel and tourism growth. However, the economies have to re-shape their overall Emissions control in general and Transport sectoral emissions in particular. Talking about India, India's transport sectoral emissions has been lower than World unity till 2007 and sharply rose afterwards.

Graph 12. India's Annual RCA on Transport Sector Emissions



Authors' calculation based on EDGAR (Emissions Database for Global Atmospheric Research), 2024

In the advance stages of development, knowledge economy bring more cleaner technologies because wealthy nations can afford to spend more on research and development (Komen et al., 1997). Further, demand for environment quality is more than unity at higher stages of development (McConnell, 1997) (Shafik, 1994). This being the reason why the developed economies like USA, Russia, Canada and Japan have effectively controlled their overall GHG emissions as well as the Transport sector emissions as showed in this study. India needs to strengthen its knowledge economy more than its Gross income economy.

India, despite introducing notable policy initiatives to promote greener mobility, the transition of the transportation sector remains constrained by multiple structural and behavioural challenges. The high initial costs associated with clean and low-emission technologies continue to deter large-scale adoption, particularly in price-sensitive markets. Inadequate charging and alternative-fuel refuelling infrastructure further limits the operational feasibility of electric and low-carbon vehicles, especially beyond major urban centres. In addition, fragmented institutional responsibilities across multiple transport and urban authorities weaken coordination and slow the implementation of integrated sustainability strategies. Persistent behavioural preferences for private vehicle ownership and use also undermine efforts to promote public and shared transport systems. Overcoming these barriers requires coherent and coordinated policy frameworks, predictable and sustained financing mechanisms, and sustained public awareness and engagement initiatives.

To strengthen green growth outcomes in the transportation sector, a comprehensive set of policy interventions is required. Priority should be given to the rapid electrification of public and shared mobility systems to achieve large-scale emissions reductions. Greater investment in railways and water-based freight corridors can help shift freight movement towards lower-carbon modes. Transport planning should be systematically aligned with urban development to reduce travel demand and promote compact, transit-oriented cities. At the same time, research, innovation, and domestic manufacturing capabilities in clean transport technologies need to be strengthened to lower costs and build long-term competitiveness. Finally, demand-side management tools such as congestion pricing, parking regulation, and other travel-demand management measures should be deployed to discourage excessive private vehicle use and promote more sustainable mobility choices.

Conclusion

This study examined the transport sector's role in India's green growth pathway through a Revealed Comparative Advantage (RCA) analysis of transport-related greenhouse gas (GHG) emissions in relation to global trends over the period 1970–2023. The findings indicate that while India's relative environmental burden remained below the world benchmark until the mid-2000s, its transport-sector emissions intensity has since surpassed the global average. This shift coincides with accelerated economic growth, rapid motorisation, urban expansion, and rising aviation demand, highlighting the growing tension between mobility-led development and environmental sustainability. Road transport and aviation emerge as the principal contributors to this revealed comparative disadvantage, whereas advanced economies have begun to decouple transport emissions from economic growth.

The results underscore that continued reliance on fossil-fuel-intensive mobility pathways risks locking India into a high-emissions trajectory at a time when international shipping and aviation already pose additional global challenges. Achieving green growth in the transport and tourism ecosystem therefore requires a coordinated policy mix that combines rapid electrification of road transport, expansion and integration of low-carbon public transport and rail, demand management in urban mobility, and accelerated deployment of sustainable aviation fuels alongside operational efficiency improvements in aviation. Complementary measures - such as strengthened emission standards, pricing of carbon externalities, investment in clean infrastructure, and region-specific mitigation strategies informed by decentralised emission inventories - are essential to enable decoupling of transport emissions from economic growth. Overall, the study demonstrates that India's development and tourism-led mobility expansion need not be environmentally regressive if supported by timely technological transitions, robust regulatory frameworks, and behavioural shifts towards sustainable travel. Aligning transport decarbonisation with national climate commitments and long-term development goals is crucial for ensuring that future growth is both economically inclusive and environmentally resilient.

The findings that India's transport-sector emissions have exceeded the global benchmark (RCA > 1) since the mid-2000s underscore the need for the structural decarbonisation measures. Rapid electrification of public and commercial fleets, expansion of rail and low-carbon freight corridors, and integrated urban transit planning are essential to reduce fossil-fuel dependence. Regulatory standards should be complemented by market-based instruments such as carbon pricing, congestion charges, and parking reforms to address demand-side externalities. Institutional coordination across transport, energy, tourism, and urban governance bodies is critical to avoid fragmented implementation. Strengthening decentralized emission monitoring systems can support targeted mitigation strategies. Long-term progress also depends on investing in research and innovation in battery storage, sustainable aviation fuels, and smart mobility systems, alongside embedding sustainable transport education in higher learning. Finally, behavioural change is vital. Promoting public transport, shared mobility, and responsible travel practices will help align mobility expansion with climate commitments and prevent long-term carbon lock-in in India's growth trajectory.

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Credit Authorship Contribution Statement

Syeeda Khatoon has been instrumental in conceptualization, laying down the Methodology, Writing – original draft and Supervision.
Syed Asghar Mehdi has been instrumental in Co-conceptualizing, Investigation, Project administration, Formal analysis, results and conclusions for the study.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of Use of Generative AI and AI-Assisted Technologies

The authors declare that they have not used generative AI and AI-assisted technologies during the preparation of this work.

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The Importance of Collaboration between Local Communities and Stakeholders in the Management of Volcano Ecotourism in Indonesia

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Abstract: Collaboration is an important aspect in the development of ecotourism, considering that the provision of tourism experiences cannot be carried out by one stakeholder. Cooperation with interested stakeholders in the tourism sector is absolutely necessary. The objective of this paper examines the collaboration between local communities and stakeholders in managing ecotourism development in Volcanic Areas in Indonesia. Data collection was carried out by means of observation, and in-depth interviews were conducted with 18 stakeholders involved in implementing ecotourism projects in the cities of Yogyakarta and Kediri, as differing examples of major destinations Indonesia. To analyze it, this study used the theory of collaboration and community participation. Stakeholder mapping was divided into three key stakeholders groups (those who have legal authority in regulating activities), namely Tourism and Culture Office, Local Government at the village/ sub-district/ district level and Village-Owned Enterprises; Primary Stakeholders (those directly affected), namely private individuals/investors, communities, jeep drivers groups, travel agents, banking, community associations, tourism object associations, women farmers groups, mass media and the Office of Communication and Information; Secondary Stakeholders (as supporters of the course of tourism), namely Family Welfare Empowerment (Women's Organization), Karang Taruna, Sleman Museum Communication Forum, Universities, Social Services and Village Community Consultative Institutions. Collaboration is carried out in accordance with their respective roles in the management of the tourism sector, starting from the development of ideas/ideas, policies, managerial, research and publications, socialization processes, human resources for goods and services product business actors, capital, technology and the development of creativity as a form of creative economy. Collaboration between players in the ecotourismch sector needs to be much more extensive than it is currently to achieve the full potential of this industry.

Keywords: ecotourism; collaboration; community participation; private; government.

JEL Classification: H10; J18; J20; J24; R11; L10.

Introduction

Nature-based tourism, or “eco-tourism” is one of the attractive options for traveling while simultaneously avoiding crowds to prevent post-Covid-19 transmission (Ariawan, Z., & Ahmat 2020). Ecotourism has been advanced as a solution to sustainable environmental development and human life because, in addition to concerning economic growth and people's lives, it also concerns the environment through conservation (Tanaya, Dhayita Rukti & Rudiarto 2014; Hadi and Yulianto 2021). During the Covid-19 pandemic, with vastly reduced numbers of

international and domestic tourist across Indonesia, there was pressure on the management of the ecotourism industry to adapt and to survive this crisis (Rahman et al. 2020; Soliku et al. 2021; Ralf Buckley 2021). The strategies offered range from arranging independent travel, minimizing hotel costs, lowering hotel room prices, exploiting cultural potential, developing inclusive infrastructure and other alternative livelihoods to survive in times of crisis (Yuni 2020; Vellycia 2021) and developing alternative tourism demanded (dark tourism) (Ariawan, Z., & Ahmat 2020). Efforts to revive the industry, apart from requiring a strategy, also require commitment from the parties concerned in maintaining the ecotourism sector.

One form of ecotourism that attracts tourists in Indonesia is mountain and volcano adventure tourism. On the Island of Java, Mount Merapi and Mount Kelud are volcanoes having a great demand for tourists. Mount Merapi, located close to the city of Yogyakarta, is still active. After the last major eruption in 2010, a tour was run by…. on Mount Merapi to commemorate and present the history of Mount Merapi's eruption from various historical narratives. Once Mt Merapi's volcanic activity had ceased and the area was considered safe to visit again, there was a lot of interest for people to go there. During 2011, tourist numbers increased from both foreign (262,000) and domestic sources (3.01 million) and these have continued to increase every year since then (BPPTKG 2017). The growth of various creative tourism industries around Mount Merapi has made tourism businesses and local government optimistic about boosting the economy through the tourism sector at Mount Merapi.

In addition, Mount Kelud is an active volcano in East Java with the last eruption in 2014 making local people more optimistic about developing the economy by exploiting the potential of Mount Kelud. Apart from tourism on Mount Kelud itself, various natural attractions are growing on the slopes of Mount Kelud as one indicator of the development of the creative tourism industry on Mount Kelud. After the pandemic, local governments and communities have played a role in helping to regenerate the ecotourism sector (Rahman et al. 2020; Soliku et al. 2021; Ralf Buckley 2021). This research maps out the stakeholders involved in tourism development and the forms of collaboration carried out by these stakeholders in reviving ecotourism on Mount Merapi, Yogyakarta, and Mount Kelud, Kediri.

1. Literature Review

1.1 Ecotourism

Ecotourism is the activity of traveling to, and being in, natural areas while prioritizing the principles of environmental responsibility and sustainability (D. J. Wood and Gray 1991; M. E. Wood 1999; Black and Crabtree 2007). According to one model, ecotourism constitutes five important elements: protecting the natural state, ecological sustainability, environmental education, beneficial to local communities and creating tourist satisfaction (Fennell and Dowling 2003; Hill, Jennifer & Gale 2009). In addition to aiming at environmental conservation, ecotourism is also related to the development of a locally-oriented tourism sector to have a positive economic impact on local communities (Fennell and Dowling 2003; Butcher 2007). The growth of the economic sector in the development of ecotourism also goes hand in hand with the development of creative industries within ecotourism itself.

The creative industries according to the Government's vision are defined as follows: industries that rely on individual creativity, skills, and talents that have the ability to improve living standards and create a workforce through the creation (ideas) and exploitation of IPR (Taken from the definition of the UK Department of Culture, Media, and Sport, 1999 in Nenny 2008). The definition of the creative industry is the utilization of individual creativity, skills, and talents to create welfare and employment through the creation and utilization of individual creativity (Pangestu 2008). Much has been developed in the nature tourism sector by presenting creative ideas through the development of ecotourism that is more modern and much in demand by both domestic and foreign tourists, such as for example the Indian Village on the slopes of Mount Kelud and the Lava Jeep Tour. Both of these activitie are made available for people to enjoy nature and present creative ideas from its development such as historical dishes.

Ecotourism is important to develop to achieve environmental sustainability and human-life in balance. Research on ecotourism conducted by Tanaya, Dhayita Rukti & Rudiarto (2014) stated that ecotourism greatly contributes to environmental conservation and economic development of local communities based on community empowerment. This study stated that by exploiting the potential of the community, the local community's economy will grow through tourism by utilizing ecological conditions in the environment. Hadi and Yulianto's research (2021) also stated that nature tourism has great potential and can take advantage of nature tourism by developing sports tourism.

The development of tourist villages is also part of empowering rural communities in the tourism sector. Kristy's research (2020) explored the development of tourist villages using social media during the Covid-19 pandemic. Social media was used successfully to reduce the impact of the Covid-19 pandemic in tourist villages.

Sari and Sitorus (2021) examined stakeholder collaboration in managing accommodation in tourist villages during the Covid 19 pandemic. In addition, Mali (2021) mentioned that there is a role for the local government in efforts to restore the tourism sector in Yogyakarta by creating the Visit Jogja Application that adapts the health advice to tourist's location. The app is expected to.provide timely and up to date information for tourists to protect them from possible future outbreaks, even though this application still needs a lot of improvement.

Buckley (2021) explains that eco-tourism has come under increasing pressure to produce different results, ecosystems, and tourist destinations (Ralf Buckley 2013; Marion et al. 2020; Monz, Pickering, and Hadwen 2013) to the extent that during a pandemic, issues have to be addressed according to the area . As with many areas of the economy, the tourism industry was very severlely affected by the impact of Covid-19 pandemic (Rahman et al. 2020; Soliku et al. 2021). Associated movement and travel restrictions, poorer economic conditions, uncertainty about travelling long distances all contributed to a sharp and sustained reduction in earnings/income for most tourism providers.

The strategy of tourism actors can focus on travel innovation by considering tourist requests (arranging their trip plan), minimizing hotel costs, lowering hotel room prices, promoting cultural potential, developing inclusive infrastructure, and other alternative livelihoods to survive in times of crisis (Yuni 2020; Vellycia 2021; Goh 2021) and developing alternative tours of interest, so called "dark tourism" (Ariawan, Z., & Ahmat 2020). Research by Sari and Sitorus (2021) and Mali (2021) with a collaborative approach of tourism industry management during a pandemic, identified all stakeholders (not only local government or the community).

1.2 Collaboration

Collaboration is a process of unifying the differences of the parties involved in recognizing problems to find a solution by working together (D. J. Wood and Gray 1991). Meanwhile, according to Thomson and Perry (2006), collaboration is a process in which actors who have autonomous authority interact through formal and informal negotiations, together creating rules and structures that govern relationships and how to act or make decisions on issues that bring them under togetherness. The actors involved come from across government and non-government sectors. Cross-sectoral collaboration is important in developing the concept of collaboration (Bryson, Crosby, and Stone 2006). According to Bryson, Crosby, and Stone (2006), there are five dimensions in cross-sectoral collaboration, namely initial conditions, structure, process, contingencies and constraints, and finally results and accountability.

Stakeholders can be defined as the individuals or groups which play a role and are a holder of an interest in an existing problem. Thus, stakeholders themselves are a form of ownership being able to determine the power over the running of the organization (Estaswara 2010; Chariri, Anis & Ghozali 2014). According to Maryono (2005) in Handayani, Fitri & Warsono (2017), stakeholders consist of three groups, namely primary, key stakeholders, and secondary stakeholders. Primary stakeholders are those directly affected by activities; key stakeholders are those with legal authority in regulating these activities, while secondary stakeholders support primary and key stakeholders for the course of activities. Reed et al. (2009) stated that in analyzing the role of stakeholders, both interest and influence must be considered. The section is analyzed through four stakeholder categories: subjects, key players, followers, and supporters. Stakeholder subjects have a high level of importance but have low influence. Key Players have equally high interest and influence. Followers are stakeholders who have a low level of interest and influence. Lastly are supporters, stakeholders with a low level of interest but have high influence.

2. Research Methods

This research design used a qualitative approach with a descriptive-analytical research type. Qualitative research methods are used to see and know more deeply about phenomena limited in terms of knowledge (Strauss, A., & Corbin 1998). Creswell, J. W., & Poth (2016) explained that qualitative research was used to understand the deep meaning of social problems. Thus, in this study, researchers reveal a phenomenon that has not been widely disclosed about how stakeholders collaborate to develop creative ecotourism on Mount Merapi, Yogyakarta, and Mount Kelud, Kediri.

Primary data were obtained through interviews with key informants, namely the Yogyakarta Provincial government in the Tourism Sector and the Kediri Regency government in tourism. Furthermore, interviews were carried out using the snowball technique in accordance with the directions of the key informants and subsequent informants to identify the stakeholders involved. Furthermore, secondary data was obtained through observations on collaborative activities carried out by stakeholders in reviving the creative ecotourism industry on Mount Merapi Yogyakarta, and Mount Kelud, Kediri. Secondary data was obtained through documentation from public

government documents, institutional activity reports, business financial reports, and documents for reference needs regarding ecotourism and collaboration.
At the Tourism Object in the Mount Merapi Area, interviews were conducted with 6 informants from various elements/institutions. The following are informants who have provided information and data in this study:

Table 1. Research informants at Mount Merapi Tourism Office in Yogyakarta, Indonesia

No	Code	Institution	Position
1	Informant 1	Government Tourism Office	Contract worker of the Government Tourism Office
2	Informant 2	Tlogo Putri	Parking Guard of Telaga Putri from Youth organization in village and Head of Neighborhood
3	Informant 3	Ledok Sambi	Marketing Officer
4	Informant 4	Klangon	Klangon Security Coordinator
5	Informant 5	Mini Sisa Hartaku Museum	Founder of Mini Sisa Hartaku Museum
6	Informant 6	Merapi Volcano Museum	Head of Sub-Division

Source: authors, 2022

In Kediri Regency, interviews were conducted with 12 informants as tourism actors of Mount Kelud Tourism Office from various elements/institutions. The following are informants providing information and data in this study:

Table 2. Research informants of Mount Kelud, Kediri, Indonesia

No	Code	Institution	Position
1	Informant 1	Department of Tourism and Culture	Tourism Development Division Employee
2	Informant 2	Orchid Village	Member of the public
3	Informant 3	Orchid Village	Director of PT Anugerah Anggrek Nusantara
4	Informant 4	Ngancar District Government	Staff member
5	Informant 5	Sempu Village Government	Staff member
6	Informant 6	Sugih Waras Village Government	Village head
7	Informant 7	Villa glamping	Security guard
8	Informant 8	Kelud Tourism	Tourism Officer
9	Informant 9	Association	Street Food Seller
10	Informant 10	IndianVillage	Manager
11	Informant 11	Pineapple Village	Association Chairperson
12	Informant 12	Kediri Flora Island	Owner

Source: researchers, 2022

Data obtained from interviews, observation, and documentation were carried out through validation using the triangulation method. Triangulation aims to ensure that the data obtained has a sufficient level of credibility and validity to be used as material to describe existing phenomena and problems (Lexy J. Moleong 2017). The process of analyzing data in this study was carried out through the process of examining, categorizing, tabling, and combining evidence and data from research to formulate initial conclusions of the research.

The initial process of data analysis was carried out with data reduction to simplify the data obtained in the field. The reduced data is related to the results of interviews about the natural conditions of ecotourism, tourist visitors, constraints, and obstacles in ecotourism development. The data categorization process was carried out by creating data categories, namely parties who collaborate, forms of collaboration, and community participation

in developing tourism. The data categorization process continued to the display of interview data in the form of data analysis displayed in the form of writing, tables, or charts as a result of the analysis process.

This data display is also the result of a dialogue between primary data and secondary data analyzed using the theory used in the study. The conclusion-making process was carried out after the data analysis process and data display were completed as the last part. In research on this collaboration, after recognizing the parties who play an important role in the collaboration process, the form of collaboration, and the existence of community participation. Conclusions need to be made by analyzing the obstacles and challenges in developing ecotourism in the two regions.

3. Result and Discussion

3.1. Identification of Stakeholder Roles in Ecotourism Development

In management tourism in the Mount Merapi area, the parties involved there are different from object tour One with others. For example, in Tlogo Putri, from field data results object tour This managed from results collaboration between the Sleman Tourism Office, AMI (Anindya Mitra International), and the National Park of the Ministry of Environment and Forestry (KLHK). Regarding the Creative Economy development strategy, the service also held an activity for interesting visitors. For example, there is a Jatilan dance performance and a dangdut orchestra. In addition, there are a number of facilities that can be rented, for example room open for activities like outbound or cultural performances. Costs the rent is also relatively affordable, namely Rp. 150,000 for the replacement cost of electricity.

Different case in point with the one in the Object Tour Ledok Sambi, because it is organizations whose nature is organic. Management is carried out directly by the local government and community institutions there, such as Karang Taruna and PKK. In this case, management ecotourism Ledok Sambi understands the importance of sustainability so that they limit visitor limits in accordance with capacity parking. The same thing also happened at Klangon Hill, the management directly by the local community, namely the Youth of Karang Taruna. However, in Bukit Klangon There is cooperation with the village and Tourism Office.

At the Sisa Hartaku Museum, management in tourism is done in a family way. Handled between the informant who as founder together nephew. Related maintenance development, income from parking jeep, visitors, and managers, his finances. However, even though this museum is initiative from founder alone, welcomed by the Tourism Office. The management of the Sisa Hartaku Museum is also aware that the collaboration with the party jeep community becomes main focus in the sustainability tour.

Meanwhile, at the Mount Merapi Museum (MGM), at the time nomenclature solution was reached between the Department of Tourism and the Department of Culture, and then MGM followed the Department of Culture. If from the side the substance culture also comes in, the staff here is a staff member of the Department of Culture. In this case, cooperation No, there are those who official recorded, but the data findings are MGM network with a travel agency, which later will contact the manager if there are group visitors who come.

In the management of ecotourism on slopes Mount Kelud and on the slopes Mount Merapi, there are stakeholders who provide contribution in development ecotourism. This stakeholder Alone become the spearhead of tourism-based natural. This will develop and exist as well as in demand community. On the slopes of Mount Kelud, stakeholders in several locations tour through management in a private way, meaning system management is carried out by the private party all over.

Kampong Anggrek tourism is done in a way independent of the private party. There is no involvement from public in management, investors, as well owner play a role main in the organization of ecotourism. Condition This is different with what is in the object Kampong Nanas and Mount Kelud tourism, local people involved in a way direct through association both PK5 (Street Vendors) and the motorcycle taxi association at Kelud Peak. Paguyuban Pamong Karyo Satriyo is a motorcycle taxi association on Mount Kelud. This is purely managed by local communities and associations This pays retribution to Government of Kediri Regency. There are differences in management between Tour Mount Kelud and tourism on its slopes become part important for follow-up as material evaluation so that tourism keeps going can walk in development area. As for investors and management private can developed with good but must controlled by the government and society of course.

This is become a big Lots development tourism on the slopes of Mount Kelud has leading to pure private, of course This dangerous for sustainable development tourism.

Involvement government within management tour This give base that all something must through procedures and controls from government. There is a number of things done by the government in effort control management tourism, besides visit direct is also necessary socialization and training as form effort strengthening human resources in managing tourism. Such as has been carried out by the Tourism Office do training to manage village

tourism in Kediri Regency. The role of government This No only gives socialization and training about tourism, but also a form other empowerment that can used for developing draft tourist based, nature in Kediri Regency. During the pandemic, when all over activity mountain tourism Kelud affected, and many are closed, the government also makes extra effort to overcome the impact of this pandemic.

Monitoring is carried out by the Tourism Office besides for carry out his duties, also supports policy government in the field of health about use of health protocols that have been determined by the government. There is monitoring periodically This give impact alone for manager tourism. This is what makes role of government as part from system control. Apart from the government, in management tourism, which also has important roles, the existence of Village and Sub-district Government. Government village, namely Sempu Village and District Ngancar give statement about his involvement. In Sempu Village there are there is several location tours such as Korea Fantasy, Kampong Anggrek, Kampong Indian, and Tourism Mbah Diang's Religion. Government villages play a role in development and management tourism in Sempu Village. There are institutions BUMDes is responsible answer main in manage tourism in Sempu Village and in the sub-district area Ngancar.

Regent Kediri Regency conveyed his commitment in business build return tourist Kediri Regency such as before the pandemic. This is also of course involving Lots parties, one of which is the media. The media should make deep spearhead effort for marketing one of the products is product tourism. Promotion This executed through cooperation publication by Radar Jawa Pos Kediri which is often review about tourism on the slopes of Mount Kelud. Besides promotion through local media, also done promotion through national media that works. The same with the Ministry of Tourism and Creative Economy on the page https://jadesta.kemenpthekraf.go.id. This Already carried out by the Tourism Village Sempu who promotes facilities and destinations tourism that can visited in Sempu Village along with price and access.

Government institutions still must be at the forefront in organization service public. In the implementation service tourism, the government also has a very important role No only as a regulator but also as a promotional medium. Private sector as funding and also partnership also provides chance for can participate as well as develop tourism in Kediri Regency. Actors tourist must focus on various variables related like knowledge, technology Information and Communication, and system digital management for increase performance ecotourism among company provider ecotourism (Mekhum and Torasa 2020).

3.2. Stakeholder Collaboration in Ecotourism Management

Key stakeholders involved in ecotourism management in the areas of Mount Merapi, Yogyakarta, and Mount Kelud, Kediri were first identified. Collaboration between many stakeholders built because of a common goal, both in the form of a blueprint and written in an agreement or policy. Thomson and Perry (2006) mention collaboration as a process in which actors who have autonomous authority interact through formal and informal negotiations, creating rules and structures to govern relationships and ways of acting or making decisions on issues to bring togetherness as a necessity.

The initial step to be taken if there are unequal interests is the equalization of perceptions, how different interests can still be achieved by working together according to a mutual agreement through a joint forum between all collaborating actors. Collaboration takes various forms, from knowledge to material resources. Ecotourism management has five important elements that must be known, namely natural nature, ecologically sustainable, educational environment, beneficial local communities, and tourist satisfaction (Dowling, 1996 in Hill, Jennifer & Gale 2009). The ecotourism development collaboration process is guided by these elements to gain various forms of cooperation according to the ecotourism elements.

3.2.1. Government Stakeholder Cooperation

Government stakeholders consist of government officials who have a role in tourism development, consisting of the Tourism and Culture Office or other agencies (social services, Regional Government offices at the Village, District, and Regency Levels). The role of the government as a policy maker, manages tourist destinations and conducts outreach-publication of.

Table 3. Government Stakeholder Cooperation

No	Institution	Interest	Impact	Stakeholder Category	Roles and Responsibilities
1	Department of Tourism and Culture	- Tourism policymakers - Executors of tourism management functions	Policy Managerial	Key	- Carrying out cooperation with the community, private companies, and youth organizations in organizing tours - Approving the establishment of a tourism organization - Providing outreach and training on tourism, but also other forms of empowerment used to develop nature-based tourism concepts - Carrying out the functions of control, coordination, education, and evaluation in tourism management - Gaining the distribution of business results
2	Government at the Village, sub-District, and District Levels	- Policies and awareness in developing the tourism sector	- Policy - Socialization - Collaboration with various stakeholders	Key	- Managing tours - Receiving the distribution of business profits - Collaborating with other stakeholders in tourism development
3	Village Owned Enterprises	- Tourism policymakers - Executor of tourism management functions - Development of Creative Ecotourism	Policy Managerial	Key	- Managing tourism locally by working with the community and youth organizations - Receiving the distribution of business profit
4	Social Services Department	- Socialization of community empowerment - Achievement of performance in the field of empowerment	- Empowerment partners - Labor/HR - Budget/Capital	Secondary	- Conducting socialization of tourist attractions - Collaborating with other stakeholders in tourism development
5	Village Community Empowerment Institution	- Field Executive	Goods/Services Products	Secondary	- Managerial and management of tourist attractions - Collaborating with other stakeholders in tourism development

Source: Primary Data Analysis, 2022

3.2.2. Private Stakeholders and Business Actors

Private stakeholders and business actors play a greater role in the management and development of tourism which is directly related to tourists, from upstream to downstream. The number of stakeholders playing a role in the classification of stakeholders is very numerous and of various types. All stakeholders involved in tourism development benefit from its implementation.

Table 4. Cooperation of Private Stakeholders and Business Actors

No	Institution	Interest	Influence Impact	Type	Roles and Responsibilities
1	Private/ investor	- Development of the tourism sector - Growing the economic sector in the tourism sector	- Capital - HR - Technology	Primary	- Running a tourism business - Benefitting from tourism development - Collaborating with other stakeholders in tourism development
2	Public	- Development of the tourism sector - Growing the economic sector in tourism	- Capital - HR - Product Goods/ Services	Primary	- Getting involved directly in organizing community tourism as executors or traders - Creative economy development - Social control of nature use - Achieving economic benefits from tourism development - Collaborating with other stakeholders in tourism development
3	Anindya Mitra International	- Development of the tourism sector - Growing the economic sector in the tourism sector	- Capital - Product Goods/ Services	Primary	- Organizing various kinds of art activities (*Jatilan*, Dangdut concerts) to attract tourists by collaborating with various stakeholders - Achieving benefit from tourism development - Collaborating with other stakeholders in tourism development
4	Jeep Community	- Development of the tourism sector - Growing the economic sector in the tourism sector	Goods /Services Products	Primary	- Developing creative tourism - Achieving benefit from organizing tours - Collaborating with other stakeholders in tourism development
5	Travel Agent	- Development of the tourism sector	Goods /Services Products	Primary	- Developing creative tourism - Achieving benefit from organizing tours - Collaborating with other stakeholders in tourism development
6	Bank Indonesia, East Java Bank	- Community empowerment - Social responsibility in the economic sector - Institutional branding - Investment	- HR - Programs	Primary	- Organizing collaborations with students to provide assistance to tourist villages - BI cooperating with various parties, including travel, culinary and hotel agencies - Developing the creative economy in the implementation of tourism sector - Achieving benefits from tourism development - Collaborating with other stakeholders in tourism development
7	Family Welfare Empowerment (Women's Organization)	- Development of the tourism sector - Growing the economic sector in the tourism sector	- HR - Product Goods/ Services	Secondary	- Organizing tours in collaboration with Youth Organizations, Agencies, and Services - Benefit from tourism development

No	Institution	Interest	Influence Impact	Type	Roles and Responsibilities
8	Village Youth Oorganization	- Development of the tourism sector - Growing the economic sector in the tourism sector	- HR - Product Goods/ Services	Secondary	- Organizing tours in collaboration with PKK, agents, Government Departments, and other stakeholders - Achieving economic and organizational benefits from organizing tours
9	Street Vendors Association	- Community Economy - Social control in the utilization of nature for tourist destination	- Labour - Product goods/ services	Primary	- Organizing tours in collaboration with other stakeholders - Achieving economic and organizational benefits from organizing tours
10	Tourism Taxibike Association	- Community economy - Social control in the utilization of nature for tourism sector	- Labour - Product goods /services	Primary	- Organizing tours in collaboration with other stakeholders - Achieving economic and organizational benefits from organizing tours
11	Farmer Women's Association	- Community economy - Social control in the utilization of nature for tourism sector	- Labour - Product goods/ services	Primary	- Organizing tours in collaboration with other stakeholders - Achieving economic and organizational benefits from organizing tours
12	Sleman Museum Communication Forum	- Community organization	- HR - Product Goods/Services	Secondary	- Socializing the existence of tourist attractions - Achieving economic and organizational benefits from organizing tours - Collaborating with other stakeholders in tourism development

Source: Primary Data Analysis, 2022

3.2.3. Stakeholders in Tourism Publications

The mass media plays a significant role in socializing and disseminating information about tourism at the regional, national, or international levels. The publication can be done through various media online. The publication process cannot be applied by itself. It is appropriate to cooperate with other parties.

Table 5. Cooperation of Tourism Publications Stakeholders

No	Institution	Interest	Influence	Type	Roles and Responsibilities
1	Media Massa Mass media	- Tourism Promotion	Publication Services	Primary	- Publishing tourist attractions to various parties, including at the local, national, or international level - Receiving benefits from information about tourism - Collaborating with other stakeholders in tourism development
2	Office of Communication and Information	- Publications - Tourism Promotion	Travel Publications Policy	Primary	- Policy makers in tourism publications - Receiving benefits of tourism development - Collaborating with other stakeholders in tourism development

Source: Primary Data Analysis, 2022.

3.2.4. Stakeholders from Higher Education

Universities play a role in developing tourism by conducting research, evaluating tourism potential and providing input to tourism managers in developing tourism places.

Table 6. Higher Education Stakeholder Cooperation

No	Institution	Interest	Influence	Type	Roles and Responsibilities
1	Higher Education (UGM, Trunojoyo, IAIN Kediri, Kadiri University, Kadiri Islamic University, Jember University, Trunojoyo University, Blitar Islamic University)	Development of tourism and environmental research	- Educational institutions - Human Resources - Creative Economy Designer	Secondary	- Facilitating tourism business development - Promoting tourist attractions - Conducting research for the development of tourism spots - Collaborating with other stakeholders in tourism development and research

Source: Primary Data Analysis, 2022

The collaborating parties can be classified into several categories of stakeholders, namely stakeholders as business actors, managers of business places and policy makers, and tourism research and development actors. An analysis of the key roles carried out by stakeholders in tourism development reveals that the provision of tourism experiences cannot be done alone. A range of different stakeholders need to work to to run the tourism sector optimally and to achieve economic benefits from implementing ecotourism.

3.2.5. The Role of Local Communities as a Main Actor in Tourism

Among other stakeholders, local communities have a major role in organizing the tourism sector. The existence of the community can create creative industries in a tourist destination. The emergence of Micro Small and Medium Enterprises (MSME) creativity in various tourist objects in the form of various types of businesses, one of which, is by selling typical souvenirs of tourist attractions. The growth of this industry relies on individual creativity, skills, and talents that have the ability to improve living standards and create a workforce through creation (ideas) (taken from the definition of the UK Department of Culture, Media and Sport, 1999 in Nenny (2008). Local communities oriented towards ecotourism development have an important role. This can be seen from the knowledge of the local area, the potential for the emergence of creative ideas, and the skills possessed by the local community. Exploring potential needs to be applied by doing outreach to community socialization to improve people's standard of living because, basically, the growth of this creative industry is the utilization of individual creativity, skills, and talents to create welfare and employment through the creation and utilization of individual creativity and creativity (Pangestu 2008). It is expected that prosperity will arise by creating opportunities and jobs for local communities.

The roles of local communities in developing the tourism sector: (1) Driving the tourism sector, starting from initiating, implementing, and supervising involving local communities, consisting of Family Welfare Empowerment , youth organizations, taxi bike associations, farming associations, and communities around tourist destinations; (2) The people living on Kelud Slope provide various facilities and tour packages, for example, outbound tours, farm education, hydroponic and honeybee cultivation development, and tour packages; (3) All sellers at tourist destinations on the slopes of Mount Kelud are local people expecting their economic conditions. The driving force is young people, community members, and local institutions working together, in the process of using a leasing system; (4) Communities play a significant role in environmental conservation so ecotourism can give an economic impact on local communities (Fennell and Dowling 2003; Goeldner, 1999 in Butcher 2007; R. Buckley 2003) on the slopes of Mount Kelud and Mount Merapi; (5) Organizations which exist at the village level, for example the Village Community Resilience Institute (LKMD), can mobilize the community in managing the parking sector in tourist areas; (6) The local community participates in managing the tourist attractions of Ledok Sambi and the Sisa Hartaku Museum at Mount Merapi by acting as food cooks in the kitchen, parking guards, operating the flying fox attraction, offering guided tours, outbound facilitators, and acting a permanent management staff; (7) Communities around the Tourism Object of the Sisa Hartaku Museum make regulations that the management and business of tourism involve all local communities; (8) The Mount Merapi Museum prioritises employing local works, with 90% of the security and cleaning workers from local communities; (9) Local communities on the slopes of Mount Kelud provide facilities and outbound tour packages, farm education,

hydroponic and honeybee cultivation development, and pineapple plantations; (10) The emergence of typical Micro Small and Medium Enterprises (MSME) creativity from the area tourism attractions, for example on the slopes of Mount Kelud, what is being developed is processed pineapples as the main product. The roles carried out by the local community show that the participation of the local community is the main driver in the development of ecotourism, especially as an actor in organizing tourist destinations Furthermore, it is also important to consider the need for alternative policies to create conservation-based ecotourism for its potential as an international tourist destination (Sumarmi and Shrestha 2022; Tiarantika and Efani 2024).

4. Participation, Communication Patterns, Opportunities, and Challenges

Limited funding and supporting infrastructure for ecotourism are the main obstacles in its management, and the program priority is to develop an integrated and sustainable ecotourism management plan (Asniar, C Kusmana, H S Arifin 2022). However, things like this can be handled through collaboration and cooperation. The implementation of tourism cannot be separated from the involvement of several parties. The involvement of parties results necessitate communication and collaboration to realize the goals of tourism. This communication and cooperation are important points in solving problems related to tourism development. For example, there was a situation at Tlogo Putri, which was managed by the Sleman Tourism Office, Anindya Mitra International Event Organizer, and the National Park of the Ministry of Environment and Forestry.

Other examples of cooperation can also be found in the Management of the Sisa Hartaku Museum and the Mount Merapi Museum with the Jeep Community at Mount Merapi. Likewise, the management of tourism around Mount Kelud cannot be handled by one party alone. Mount Kelud ecotourism is managed by the District-level Government, but, in the implementation process, it also involves the community such as the taxi bike community and the street vendor community. Many parties involved need a joint forum, a forum for communication in tourism management in Kediri. There is a WhatsApp group which is a medium of communication, but it is considered not yet able to represent a forum for collaboration. The joint forum, which is a requirement for collaboration, has not yet appeared on the official forum so only the Whatsapp group is used as a medium of communication. Dalam praktiknya, The one-way communication pattern is the main feature in the findings of this study, so the community and business actors or tourism managers only have to implement it. In addition, the relationship created by the Tourism Officeat Mount Kelud Kediri with the sub-districts and tourist villages was found to have insufficient communication and coordination.

The pattern of communication existing between the district government, the tourism office, and the vertical agencies, is very minimal or it can be concluded that they do not exist. This is because the management is purely managed by the private sector, thus, it is possible that there is no need for communication between the two vertical institutions. The form of communication carried out by the management of the Orchid Village at Mount Kelud, Kediri with the government is only one-way. Limited communication with the government also results in issues which need to be addressed in the future. On the other hand, the communication and collaboration established by tour managers and travel agencies for tourism activities have been well established, although it has not been maximized, which was especially apparent during the Covid-19 pandemic.

Collaboration is carried out by tourism managers to run tourism businesses through travel agencies. Not many travel agencies have been founded/established in the Kediri Regency tourist destinations. This is because the Department of Tourism and Culture is still not aggressive enough in promoting tourism in Kediri. Collaboration with travel agents is a potential that must be developed. It is known that when collaboration is established, there will be more intense visitation, and, of course, both will gain benefits. This agreement gives benefits to both sides that must be explored so that travel agents and marketing bureaus do not hesitate to enter into agreements.

Communication and collaboration built by managers and travel and marketing bureaus are carried out to attract visitors. Sometimes packages are arranged which involve several tourist destinations in different locations. In addition to travel, establishing cooperation between managers of tourist destinations is also found in the management of Mount Kelud tourism, one of which is between the managers of the Orchid village and the Association at the Pineapple Village tourist site.

The pattern of communication and cooperation developed in the management of tourism in Orchid Village Kampung Anggrek occurred between managers and travel agencies and travel agents, local communities, and the government. Each stakeholder has a role but not all are able to cooperate actively. The government does not have direct interaction with tourism management. All the explanations from informants on the patterns of communication and cooperation that have been built in ecotourism management show that the collaboration created is limited to certain parties. The government does not have active and direct cooperation in tourism management. This is an important consideration to improve in managing creative ecotourism in Kediri. Various obstacles and challenges need to be overcome by tourism actors in the Mount Merapi and Mount Kelud Tourism Areas, including: (1) An

unwillingness to be open with each other and each management commitment; (2) An unwillingness to to obey rules made together; (3) The high number of regulations imposed by the Department of Tourism; (4) Lack of ability and competence of tour guides in developing tourism sector so there is a need for continuous training for tour guides; (5) Tourism activities were hampered during the pandemic and are currently only in the recovery stage; (6) Lack of capital to develop innovative tourism destinations; (7) The development of tourism infrastructure is still not optimal, especially road and tourist attractions; (8) High costs for recovery from the pandemic, it's need for government assistance for the tourism sector is organized independently or privately; (9) Tourism promotion and publication needs to be carried out massively using either mass media or social media. This must be seriously examined by policymakers, because relying on viral broadcasts to the public is not effective; (10) The need for high commitment from key stakeholders as policymakers in tourism development. The government is considered to be lacking in providing support to revive tourism management, especially those managed independently by the private sector. Apart from capital, the lack of promotion and strategy makes Kediri a less attractive destination to tourists from outside Kediri; (11) It is necessary to increase community participation to be aware of tourism.

Community motivation towards ecotourism will increase if they have the opportunity to participate in ecotourism management, and to do so, they need to improve their ecotourism management skills (Bagus et al. 2023).To ensure the sustainability of ecotourism activities at both the local and national levels, a participatory approach is needed by creating a balance between the expectations of local communities and the income generated from ecotourism, by providing central authority, and by making improvements to infrastructure (Ayadin and Öztürk 2023) ; (12) Social capital needs to be maintained for the success of tourism. This is found in the Mount Merapi Tourism Area. The existence of social capital, such as mutual trust, holding commitments, and obeying rules among the tourism operators has contributed to extensive development of tourism in the Merapi Area develop. This is very evident in Ledok Sambi, where there has been rapid tourism development, which has in part been due to the support of the social capital of the local community. A lack of capital is the main obstacle for rebuilding or improving shops or street vendor stalls around tourist sites. Not only street vendors, but many tour business owners are finding it difficult to get back on their feet, due to high operational costs. This capital, of course, must be sought to provide fresh air to business actors so that they do not survive alone. The strategies undertaken in the tourism industry to survive during the pandemic range from independent travel arrangements, minimizing hotel costs, lowering hotel room prices, exploiting cultural potential, inclusive infrastructure development, and other alternative livelihoods to survive during times of crisis; (13) It is necessary to establish cooperation with local representatives or public figures who have a big influence in moving the audience.

Conclusion

Some conclusions about collaborative tourism development explained that collaboration has been carried out by tourism actors in several ways, but the creative side is still very limited. The local community has a very decisive role in tourism development, both in tourism to the Mount Merapi and Mount Kelud areas which already involve the participation of the local community. However, the role of the local community is minimal in terms of planning, monitoring, and evaluation. Community participation is still at the technical level. Whereas for certain tourist operators we identified, it was found that the intense involvement of the community in the implementation of tourism greatly determines the sustainability of tourism, because it creates a sense of collective ownership. The main obstacles experienced by business actors and the surrounding community in rebuilding ecotourism during the pandemic were lack of capital and government support while the challenges faced are the promotion strategy and commitment of tourism actors. Tourism is still focused on material capital, not yet utilizing social capital which has great potential in tourism development. Social capital such as good local values, solidarity, commitment, and thinking about the public interest need to be developed. Community participation is very high in community tourism, but there needs to be more with the private sector to reach a more effective collaboration.

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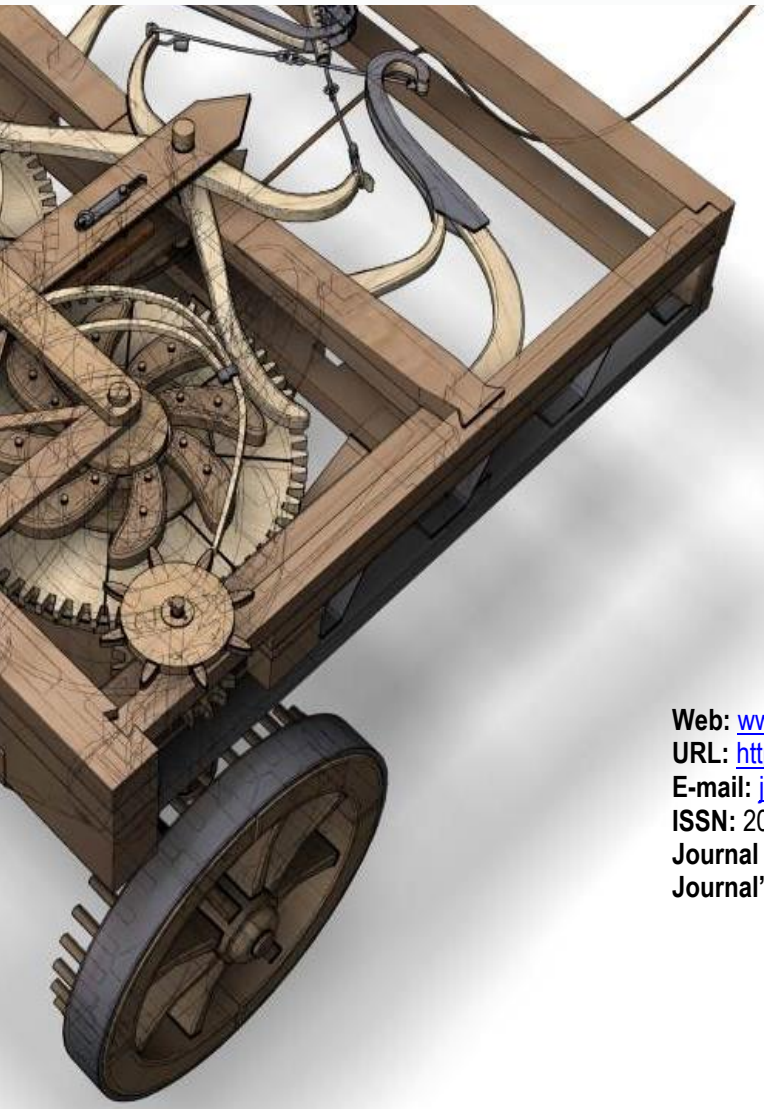

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