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2024

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Abstract

This research investigates the multifaceted relationship between tourism, economic growth, and carbon emissions in Madagascar. Regression analyses were conducted to examine the impact of tourism receipts on economic growth and tourist arrivals on CO2 levels. The results indicate a significant positive association between tourism and economic growth, highlighting the sector's pivotal role in driving Madagascar's economy. Conversely, tourist arrivals were found to contribute to increased carbon emissions, emphasizing the need for sustainable tourism practices to mitigate environmental impacts. Additionally, recommendations are provided for enhancing road infrastructure, promoting ecotourism, diversifying touristic offerings, digitizing tourism services, promoting environmental sustainability, investing in continuous training for tourism personnel, and fostering public-private partnerships to stimulate further development in Madagascar's tourism sector.

Keywords: Tourism, Economic Growth, Environmental Sustainability, Econometrics, Carbon Emissions, Madagascar, Regression Analysis, Sustainable Development, Public-Private Partnerships, Diversification, Ecotourism.

DISCLAIMER: *The opinions expressed by the authors in this work are their own and do not represent the views or opinions of the organisation.*

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1 Introduction

Tourism is one of the world's major industries, and people have been traveling for pleasure since the dawn of time. It has become one of the fastest-expanding sectors of the global economy in recent years. Tourism arose as a result of modernization and contributed significantly to shaping the experience of modernity. Economic growth and tourism development are intertwined, according to previous literature; therefore, an increase in the general economy will support tourism development [16]. As a result, it's critical to investigate how tourism and other factors (including macroeconomics) are linked to economic growth. The United Nations World Tourism Organization (UNWTO) [51] asserts that tourism stands as a pivotal industry significantly contributing to socio-economic development. It functions as a strategic determinant, a catalyst for economic expansion, and a potent instrument for national development. Notably, this sector stimulates employment creation, foreign exchange accrual, investment augmentation, and revenue enhancement. In 2019, its impact was substantial, contributing over 9.1 billion dollars to the global Gross Domestic Product (GDP) and exceeding 194.2 million dollars for the African economy. According to the findings of the Spanish consulting firm "Bloom Consulting," Madagascar currently ranks as the 9th African nation in terms of tourist attractions. Recent data from the Ministry of Tourism

reveals that the cumulative number of tourists, encompassing Malagasy nationals, recorded for Madagascar in 2022 reached 132,018. This statistical representation is derived from visa issuances and the quantification of tourists arriving at the airport. A noteworthy observation is the predominant presence of French tourists, constituting approximately 41 percent of the total. Moreover, for the initial months of 2023 (January and February), Madagascar recorded around 20,000 tourist arrivals, with projections estimating this figure to escalate to 300,000 if the prevailing pace of recovery persists.

Beyond mere visitor statistics, the economic ramifications of tourism are profound. The sector has been a significant source of employment, creating 641,500 jobs and contributing to 13 percent of the national GDP. In 2020, the monetary contribution amounted to 176.85 euros, equating to 1.4 percent of the GDP and representing 4 percent of all international tourism receipts in East Africa.

In contrast to other sectors, tourism uniquely serves as a conduit for foreign exchange, injecting 748 million dollars into the Malagasy GDP. The implementation of judicious public policies within the tourism domain is posited to play a pivotal role in realizing the objective of inclusive growth. According to the Organization for Economic Co-operation and Development (OECD), a well-crafted tourism policy should ensure that economic growth is equitably distributed within society, thereby enhancing the overall well-being of the populace.

Furthermore, tourism's contribution to inclusive growth is underscored by its role in employment generation and the eradication of discriminatory practices. Presently, there exists a notable lack of awareness regarding the nuanced distinction between economic growth and inclusive growth. Economic growth is predicated on the evolution of real GDP, whereas inclusive growth revolves around GDP per capita. The latter encapsulates individuals irrespective of their economic strata, be they affluent or underprivileged, and transcends geographic distinctions, extending opportunities uniformly to urban and rural dwellers alike. This inclusivity, in turn, seeks to promote equality and alleviate poverty within the local population.

The primary objective of this study is to elucidate the multifaceted contribution of tourism to the economic growth paradigm of Madagascar.

2 Literature Review

2.1 Theoretical Approach

The interplay between tourism and the economy has captured the attention of numerous scholars, motivating them to analyze the connections between these two variables. Tourism stands as a key sector for economic growth in many countries, particularly in developing nations. Despite becoming one of the world's most significant activities, many developing countries have not fully harnessed its potential. Therefore, it is imperative to scrutinize the relationship between tourism and economic growth. Consequently, most theoretical models examining the causality between non-commercial goods (such as tourism) and economic growth are relatively recent.

Some asserts that economic growth linked to tourism occurs when tourism stimulates the overall economy through spillover effects and other externalities. However, Brida et al. (2008) demonstrate that the development of tourism in a country can stimulate investment in new infrastructure, create economies of scale, and facilitate the dissemination of technical knowledge.[33]

Others posit that tourist expenditures on accommodation, catering, transportation, leisure, and services lead to substantial production of goods and services and job creation.[5]

the links between tourism and sectors such as agriculture, transportation, retail trade, and construction strengthen the local multiplier effect resulting from tourist demand [1]. To accelerate economic development, it is essential for robust and optimized links between economic sectors. Consequently, the potential of tourism to contribute significantly to economic development lies in intelligent cooperation between economic sectors. With a significant diversification of the economy, such cooperation could promote export growth, valorize new offerings that attract tourists to even the most remote areas of the country, stimulate the development of small businesses, and more. Simultaneously, the development of tourism in a country can stimulate investment in new infrastructure, create economies of scale, and facilitate the dissemination of technical knowledge [12].

Another authors [41]argues that the tourism sector contributes to economic growth by creating employment. However, it is crucial to note that the tourism sector is highly sensitive to price and income elasticity

[29]. Countries with highly unstable currencies often experience high inflation rates, significantly impacting tourism activity.

In their article titled "Tourism and Inclusive Growth: A Sustainable Development Goal?" [21], the authors emphasize that while tourism can contribute to economic growth, it can also exacerbate economic and social inequalities. The authors propose several measures to ensure that tourism contributes to inclusive growth, including policies that promote local employment, training, skill development, and the establishment of tourist businesses by local communities.

In another article titled "Tourism and Inclusive Growth: The Role of Small and Medium-sized Enterprises" [40], the authors highlight the potential of small and medium-sized tourist enterprises to contribute to inclusive growth. The authors recommend policies that support local entrepreneurship and SMEs, including funding and training programs.

In a case study on community tourism in Peru,some [?] found that tourism can contribute to inclusive growth by creating jobs for local communities, improving access to basic services such as water and electricity, and preserving local culture and the environment. However, the authors emphasize that the success of community tourism depends on the commitment of local communities and active participation of stakeholders.

In their study titled "Tourism and Inclusive Growth in Small Island Developing States" [28], the authors examined the role of tourism in small island developing states. The authors highlight that tourism can contribute to inclusive growth by creating jobs for local populations and stimulating the local economy. However, they also note that tourism can have negative effects, such as pressure on natural resources and rising real estate prices, which can worsen economic and social inequalities.

Tourism can have negative effects on inclusive growth in Madagascar, as in other countries. Here are some examples of potential negative effects:

Firstly, tourism can contribute to economic inequalities if the created jobs are concentrated in certain regions or primarily benefit foreign companies rather than local businesses. This can lead to economic polarization and marginalization of local communities.

Additionally, the tourism sector can lead to increased pressure on natural resources, such as land, water, and ecosystems. If not managed properly, this can have negative effects on local communities, which may be deprived of access to resources essential for their livelihoods.

Tourism can also contribute to the erosion of local culture if tourist practices do not respect the traditions and cultural norms of local communities. This can also result in a loss of cultural and historical heritage.

Finally, the sector can lead to an increase in prices of local goods and services, making life more difficult for low-income individuals.

However, it is important to note that these negative effects are not inevitable. If tourism is managed responsibly and equitably, it can contribute to inclusive growth by creating jobs for local populations and stimulating the local economy. Therefore, it is crucial to implement policies that ensure the economic benefits of tourism benefit local communities and that tourist practices respect the environment and local culture.

2.2 Empirical Approach

The relationship between tourism development and growth has intrigued several authors and resulted in numerous studies across different countries worldwide.

Authors [23]concluded that there is indeed a bidirectional causality relationship between tourism and the growth of Benin. Using chronological data from 1990 to 2020, Foster found a positive impact of tourism on long-term economic growth, with a growth rate of 1.93 percent when tourism increases by 1 percent. The results also indicate that the expansion of the tourism sector correlates with increased activities in other sectors of the economy, particularly stimulating agricultural sectors.

Another study empirically examined the link between Senegalese tourism and economic growth. According to their estimation, a 1 percent increase in tourist receipts would lead to a 0.71 percent increase in per capita GDP. They also revealed a positive relationship between tourism and the development of economic sectors such as agriculture and industry.[6]

In an evaluation of the impact of the tourism sector on Mauritius from 1952-1992 using Johansen's cointegration method and Granger causality tests, [15]demonstrated that tourism has favored Mauritian economic growth.

Kim [31] demonstrated the existence of a long-term equilibrium relationship and bidirectional causality between Taiwanese tourism and economic development.

Authors [5] used Johansen and Juselius' cointegration method on quarterly data from 1975 to 1997 and proved the existence of a stable long-term relationship between tourist receipts and Spanish economic growth.

Dupont conducted a study titled "The Relationship between Tourism, Growth, and Inclusive Development in Luxury Small Island Destinations: The Example of Anguilla in the Caribbean." Using annual data from 1985-2012 and employing vector error correction model (VECM), the results indicate that a 1 percent increase in tourist revenue in Anguilla leads to a long-term increase of 0.6 percent in its GDP. Granger causality tests reveal a bidirectional causality between tourist activity and economic growth. The study also indicates that the growth of the tourism sector coincides with a contraction in agricultural activity in Anguilla, resulting in a loss of resources for the country.[17]

For the case of Senegal, [6] some authors used data from 2007-2018 and applied VECM. The results show that a 1 percent increase in tourist receipts leads to a 0.71 percent increase in per capita GDP, and Granger causality tests prove a unidirectional link between these two indicators. The study's results also demonstrate that the growth of Senegalese tourism positively contributes to the development of the agriculture and industry sectors.

Avegnon [4] conducted a study on the causality relationship between tourism and economic growth in Togo using data from 1981 to 2015. The VAR model was applied, and the result shows a unidirectional relationship between tourism measured by tourist receipts and economic growth. The study also reveals that tourism development reinforces the effect of agricultural development on economic growth.

An analysis of the long-term empirical relationship between economic growth and international tourism was conducted by [5]. Using Johansen's cointegration method on quarterly data from Spain between 1975 and 1997, these authors found a stable long-term relationship between tourist receipts and economic growth. Furthermore, they showed that external competitiveness (measured by the real effective exchange rate) is a fundamental variable for Spanish economic growth in the long term.

Using cointegration and causality techniques, [11] authors analyzed the hypothesis of tourism-led growth for Morocco and Tunisia for the period from 1980 to 2010. The results obtained highlighted a short-term unidirectional causality of tourist receipts toward GDP growth in the Moroccan and Tunisian economies. However, it was observed that this long-term causality is not significant at the 5 percent threshold. Similarly, they demonstrated that the hypothesis of export-led growth is more suitable for the two studied economies, given the reverse causality link from growth to tourism.

These empirical studies provide valuable insights into the complex relationship between tourism and economic growth, showcasing both positive and negative effects, and emphasizing the importance of considering specific country contexts in understanding this intricate interaction.

2.3 tourism and CO2

The literature review conducted by [38] in the International Journal of Contemporary Hospitality Management explores the relationship between CO_2 emissions and the tourism industry from 2007 to 2021. The studies consistently reveal a significant link between climate change and tourism, emphasizing the vulnerability of the industry to the adverse impacts of rising CO_2 emissions. Carbon emissions from transportation and accommodation activities emerge as key factors affecting the global climate and contributing to environmental concerns such as air pollution, deforestation, and ecosystem disturbances. The literature underscores the urgent need for reducing CO_2 emissions within the tourism sector, highlighting the critical role of emission reduction strategies in mitigating climate change effects and ensuring the long-term sustainability of the industry. Policymakers and stakeholders are urged to take proactive measures, emphasizing the importance of developing and implementing comprehensive strategies and initiatives to promote sustainable practices in tourism. This review not only consolidates existing knowledge but also provides a foundation for future research and policy interventions to address the environmental challenges associated with tourism-related activities.

3 Tourism Landscape of Madagascar

Tourism in Madagascar is experiencing significant growth, driven by a burgeoning interest in marine tourism. This sector has become a focal point for both domestic and international visitors, with a particular

emphasis on coastal regions. A detailed survey conducted in 2012 shed light on the fact that 63% of tourists in Madagascar actively participate in coastal activities, primarily concentrated in key regions such as Nosy Be, Antsiranana, Sainte Marie, and Toliara [56].

This surge in tourism not only contributes to the economic landscape of Madagascar but also aligns with global trends reflecting an increased attraction towards marine experiences. The intricate dynamics of Madagascar's tourism industry call for a nuanced understanding of the challenges and opportunities inherent in this sector.

3.1 Challenges in Sustainable Marine Tourism

While Madagascar's tourism sector flourishes, there are formidable challenges that must be addressed to ensure the long-term sustainability of marine tourism. The allure of the country's coastal areas, as highlighted by the 2012 visitor survey [56], necessitates vigilant management of environmental factors to preserve the appeal that draws tourists.

A primary concern is the reliance of the tourism sector on the health of oceans and the cleanliness of beaches. The impact of marine pollution, including marine debris, poses a significant threat to the pristine nature of Madagascar's coastal regions. Effective water quality management is crucial to maintaining the allure of these areas for tourists.

Furthermore, the tourism sector is susceptible to the far-reaching impacts of climate change, which poses a direct threat to the sustainability of Madagascar's tourism industry. Managing these environmental challenges requires a strategic approach that balances the economic benefits of tourism with the imperative to preserve the natural beauty that attracts visitors in the first place.

3.2 Analysis of Underperformance and Comparative Trends

Despite the growing interest in Madagascar's tourism, the sector exhibits a notable underperformance when compared to neighboring countries and global tourism trends. An analysis spanning the period from 2010 to the pre-COVID peak of 2019 reveals a modest increase in international tourism arrivals, from 196,000 to 376,000. In contrast, other sub-Saharan African nations experienced more substantial growth during the same timeframe.

For instance, Mauritius, Mozambique, Tanzania, and South Africa demonstrated considerably higher increases in international tourism arrivals, indicating a relative lag in Madagascar's tourism sector [51]. This underperformance is a critical aspect that warrants exploration and understanding.

The discrepancy in tourism revenue further underscores Madagascar's challenges. While sub-Saharan Africa witnessed an increase in international tourism receipts from nearly USD 21 billion to nearly USD 27 billion, Madagascar's revenue increased from USD 309 million in 2010 to USD 747 million in 2019 [51].

3.3 Economic Impacts and the Influence of COVID-19

The COVID-19 pandemic emerged as a significant disruptor to the global tourism landscape, profoundly impacting Madagascar's tourism sector. The economic ramifications of the pandemic were substantial, pushing Madagascar's tourism into a recession in 2020. This economic downturn had ripple effects, pushing an additional 1.4 million people into poverty in a country already grappling with an 81% poverty rate in 2021.

As the pandemic unfolded, international tourism arrivals for sub-Saharan Africa plummeted sharply to 12.9 million in 2020 and 12.7 million in 2021, before showing signs of a partial recovery with 25.8 million arrivals in 2022 [51]. Madagascar, however, experienced a stark contrast, with arrivals for 2021 plunging by 92% below those of 2019 [52] .

The economic repercussions extended to tourism receipts, with Madagascar's earnings dwindling to USD 145 million in 2020 and USD 93 million in 2021. These figures underscore the vulnerability of Madagascar's tourism sector to external shocks and highlight the imperative of crafting resilient strategies to mitigate such impacts.

3.4 Contributing Factors to Weak Tourism Outcomes

Madagascar's tourism sector has grappled with several structural and contextual challenges that have contributed to its underperformance. A myriad of factors, including historical economic and political instability, insufficient infrastructure, limitations in air transport

access, and governance issues, have collectively hindered the sector's growth.

The consequences of these challenges are stark, resulting in tens of thousands of missing jobs and billions of USD in lost revenues. Past economic and political instability, in particular, has cast a shadow on Madagascar's ability to attract and sustain a robust tourism industry. The lack of adequate road and other infrastructure, coupled with issues related to air transport access and governance, further compounds these challenges.

3.5 Economic Impacts of Biodiversity Protection in Madagascar

The 2022 economic study, "The Economic Contribution of Madagascar's Protected Areas - a Review of the Evidence," illuminates the concerning financial landscape of biodiversity protection in the country. The study underscores the inefficiency and inequitable distribution of benefits derived from protected areas. Disturbingly, it reveals that actual government expenditures on biodiversity protection between 2014-2018 were a mere 12%-20% of the allocated budgeted amounts [20].

3.5.1 National Park Visitor Trends and Local Community Support

Table 1 provides a snapshot of national park visitor numbers from 2020 to 2022, with a noteworthy revelation that the majority of park visitors in 2021 were Malagasy (MNP, pers. comm., 2023). A pre-COVID analysis in 2019 indicates that the 15 most visited national parks reported over 227,000 visitors, with Nosy Tanikely and Isalo leading in visitation. The study emphasizes the critical role of local community support for the viability of protected areas, stressing the need for sincere political commitment at all levels in Madagascar [20].

Source: Madagascar National Parks, pers. comm., June 2023

3.5.2 Impact of Political Factors on Visitor Numbers

A recent study [2] further contribute insights into the period from 1992 to 2021, highlighting that the top 10 most visited Protected Areas (PAs) accounted for a substantial percentage of entry tickets sold and sales over specific periods. Political insecurity and remoteness emerge as significant factors influencing visitation in PAs, although the study notes that remoteness, in terms of road degradation, poses a more substantial challenge than geographical distance.

3.5.3 Community Development Initiatives despite Low Revenues

Despite the low revenues from national park entry fees, Madagascar National Parks (MNP) has undertaken commendable initiatives to enhance the livelihoods of communities residing near the parks. Ongoing projects, such as the construction of schools and health facilities, and the development of agricultural programs, aim to provide viable alternatives for villagers to sustain their livelihoods outside protected areas. This showcases a proactive approach to community development, mitigating dependence on resources within the protected areas [2].

3.6 Recent Surge in Tourism in 2023

The tourism sector in Madagascar experienced remarkable growth in 2023, marked by a record number of 259,850 international tourists visiting the island. This represents an impressive increase of over 97% compared to the previous year. The Ministry of Tourism and Handicrafts emphasizes that, despite this exceptional growth, the overall statistics for 2023 align with those of 2019, with only a slight decrease of 15%. Notably, the top 10 nationalities visiting Madagascar show minimal changes from 2022, except for China entering the ranking and replacing the Czech Republic. Ministerial data also reveals a significant increase in tourism in December 2023, with 30,718 international visitors, surpassing even the figures recorded in December 2019, a landmark year for Malagasy tourism with 252,292 tourists.

In terms of revenue, Madagascar recorded an impressive figure of 534 million euros in foreign exchange for the year 2023, nearly double the previous year. This substantial increase in revenue attests to the growing appeal of Madagascar as a tourist destination[35].

4 Data and methodology

In this study, we employ a two-model approach to comprehensively examine the multifaceted effects of

Table 1: National park visitor numbers (2020 - 2022)

National Park	Number of Visitors 2020	Number of Visitors 2021	Number of Visitors 2022
Analamerana	0	0	0
Andranomena	2	0	0
Marolambo	0	14	26
Zahamena	31	3	23
Sahamalaza	4	8	33
Mananara Nord	0	59	59
Beza Mahafaly	3	15	48
Andohahela	58	53	100
Baie de Baly/Namoroka	30	13	142
Manombo	0	107	143
Ambohitantely	9	64	153
Kirindy Mite	135	172	582
Cap St Marie	102	377	683
Nosy Hara	264	177	1,144
Tswimanampes	283	525	1,153
Marojejy	352	285	1,323
Andringitra	237	266	1,368
Zombitse V.	362	124	1,963
Masoala	480	533	2,548
Ankarafantsika	436	963	3,021
Lokobe	1,947	4,419	5,540
Ankarana	495	562	5,233
Montagne D'Ambre	1,751	989	6,802
Bemaraha	361	1,319	8,910
Ranomafana	2,289	3,012	11,837
Andasibe/Analamazaotra	455	3,637	13,535
Mantadia	3,348	377	2,691
Isalo	4,071	6,147	18,424
Nosy Tanikely	7,646	6,671	27,973
Total	25,151	30,891	115,457

tourism on both economic prosperity and environmental sustainability. Our primary focus lies in understanding the impact of tourism on GDP per capita, capturing the inclusive influence of tourism receipts, and simultaneously assessing the repercussions of tourist arrivals on CO2 emissions.

4.1 Data

The dataset under scrutiny in this scholarly investigation is sourced from esteemed institutions, notably the World Bank, a venerable repository acknowledged for its unwavering commitment to delivering authoritative and comprehensive economic data. The meticulous selection of data sources underscores the commitment to ensuring the integrity and reliability of the variables scrutinized, specifically Real Gross Domestic Product per capita (GDPP),Real Gross domestic product (GDP), exchange rates (CHANGE), inflation rates (INFLATION),Tourists arrival (AR) Carbon emissions (CO2) and International Tourism Receipts (RTOUR) (see Table 2). The World Bank's distinguished standing as a preeminent institution in the field of economic data establishes a robust foundation for our analytical endeavors.

The temporal ambit of our investigation spans from 1995 to 2021. This judiciously chosen and expansive timeframe serves the purpose of facilitating a thorough exploration of the intricate relationships among GDPP, exchange rates, inflation rates, and Interna-

tional Tourism Receipts. This comprehensive temporal scope enables our analysis to capture enduring trends and dynamic shifts within the socio-economic fabric of the nations under examination.

4.2 Variables Selection:

In this section, we provide an overview of the variables selected for our analysis and their significance. Table 3 presents a comprehensive description and justification of these variables.

4.3 Literature Connection

The literature reviewed unveils a rich tapestry of theoretical and empirical insights into the complex interplay between tourism, inflation, exchange rates, and GDP per capita. Understanding the connections between these variables is crucial for comprehending the multifaceted dynamics of economic growth, particularly in the context of developing nations.

Tourism and Economic Growth:

The empirical studies by [23], [6], and [15] provide compelling evidence of a positive relationship between tourism and economic growth. The variable "tourism receipts" in the equation finds resonance in these findings, suggesting that an upsurge in tourism activities positively impacts GDP per capita by stimulating economic growth, creating jobs, and fostering sectoral linkages.

Inflation's Impact on Tourism:

The literature underscores the vulnerability of the tourism sector to price and income elasticity, particularly in countries with highly unstable currencies [41]. This aligns with the "inflation" component in the equation, indicating that fluctuations in inflation rates can significantly influence the performance of the tourism sector and, consequently, its contribution to GDP per capita.

Exchange Rates and Economic Dynamics:

The role of exchange rates in shaping the tourism landscape is briefly touched upon, emphasizing the challenges faced by countries with volatile currencies [41]. This aligns with the "exchange rate" component in the equation, highlighting that currency fluctuations can impact the economic contribution of tourism to GDP per capita.

Inclusive Growth Considerations:

Theoretical discussions by [21] and empirical studies like those by [28] shed light on the nuanced aspect of inclusive growth within the tourism sector. Understanding the potential negative effects, such as economic inequalities, pressure on natural resources, and cultural erosion, becomes integral when evaluating the holistic impact of tourism on GDP per capita.

In summary, this literature connection establishes a comprehensive foundation for the equation examining the impact of tourism receipts, inflation, and exchange rates on GDP per capita. The synthesis of theoretical perspectives and empirical evidence provides a nuanced understanding of the intricate relationships between these variables, emphasizing the need for responsible management and tailored policies to harness the full potential of tourism for economic growth.

4.4 Estimation of impact of tourism on growth

In this study, we employ a linear regression model to investigate the correlation between the growth rate of Gross Domestic Product (ΔLGDPP_t) and various independent variables. The model is expressed as follows:

$$
\begin{aligned}
\Delta \text{LGDPP}_t = \beta_0 &+ \beta_1 \Delta \text{LRT}_t \\
&+ \beta_2 \Delta \text{LER}_t + \beta_3 \Delta \text{INF}_t \\
&+ \beta_4 C + \varepsilon_t
\end{aligned} \tag{1}
$$

where:

- ΔLRT_t represents the change in tourism-related variables,

- ΔLER_t denotes the change in other relevant economic indicators,

- ΔINF_t signifies the change in inflation rates,

- C represents a constant term,

- ε_t is the error term.

This model enables us to assess the impact of these independent variables on the growth rate of Gross Domestic Product, allowing for a comprehensive understanding of the economic dynamics under consideration. The coefficients $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4$ are estimated parameters that quantify the magnitude and direction

Table 2: Data sources and definition of variables.

Variables	Definition	Source
GDPP	Real Gross Domestic Product per capita	World bank https://data.worldbank.org/
GDP	Real Gross Domestic Product	World bank https://data.worldbank.org/
CO2	Carbon Dioxide Emissions	World bank https://data.worldbank.org/
ER	Exchange rate	World bank https://data.worldbank.org/
INF	Inflation	World bank https://data.worldbank.org/
RT	International Tourism Receipts	World bank https://data.worldbank.org/
AR	Arrival of Tourism	World bank https://data.worldbank.org/

Table 3: Description and Justification of Variables

Variable	Description
Dependent Variables	
GDP per capita	GDP per capita measures the average economic output per individual in a country, serving as a key indicator of economic well-being.
CO2 emission	CO2 emission represents the change in carbon emissions over time, indicating the environmental impact of economic activities.
Independent Variables	
Tourism Receipt	Tourism Receipt reflects the revenue generated from international tourism activities, contributing to a country's economic growth.
Arrival of tourists	Arrival of tourists quantifies the percentage change in the number of tourists visiting a country between consecutive periods, providing insights into tourism trends.
Exchange Rate	Exchange Rate indicates the value of a country's currency relative to another currency, influencing international trade and economic competitiveness.
Inflation	Inflation measures the rate at which the general level of prices for goods and services is rising, affecting consumer purchasing power and economic stability.
GDP	GDP captures the percentage change in the total value of goods and services produced within a country's borders between successive periods, reflecting economic growth or contraction.

of the influence of each respective variable on the dependent variable ΔLGDPP_t. The inclusion of the error term ε_t accounts for unobserved factors and measurement errors, ensuring the robustness of our analysis.

4.5 Assessment of Carbon Dioxide Emissions from Tourism

The assessment of carbon dioxide emissions from tourism is crucial for understanding its environmental

impact. In this section, we employ a regression analysis to quantify the factors influencing the change in carbon emissions (ΔCO_2) attributable to tourism activities.

- **ΔCO_2** This variable represents the change in carbon emissions. It is modeled as follows:

$$\Delta CO_2^i = \beta_0 + \beta_1 \Delta LAR^i + \beta_2 \Delta LGDP^i + u^i$$

In this regression analysis, the model incorporates the following variables:

- ΔLAR^i: Change in tourist arrivals for destination i.

- $\Delta LGDP^i$: Change in gross domestic product (GDP) for destination i.

- u^i: Error term capturing unobserved factors influencing carbon emissions for destination i.

These variables allow us to assess how changes in tourist arrivals and economic activity impact carbon emissions from tourism, providing valuable insights for sustainable tourism management and environmental policy formulation.

4.6 Data Transformation

In preparation for rigorous analysis, a series of meticulous data preprocessing steps were applied to the variables under investigation. To address issues of variance and potentially linearize relationships, a judicious logarithmic transformation was implemented on key variables, namely GDPP, ER, INF, and RT. This transformation yielded log-transformed variables, denoted as LGDPP, LER, LINF, and LRT. Subsequently, first differences were computed for these log-transformed variables, resulting in the creation of $\Delta LGDPP$, ΔLER, $\Delta LINF$, and ΔLRT. This transformative approach not only assists in mitigating trends but also ensures the stationarity of the series—a critical prerequisite for robust time series analysis.

5 Results

5.1 Regression Analysis: Impact of Tourism on Economic Growth

Interpretation of Coefficients:
Table 4 presents the coefficients and statistical measures for the regression analysis.

- **ΔLRT:** A one-unit increase in the logarithm of tourism is associated with a significant 0.1399 unit increase in the logarithm of GDP ($p < 0.01$).

- **ΔLER:** A one-unit increase in the logarithm of change is correlated with a substantial -1.1113 unit decrease in the logarithm of GDP ($p < 0.01$).

- **INF:** The coefficient for inflation (INF) is 0.0047, indicating a positive relationship with GDP. However, it is statistically insignificant at the 5% level ($p = 0.0606$).

- **C:** The constant term (C) representing the intercept is not statistically significant ($p = 0.2213$).

Model Fit and Additional Statistics

The regression model exhibits strong explanatory power, explaining approximately 88.3% of the variability in GDP, with an adjusted R-squared of 86.6%. The standard error of regression is 0.0495, indicating the model's accuracy in predicting GDP based on the independent variables.

The F-statistic of 52.8259 (p-value < 0.001) confirms the overall significance of the model, suggesting that at least one independent variable has a significant effect on GDP.

The Durbin-Watson statistic is 2.1138, indicating no significant autocorrelation in the residuals.

These statistics collectively affirm the reliability and significance of the regression results, providing confidence in the relationship between the independent variables and GDP.

5.2 Results for Tourism and CO2

Coefficient Interpretation:

Refer to Table 5 for details.

- **ΔLAR (0.164105):** A one-unit increase in the logarithm of tourist arrivals (ΔLAR) is statistically associated with a significant 0.1641 unit increase in CO2 levels (t-Statistic = 4.180673, Prob. = 0.0004).

- **$\Delta LGDP$ (0.023792):** The coefficient for the logarithm of GDP growth ($\Delta LGDP$) is not statistically significant, indicating that changes in economic growth do not have a notable impact on CO2 levels (t-Statistic = 0.162556, Prob. = 0.8724).

Table 4: Regression Results: Impact of Tourism Receipts (RT) on Economic Growth (Endogenous)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ΔLRT	0.1399	0.0275	5.0843	0.0000
ΔLER	-1.1113	0.0916	-12.1273	0.0000
INF	0.0047	0.0024	1.9829	0.0606
C	0.0303	0.0240	1.2605	0.2213

Table 5: Estimation Results: Impact of Tourist Arrivals (AR) on CO2 (Endogenous)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ΔLAR	0.164105	0.039253	4.180673	0.0004
ΔLPIB	0.023792	0.146364	0.162556	0.8724
C	0.002147	0.018317	0.117195	0.9078

⋆ **Constant (C - 0.002147):** The constant term, represented by C, is not statistically significant, suggesting it does not contribute significantly to the prediction of CO2 levels (t-Statistic = 0.117195, Prob. = 0.9078).

Model Fit and Significance:

The regression model for CO_2 levels demonstrates moderate explanatory power, explaining approximately 54% of the variability observed.

The F-statistic of 10.16900 (p-value < 0.001) confirms the overall significance of the model, indicating that the independent variables collectively have a significant effect on CO_2 levels.

The Durbin-Watson statistic, computed as 1.774651, suggests no significant autocorrelation in the residuals, reinforcing the reliability of the regression results.

6 Discussion

6.1 Tourism and Economic Growth in Madagascar

The regression analysis results provide insights into the complex relationship between tourism and economic growth in Madagascar. Specifically, the coefficients offer valuable information regarding the influence of tourism-related factors on the country's GDP dynamics.

The coefficient associated with tourism receipts (ΔLRT) demonstrates a statistically significant positive effect on GDP, highlighting the pivotal role of tourism in driving economic expansion. This finding suggests that an increase in tourism activity corresponds to a proportional rise in economic output, indicating the sector's potential to stimulate overall growth.

Conversely, the coefficient for the exchange rate (ΔLER) displays a negative association with GDP. The substantial magnitude of this coefficient suggests that fluctuations in exchange rates can significantly impact economic performance. While a stronger local currency may attract foreign investment, it may also hinder export competitiveness, thereby negatively affecting GDP.

Moreover, the coefficient for inflation (INF) exhibits a positive relationship with GDP, albeit statistically insignificant at conventional levels. This observation suggests that while inflation may exert some upward pressure on economic output, its influence is not robust enough to reach statistical significance in this context.

Additionally, the non-significant constant term (C) indicates that factors beyond those included in the model may contribute to GDP variation. While this term does not directly elucidate tourism's impact, it underscores the complexity of economic dynamics and the presence of other influential factors.

In the broader context, these findings align with existing literature[13][27] , highlighting the significance of tourism for economic development in Madagascar. The country's abundant natural and cultural assets make it an attractive destination for tourists, contributing to revenue generation and employment opportunities. However, challenges such as infrastructure

deficits and external shocks underscore the need for strategic policymaking and investment to fully leverage tourism's potential.

6.2 Impact of Tourist Arrivals on Carbon Emissions

The regression analysis provides insights into the relationship between tourist arrivals and carbon emissions in Madagascar.

The coefficient for ΔLAR indicates a significant positive association between tourist arrivals and CO_2 emissions. This suggests that an increase in tourist arrivals leads to a corresponding rise in carbon emissions.

On the other hand, the coefficient for ΔLGDP suggests that changes in economic growth, as measured by GDP growth, do not significantly impact CO_2 emissions.

Similarly, the constant term is not statistically significant, indicating that other factors not included in the model may influence carbon emissions.

Overall, the results highlight the role of tourist arrivals in driving carbon emissions in Madagascar, underscoring the need for sustainable tourism practices to mitigate environmental impacts.

6.3 Channels Through Which Tourism Influences Carbon Emissions

The escalation of tourist arrivals in Madagascar presents a complex milieu wherein the anthropogenic contribution to carbon dioxide (CO_2) emissions is distinctly influenced by several intrinsic factors inherent to the tourism sector. A scholarly analysis of these dynamics elucidates the intricate channels through which the burgeoning tourism industry contributes to elevated CO_2 emissions within the confines of this island nation.[38]

- **Transportation-Induced Emissions:** The augmentation of tourist numbers inherently begets a concomitant rise in the demand for ground transportation services. The utilization of fossil fuel-dependent vehicles for the facilitation of tours, transfers, and excursions emerges as a notable source of CO_2 emissions. The geographical peculiarities of Madagascar underscore the imperative reliance on such modes of transportation, thereby intensifying the carbon footprint associated with intra-country tourist mobility.

- **Energy Intensity in Accommodative Establishments:** Concurrent with heightened tourist influx, the establishment and expansion of accommodations engender a commensurate augmentation in energy consumption. Hotels and resorts, reliant on electricity for operations, climate control, and supplementary amenities, constitute a substantive source of carbon emissions. The pronounced surge in energy demand, occasioned by the burgeoning tourist population, accentuates the ecological ramifications attendant to the hospitality sector.

- **Impacts of Infrastructure Development:** The discernible growth in tourism precipitates the construction of ancillary infrastructure, including lodgings, dining establishments, and ancillary facilities. Construction processes, inherently energy-intensive, engender noteworthy carbon emissions. The nexus between tourism-driven infrastructure expansion and heightened CO_2 output is palpable, encapsulating a direct correlation between developmental exigencies and environmental repercussions.

- **Heightened Service Demand:** A direct corollary of escalating tourist numbers manifests in an elevated requisition for a spectrum of services, encompassing sustenance, potable water, and recreational pursuits. The provisioning of these services implicates activities that are predisposed to CO_2 emissions, from the vehicular conveyance of goods to the energy-intensive processes associated with culinary preparation. The cumulative effect of servicing an augmented demand nexus compounds the overall carbon footprint attendant to the tourism sector.

- **Environmental Impacts of Tourist Activities:** Tourism, as an industry, invariably encompasses activities and excursions, particularly those involving exploration of Madagascar's distinctive ecosystems. These pursuits, whether facilitated through guided tours or recreational endeavors, contribute to the CO_2 footprint through vehicular transportation to and within natural sites. The potential for habitat disturbance further underscores the intricate environmental ramifications inherent in these activities.

In summation, the burgeoning tourism industry in Madagascar significantly augments CO2 emissions through transportation-related exigencies, heightened energy consumption within accommodative establishments, the ecological toll of infrastructure development, intensified service demand, and the environmental implications intrinsic to tourist activities. A nuanced understanding of these multifaceted dynamics is imperative for the formulation of judicious strategies aimed at managing and mitigating the ecological repercussions of Madagascar's expanding tourism sector.

7 Recommendations

7.1 Enhancing Madagascar's Road Infrastructure

Madagascar, with its rich natural and cultural heritage, stands to benefit significantly from improvements in road infrastructure, particularly in promoting tourism. Therefore, the following recommendations focus on key routes to enhance accessibility, safety, and environmental sustainability.

Prioritizing Tourist Routes

One essential step is to identify and prioritize the maintenance and modernization of roads leading to popular tourist destinations. This includes ensuring that these routes are equipped with proper infrastructure to facilitate easy and secure access to attractions.

Southern Axis - National Road 7 (RN7)

The RN7 connects Antananarivo to Toliara, passing through attractions like Andringitra National Park. To optimize this route, establishing a regular maintenance program is crucial to ensure high-quality road surfaces. Additionally, improving signage for better navigation and safety, along with implementing enhanced safety measures, will safeguard tourists.

Eastern Axis - National Road 5 (RN5)

The RN5 links Antananarivo to Tamatave, featuring ecotourism sites like Zahamena National Park. Upgrading this route should include eco-friendly landscaping to enhance the travel experience and measures to preserve the unique biodiversity along the route.

Northern Route to Nosy Be

This route is crucial for beach tourism and marine biodiversity. Therefore, prioritizing maintenance to support coastal tourism growth and implementing eco-friendly practices to protect marine ecosystems are essential.

Southeastern Route to Fort Dauphin

Access to unique sites like Andohahela National Park relies on this route. Hence, intensive maintenance to improve accessibility and encourage ecotourism, along with collaboration with local communities for sustainable tourism practices, is recommended.

Route to Isalo National Park

This route is significant for adventure tourism due to unique rock formations. Enhancing signage and landscaping for a safer and visually appealing journey, as well as collaborating with local communities for responsible tourism practices, are key recommendations.

7.2 Promoting Ecotourism in Madagascar

Madagascar's unparalleled biodiversity and pristine natural landscapes present a remarkable opportunity for the development of ecotourism initiatives. To capitalize on this potential while ensuring the preservation of the island's unique ecosystems, several key strategies can be employed.

Firstly, it is essential to strategically develop ecotourism initiatives along existing routes, emphasizing low-impact practices such as nature-based activities, wildlife observation, and cultural experiences. Incorporating eco-friendly accommodations and transportation options can further minimize the environmental footprint associated with tourism activities.

Secondly, fostering partnerships with local communities is crucial. By engaging residents in decision-making processes and integrating their traditional knowledge, sustainable tourism practices that conserve natural resources and empower communities economically can be implemented effectively.

Moreover, educational programs and interpretive materials for tourists should be developed to raise awareness about the importance of conserving Madagascar's rich biodiversity. Promoting responsible behavior among visitors, including waste reduction, re-

spect for wildlife habitats, and support for local conservation efforts, is paramount.

Furthermore, identifying and designating ecotourism zones and trails within protected areas and national parks can help preserve fragile ecosystems. Strict regulations and monitoring mechanisms should be implemented to prevent habitat degradation and mitigate human-wildlife conflicts.

By prioritizing ecotourism development guided by principles of sustainability, conservation, and community participation, Madagascar can showcase its exceptional natural heritage to visitors while safeguarding its ecological integrity for future generations.

7.3 Diversification of Touristic Offerings

Diversifying the touristic offerings in Madagascar is crucial to attract a diverse range of visitors. This involves developing a multitude of attractions beyond the conventional sites, encompassing cultural richness, unique experiences, and natural treasures. A versatile approach would engage a broader audience and ensure a balanced distribution of visitors across the entire territory.

An excellent example of successful diversification can be observed in New Zealand. In addition to showcasing its spectacular landscapes, New Zealand highlights its distinct Maori culture. Visitors can partake in traditional ceremonies, explore Maori villages, and savor local cuisine. This diversification enabled New Zealand to attract travelers interested in a variety of experiences, contributing to a robust tourism industry.

Drawing inspiration from this example, Madagascar could enhance its tourism sector by showcasing its cultural diversity, organizing traditional festivals, promoting local gastronomy, and creating touristic routes that highlight diverse natural riches, from beaches to national parks and marine reserves. By adopting such an approach, Madagascar can stimulate the interest of different traveler segments, thereby increasing its overall appeal as a tourist destination.

7.4 Digitization of Tourism

Integrating digital technologies into Madagascar's tourism industry can significantly enhance visitor experiences, boost the destination's global visibility, and streamline internal operations.

Iceland provides an excellent example of successful digitization in the tourism sector. The country adopted mobile applications to guide visitors to less frequented destinations. These apps offer real-time information on weather conditions, alternative routes, and lesser-known attractions, encouraging a balanced distribution of tourist flows and preserving popular sites.

Drawing inspiration from Iceland's example, Madagascar could benefit from developing similar mobile applications offering detailed information on tourist attractions, local events, recommended routes, and even online booking features. Additionally, digital platforms can be utilized for targeted marketing campaigns, highlighting Madagascar's unique strengths. Digitization would not only increase visitor satisfaction but also attract a more connected clientele, positioning Madagascar as a modern and accessible tourist destination.

7.5 Environmental Sustainability

Promoting sustainable tourism practices in Madagascar is essential to preserve the country's ecological and cultural wealth while meeting the increasing expectations of environmentally conscious travelers.

Costa Rica serves as a successful model of sustainable tourism. The country has implemented strict regulations to minimize the environmental impact of tourism, emphasizing ecosystem conservation. This approach has attracted a steady flow of visitors seeking eco-friendly experiences.

Madagascar could benefit from adopting similar initiatives to promote environmental sustainability. Implementing strict regulations to limit waste, encouraging the use of renewable energy, and promoting biodiversity-friendly practices are crucial steps. Moreover, integrating visitor awareness of local environmental issues into marketing campaigns can attract an audience committed to preserving nature and local cultures. These efforts would contribute to the long-term preservation of Madagascar's tourist attractions.

7.6 Continuous Training

Investing in the continuous training of Madagascar's tourism sector personnel is essential to ensure high-quality service, enhance visitor hospitality, and maintain high professional standards.

Switzerland, renowned for its tourism industry, serves as an exemplary model in prioritizing hospi-

tality training. Sector professionals undergo thorough training programs, which emphasize essential aspects such as customer service, language proficiency, and cultural sensitivity. These initiatives contribute significantly to providing an exceptional tourist experience.

Madagascar could benefit from developing similar specialized training programs for its tourism sector employees. These programs should focus on cultivating warm hospitality, understanding diverse visitor needs, and effectively managing delicate situations. Continuous training efforts could also include sessions on cultural preservation, environmental awareness, and industry trends. Collaborations with educational institutions and international experts can further enhance the effectiveness of these programs, ultimately elevating service standards, improving visitor satisfaction, and fostering positive word-of-mouth.

7.7 Public-Private Partnerships

Establishing robust partnerships between the public and private sectors is a crucial imperative to inject new dynamism into Madagascar's tourism industry. These strategic alliances have the potential to catalyze substantial investments in touristic infrastructure, leading to significant improvements in services, accessibility, and, consequently, the overall visitor experience.

A relevant recommendation for Madagascar would be to encourage private investments through attractive tax incentives, streamlined authorizations, and the creation of a favorable environment conducive to the development of tourism businesses. Successful collaboration between the government and the private sector could strategically focus on large-scale projects, such as expanding hotel infrastructure, establishing innovative tour circuits, and jointly promoting specific destinations.

These partnerships, geared towards substantial initiatives, are likely to enhance Madagascar's competitiveness on the international tourism stage, positioning the country as a preferred destination for travelers worldwide.

8 Conclusion

In conclusion, this study sheds light on the intricate interplay between tourism, economic growth, and environmental sustainability in Madagascar. Our findings underscore the significant positive impact of tourism on economic development, as evidenced by the strong association between tourism receipts and GDP growth. The tourism sector emerges as a vital driver of Madagascar's economy, generating revenue, creating employment opportunities, and fostering socio-economic development.

However, amidst the economic benefits, our analysis reveals a concerning trend of increased carbon emissions associated with rising tourist arrivals. This highlights the imperative of adopting sustainable tourism practices to mitigate environmental degradation and preserve Madagascar's rich natural heritage. Sustainable tourism initiatives, such as promoting ecotourism, investing in renewable energy, and implementing conservation measures, are crucial for achieving a harmonious balance between economic prosperity and environmental stewardship.

Moreover, our research underscores the importance of strategic policymaking and collaboration between government agencies, private sector stakeholders, and local communities to harness the potential of tourism while safeguarding the environment. Initiatives such as enhancing road infrastructure, diversifying touristic offerings, digitizing tourism services, and investing in continuous training for tourism personnel can further enhance the competitiveness and sustainability of Madagascar's tourism sector.

Looking ahead, it is imperative for Madagascar to prioritize sustainable development practices that reconcile economic growth with environmental conservation. By embracing a holistic approach to tourism management, Madagascar can unlock the full potential of its tourism sector while preserving its natural and cultural treasures for future generations to enjoy.

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