The Impact of Digital Transformation, Renewable Energy, and Sustainable Tourism on Economic Growth and Environmental Sustainability: A Comparative Analysis Across Global Regions

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ABSTRACT

This study examines the interplay between foreign direct investment (FDI), digital transformation, renewable energy consumption and sustainable tourism in shaping economic growth and environmental sustainability. The objective is to analyze how these factors influence regional development and to identify key differences and policy implications. Using a quantitative approach, data from the World Bank database statistics were analyzed using Jamovi software to perform correlation, regression and moderation analysis. The results show that FDI has a positive impact on GDP growth, although its impact varies regionally. Digital transformation, characterized by Internet usage and mobile phone subscriptions, shows a complex relationship with economic growth, sometimes with unexpected negative results in certain regions. Renewable energy consumption significantly reduces CO_2 emissions, supporting global decarbonization efforts, while the impact of tourism on emissions is nuanced. The study highlights significant regional disparities, with developed regions having advanced digital infrastructure compared to developing regions. The implications underscore the need for targeted policies to improve digital connectivity, support the transition to renewable energy, and promote sustainable tourism. Recommendations include investing in digital infrastructure, facilitating renewable energy projects, developing sustainable tourism policies, and improving the investment climate. Future research should focus on longitudinal studies and sector-specific analysis to better understand regional differences and emerging trends. This comprehensive approach provides valuable insights for policymakers and stakeholders seeking to bridge regional gaps and promote sustainable development.

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Introduction

In the 21st century, transformative factors such as literacy, the digital revolution, renewable energy, sustainable tourism, and foreign direct investment (FDI) have profoundly influenced the global economic and environmental landscape. Literacy, as a fundamental component of personal empowerment and societal progress, serves as a critical foundation for both individual and collective advancement. It is integral to promoting economic growth, reducing inequality, and improving quality of life (Núñez Errázuriz, 2005; Torres, 2013).

FDI, defined as capital invested by firms in one country in industries in another, plays a vital role in the global economy. It facilitates job creation, technological advancement, and market access, contributing to industrialization, infrastructure development, and capacity building, especially in developing countries (Ndlovu & Haabazoka, 2024). FDI has a contextual impact, with different outcomes in different regions. For example, in Zambia, FDI positively affected economic growth by reducing inflation, but had limited effects on savings, interest rates, and unemployment. Similarly, Zekarias (2016) found a positive correlation between FDI and economic growth in East Africa, highlighting the need for improved investment climates and regional cooperation to maximize benefits.

The rapid advancement of digital technologies, including the Internet of Things (IoT) and artificial intelligence (AI), has revolutionized industries and economies. Digital transformation increases productivity, efficiency, and innovation, creating new business opportunities and driving economic growth. However, it also poses challenges such as digital inequalities and cybersecurity threats (Myovella et al.,

2020). Digital connectivity, particularly through mobile communications and internet access, is a key driver of economic growth, with varying impacts depending on a country's level of development.

The transition to renewable energy is essential for sustainable development and climate change mitigation. Investment in renewable energy improves energy security, reduces dependence on fossil fuels, and creates jobs, especially in developing regions (Bhattacharya et al., 2016). Renewable energy supports the development of rural communities and contributes to environmental sustainability. Saidi and Omri (2020) emphasize that while renewable energy promotes economic growth and environmental sustainability, its impact varies regionally and depends on strong governance and institutional frameworks.

Tourism, an important economic sector, has the potential to drive growth, but it must be managed responsibly to minimize its environmental impact. Sustainable tourism promotes ethical travel practices that protect the environment, respect local cultures, and support community development (Erdoğan et al., 2022). By investing in green technologies and sustainable practices, countries can preserve their natural heritage while achieving economic prosperity.

FDI, digital transformation, renewable energy, and sustainable tourism are interrelated factors that influence each other. For instance, FDI can finance renewable energy projects (UNCTAD, 2020), while digital transformation can improve operational efficiency, marketing, and customer experience in sustainable tourism businesses (Buhalis & Amaranggana, 2014). Understanding these relationships is essential to achieving global economic progress and environmental sustainability (OECD, 2022). To this end, policymakers must establish an environment that attracts responsible investment, accelerates green innovation, promotes inclusive growth, safeguards natural resources, and enhances the overall quality of life (World Bank, 2023).

Given the complex interrelationships between these factors, this study aims to explore their collective impact on both economic growth and environmental sustainability. The main objectives are:

1. Evaluate the impact of foreign direct investment (FDI) on economic growth in selected countries in Africa, Asia, Europe, and Latin America.
2. Assess the impact of digital transformation on economic development in the same selected countries in Africa, Asia, Europe, and Latin America.
3. Analyze the role of renewable energy in promoting economic growth and environmental sustainability in the same selected countries in Africa, Asia, Europe, and Latin America.
4. Examine the contribution of sustainable tourism to economic and environmental outcomes in the same selected countries in Africa, Asia, Europe, and Latin America.

This study is significant because it comprehensively examines how foreign direct investment (FDI), digital transformation, renewable energy, and sustainable tourism jointly influence economic growth and environmental sustainability (OECD, 2020; UNCTAD, 2020). By identifying the synergies and trade-offs among these factors, the study offers practical policy recommendations for inclusive, green recovery strategies. Understanding these dynamics is essential for developing resilient policies that address regional disparities and bolster post-pandemic recovery (World Bank, 2023).

Literature Review

It is crucial to understand the interplay between factors such as literacy, foreign direct investment (FDI), digital transformation, renewable energy, and sustainable tourism in order to assess their collective impact on economic growth and environmental sustainability (World Bank, 2023). These elements each play a significant role in shaping global economic and environmental outcomes and often interact in synergistic and reinforcing ways (UNCTAD, 2020; Buhalis & Amaranggana, 2015). The purpose of this literature review is to comprehensively examine these dimensions, synthesize key findings from previous studies, and identify critical gaps in the existing body of research to inform future policy and scholarly work (Bocken et al., 2014; Zahra & Wright, 2011).

Literacy and Economic Development

Literacy is fundamental to socioeconomic development and is closely linked to economic performance. Okpala and Okpala (2006) highlight significant barriers to increasing literacy rates in sub-Saharan Africa, including political instability and financial constraints. Zua (2021) emphasizes the need for targeted investments in education to overcome socio-political challenges and improve literacy. Fute et al. (2023) argue that literacy lays the foundation for a knowledge economy and human capital development, which are essential for achieving socioeconomic goals.

Foreign Direct Investment (FDI) and Economic Growth

Foreign direct investment (FDI) has long been recognized as a key driver of economic growth, particularly in developing countries. Foreign Direct Investment facilitates industrialization, infrastructure development, and job creation through the transfer of capital, technology, and expertise across

borders. Mukupa et al. (2016) found that in Zambia, Foreign Direct Investment contributed significantly to economic growth, with each unit of FDI leading to a fourfold increase in real domestic output. However, the impact of Foreign Direct Investment is not uniform across contexts. Ndlovu and Haabazoka (2024) found that while FDI had a positive impact on overall economic growth in Zambia by reducing inflation, its impact on national savings, interest rates, and unemployment remained minimal. This highlights the need for tailored FDI policies that take into account the unique economic conditions of each country. In a broader regional context, Zekarias (2016) examined 14 East African countries and found a positive correlation between FDI and economic growth, with FDI promoting economic convergence without crowding out domestic investment. Similarly, Claudio-Quiroga et al. (2022) found that Chinese FDI had a statistically significant positive impact on economic growth in Nigeria, although the impact was less pronounced in other African countries such as South Africa and Kenya. These findings underscore the importance of creating an enabling investment climate to optimize the benefits of Foreign Direct Investment.

Digital Transformation and Economic Impact

The digital revolution has transformed industries worldwide, increasing productivity, efficiency, and innovation. Myovella et al. (2020) show that digital infrastructure, such as mobile communications and internet access, plays a critical role in driving economic growth, with developed countries benefiting significantly from digital advances. In contrast, developing countries face challenges such as digital inequality and limited access to advanced technologies, which may hinder their ability to fully benefit from digital transformation. Feng and Qi (2024) similarly found that broadband penetration in Asian countries led to significant economic gains, highlighting the importance of investing in digital infrastructure to drive growth. However, research gaps exist in understanding how digital connectivity interacts with other factors such as financial inclusion and economic policies, as noted by Shofawati (2019) and Xun et al. (2020). This study aims to address these gaps by examining the relationship between digital connectivity, financial inclusion, and GDP growth.

Renewable Energy and Economic Performance

Renewable energy is increasingly recognized as critical to achieving both economic growth and environmental sustainability. Bhattacharya et al. (2016) found that renewable energy consumption has a positive impact on economic growth and supports low-carbon development. Saidi and Omri (2020) demonstrated that renewable energy contributes to economic growth and carbon emission reductions. However, regional differences persist, with Latin America and sub-Saharan Africa facing challenges in the transition to renewable energy. In Zambia, renewable energy deployment remains limited despite its potential to address power shortages and support development goals. Nyasha and Odhiambo (2022) emphasize the importance of strong governance and institutional quality in maximizing the benefits of renewable energy. Similarly, Muazu, Yu, and Liu (2023) highlight the role of institutions in ensuring that renewable energy investments are effectively managed for long-term sustainability. Kirikkaleli et al. (2022) and Ahmed & Shimada (2019) highlight regional differences and the dominance of non-renewable energy sources, while Vlahinić and Zikovic (2010) and Wolde-Rufael (2009) provide contrasting evidence on energy consumption and economic growth.

Sustainable Tourism and Environmental Conservation

Tourism is an important economic sector that can drive growth, particularly in developing countries. However, the environmental impact of tourism, particularly in terms of carbon emissions, poses significant challenges. Sustainable tourism practices aim to mitigate these impacts by promoting green travel, protecting natural resources, and benefiting local communities. Erdoğan et al. (20-22) highlight the role of environmentally friendly transportation technologies in reducing the carbon footprint of tourism, emphasizing the need for innovation to achieve sustainability goals. The Environmental Kuznets Curve (EKC) hypothesis, explored by El Menyari (2021), suggests that while economic growth initially leads to higher emissions, environmental quality improves as economies adopt more sustainable practices. This highlights the importance of integrating sustainable tourism strategies into broader economic and environmental policies. Nademi and Najibi (2011) and Ghosh (2022) advocate investment in green technologies and sustainable tourism practices to address emissions from the tourism industry.

Interconnectedness of FDI, Digital Transformation, Renewable Energy, and Sustainable Tourism

The interplay between FDI, digital transformation, renewable energy, and sustainable tourism is critical to understanding their collective impact on economic growth and environmental sustainability. For example, FDI can support the development of renewable energy projects, while digital technologies can improve the efficiency of sustainable tourism operations. Sustainable tourism can attract foreign investment, which in

turn supports renewable energy initiatives. Ndlovu and Haabazoka (2024) highlight the importance of FDI in sectors such as renewable energy and tourism in Zambia, while Myovella et al. (2020) demonstrate the positive impact of digital connectivity on growth, particularly in developed economies. These findings suggest that a holistic approach that integrates FDI, digital transformation, renewable energy, and sustainable tourism is essential for achieving long-term economic resilience and environmental sustainability.

Gaps in Literature

Despite extensive research, significant gaps persist in the literature. Studies often analyze FDI, digitalization, renewable energy, or tourism in isolation rather than their integrated impact. For instance, while FDI's role in economic growth is well documented (Borensztein et al., 1998), its spillover effects on renewable energy development and tourism infrastructure are understudied, especially in emerging markets. Similarly, digital transformation is known to drive productivity, but its interaction with financial inclusion and carbon intensity remains underexplored (Banga & te Velde, 2018). This study addresses these gaps by assessing interlinkages across regions and identifying region-specific drivers of post-pandemic resilience.

Methodology

The study employs a descriptive and exploratory quantitative research design (Bhattacherjee, 2012). Descriptive statistics summarize variables, and inferential techniques (regression, correlation, and moderation analysis) identify significant relationships and trends. This design is appropriate for large-scale, cross-sectional datasets and supports regional and temporal comparisons (Hair et al., 2010).

Research Design

This quantitative, comparative, correlational study (Creswell, 2014) is based on macro-level panel data from the World Bank from 1990 to 2022. It examines the relationships among economic indicators, technological indicators, environmental indicators, and social indicators. By focusing on different global regions and economies, the study facilitates comparative analysis across different contexts.

Variables and Measurement

The study uses a comprehensive set of variables. Foreign direct investment is measured as net inflows as a percentage of GDP (World Bank, 2023; UNCTAD, 2020). Digital transformation is proxied by two indicators: the percentage of individuals who use the internet and the number of mobile cellular subscriptions (ITU, 2022). Literacy is measured by the adult literacy rate for individuals aged 15 and older (World Bank, 2023). Tourism is measured by receipts as a percentage of total exports and the number of international tourist arrivals (World Bank, 2023). Economic performance is assessed using GDP growth (annual percentage) and GDP in current U.S. dollars (World Bank, 2023). Environmental performance is measured by CO_2 emissions per capita and by renewable energy consumption as a percentage of total final energy consumption. Public debt is analyzed by examining public and publicly guaranteed debt service as a percentage of GNI and exports, as well as central government debt as a percentage of GDP.

Study Regions and Economies

The study covers a wide range of regions and countries. These include Africa Eastern and Southern, such as Zambia, South Africa, and Kenya; East Asia and Pacific, including Viet Nam, Japan, and China; OECD Members like the United States, Canada, and Australia; and the Middle East and North Africa, with countries such as the United Arab Emirates, Morocco, and Egypt. Other regions covered are Sub-Saharan Africa, Europe & Central Asia, the European Union, Africa Western and Central, Central Europe and the Baltics, and Latin America and Caribbean.

Analytical Techniques

Descriptive statistics are used to summarize and describe the basic characteristics of the data. This includes calculating mean, median, standard deviation, and range to provide an overview of the distribution and central tendencies of the variables across different regions.

Correlation analysis is used to assess the strength and direction of relationships between variables, with Pearson's correlation coefficients calculated to explore the relationships between FDI, digital connectivity, renewable energy consumption, and economic performance indicators. Regression analysis is conducted to understand the impact of the independent variables on the dependent variables, specifically GDP growth (annual percentage) and GDP (current US$ million). The independent variables include FDI, Internet usage, mobile phone subscriptions, literacy rate, international tourism receipts and arrivals, CO_2 emissions, renewable energy consumption, and public debt indicators. Multiple regression models are used to examine the effect of each independent variable on GDP growth and GDP, controlling for other factors to provide a more nuanced understanding of their contributions to economic outcomes. Moderation analysis examines how certain variables

influence the strength or direction of relationships between other variables. For example, the study examines how public debt and literacy rates might moderate the relationship between renewable energy consumption and CO_2 emissions.

Comparative analysis is conducted to compare results across regions and economies, examining differences in the impact of foreign direct investment, digital transformation, and renewable energy on economic growth and environmental sustainability in developed, developing, and emerging economies.The analysis is conducted using Jamovi software.

Results

Descriptive Statistics of Economic, Technological and Environmental Indicators

Table 1 presents descriptive statistics and provides a comprehensive comparison of various economic , technological, and environmental indicators across global regions, offering insight into their development patterns and disparities.

Table 1.Descriptive Statistics of Economic, Technological and Environmental Indicators

	Global Regions and Economies	Foreign direct investment, net inflows (% of GDP)	Individuals using the Internet (% of population)	Mobile cellular subscriptions (000)	Literacy rate, adult total (% of people ages 15 and above)	International tourism, receipts (% of total exports)	GDP growth (annual %)	International tourism, number of arrivals	GDP (current US$Million)	CO_2 emissions (metric tons per capita)	Renewable energy consumption (% of total final energy consumption)	Public and publicly guaranteed debt service (% of GNI)
Mean	Africa Eastern and Southern	2.25	11.0	22140	17.7	7.26	3.31	3.01e+6	109537	2.40	56.4	2.89
	Africa Western and Central	2.50	11.5	29650	8.46	6.00	4.41	1.02e+6	102860	0.475	61.6	1.79
	Central Europe and the Baltics	4.45	43.4	10837	7.06	6.38	2.63	2.02e+7	131520	7.83	15.8	0.00
	East Asia & Pacific	2.98	33.5	276624	8.35	2.11	5.50	3.28e+7	3.55e+6	4.75	23.5	0.888
	Europe & Central Asia	2.70	36.7	60138	15.7	3.74	2.48	1.50e+7	1.17e+6	8.65	7.40	1.54
	European Union	1.94	42.6	44490	18.8	4.53	1.43	7.81e+7	1.63e+6	5.85	10.7	0.00
	Latin America & Caribbean	3.32	29.0	59484	35.5	7.39	2.85	2.56e+7	740689	2.21	30.2	2.72
	Middle East & North Africa	2.19	32.6	24080	14.5	12.8	4.14	5.19e+6	161789	8.85	7.36	2.45
	OECD Members	2.38	51.4	77350	0.00	6.63	2.51	4.28e+7	5.24e+6	15.7	11.9	0.00
	Sub-Saharan Africa	2.24	5.59	12183	9.49	12.5	5.45	432101	28584	0.153	84.5	2.09
Standard deviation	Africa Eastern and Southern	2.49	17.5	29444	34.7	8.10	3.07	4.38e+6	136461	3.23	34.2	2.78
	Africa Western and Central	2.34	16.6	52514	20.6	6.37	3.01	1.57e+6	152139	0.223	21.5	1.68
	Central Europe and the Baltics	3.97	33.9	18280	25.7	6.94	6.15	3.11e+7	192648	4.30	9.54	0.00
	East Asia & Pacific	2.61	32.6	470831	26.6	2.75	4.04	4.98e+7	4.09e+6	3.62	20.6	1.03
	Europe & Central Asia	3.11	35.1	71670	35.4	4.77	5.28	1.33e+7	1.23e+6	4.11	6.84	1.55
	European Union	1.34	32.6	30513	38.8	5.33	2.83	6.72e+7	667127	1.80	4.48	0.00
	Latin America & Caribbean	1.68	27.8	80582	45.2	8.11	3.14	3.95e+7	706043	1.19	15.7	1.33
	Middle East & North Africa	1.91	33.6	31674	29.7	12.9	3.59	5.97e+6	130297	11.2	6.81	2.60
	OECD Members	1.68	35.4	114686	0.00	5.56	1.81	5.72e+7	6.76e+6	4.63	7.24	0.00
	Sub-Saharan Africa	1.59	10.6	16441	22.4	13.9	4.49	510988	25914	0.128	16.9	2.02
Minimum	Africa Eastern and Southern	-0.223	0.00	0.00	0.00	0.00	-8.63	0.00	3182	0.00	0.00	0.00
	Africa Western and Central	-0.104	0.00	0.00	0.00	0.00	-2.04	0.00	4983	0.00	0.00	0.00
	Central Europe and the Baltics	-3.13	0.00	0.00	0.00	0.00	-21.3	0.00	0.00	0.00	0.00	0.00
	East Asia & Pacific	-0.0521	0.00	0.00	0.00	0.00	-5.69	0.00	6472	0.00	0.00	0.00

		Europe & Central Asia		-1.76		0.00		0.00		0.00		0.00		-14.5		0.00		16871		0.00		0.00		0.00	
		European Union		-0.899		0.0129		54.7		0.00		0.00		-11.2		0.00		525076		0.00		0.00		0.00	
		Latin America & Caribbean		0.257		0.00		0.00		0.00		0.00		-8.62		0.00		5712		0.00		0.00		0.490	
		Middle East & North Africa		-1.17		0.00		0.904		0.00		0.00		-7.18		0.00		30180		0.00		0.00		0.00	
		OECD Members		-3.61		0.00		0.00		0.00		0.00		-5.04		0.00		311421		0.00		0.00		0.00	
		Sub-Saharan Africa		-0.137		0.00		0.00		0.00		0.00		-8.67		0.00		2857		0.00		0.00		0.0953	
Maximum		Africa Eastern and Southern		9.68		72.3		100328		95.0		28.2		10.3		1.51e+7		458199		8.45		90.7		16.4	
		Africa Western and Central		9.47		68.2		222225		80.4		22.2		15.3		6.11e+6		574184		0.916		88.6		7.74	
		Central Europe and the Baltics		21.7		91.0		56973		99.9		23.5		13.1		8.91e+7		689763		22.0		40.4		0.00	
		East Asia & Pacific		11.9		93.2		1.78e+6		96.7		10.0		14.2		1.63e+8		1.79e+7		9.94		75.9		4.79	
		Europe & Central Asia		13.0		92.3		246569		99.9		19.5		13.5		5.17e+7		4.28e+6		15.4		24.4		6.01	
		European Union		6.77		94.5		97189		99.3		20.4		8.31		2.18e+8		2.96e+6		8.19		19.3		0.00	
		Latin America & Caribbean		8.34		82.7		280729		98.0		25.1		9.20		1.06e+8		2.62e+6		4.22		50.0		8.15	
		Middle East & North Africa		9.35		100		103450		98.3		35.5		18.3		2.53e+7		507064		30.9		23.0		11.2	
		OECD Members		9.17		96.4		372682		0.00		15.9		5.80		1.83e+8		2.57e+7		20.5		23.9		0.00	
		Sub-Saharan Africa		6.66		45.4		69123		89.9		46.5		13.6		2.07e+6		126773		0.425		97.5		9.19	

Foreign Direct Investment

Regions such as Central Europe and the Baltics have the highest average FDI inflows at 4.45%, while the European Union has the lowest at 1.94%. Sub-Saharan Africa has a comparable average (2.24%) to Africa East and Southern (2.25%), but with a higher variability, reflecting greater inconsistency in FDI attraction across African countries. High standard deviations in Western and Central Africa (2.34) and East Asia and the Pacific (2.61) also highlight the volatility of FDI inflows, which may indicate periodic policy changes or external economic shocks.

Individuals Using the Internet

OECD members have the highest Internet usage (average: 51.4%), followed by the European Union (42.6%) and Central Europe and the Baltic States (43.4%), indicating more mature digital infrastructures. In contrast, Eastern and Southern Africa (11%) and Sub-Saharan Africa (5.59%) have the lowest averages, indicating the digital divide in less developed regions. Internet usage shows significant variation across all regions, with East Asia and the Pacific ranging from 0% to a high of 93.2%, illustrating the vast differences in connectivity even within regions.

Mobile Cellular Subscriptions

East Asia and the Pacific (mean: 276,624,000) and OECD members (mean: 77,350,000) have the highest average mobile subscriptions, reflecting the large populations and high technology adoption in these regions. In contrast, Central Europe and the Baltic states have the lowest number of subscriptions (mean: 10,837,000). Sub-Saharan Africa (mean: 12,183,000) continues to lag behind, possibly due to affordability issues and limited infrastructure. The high standard deviations in East Asia and the Pacific and Sub-Saharan Africa reflect the significant variability within these regions.

Literacy Rate

Latin America and the Caribbean stands out with the highest literacy rate (mean: 35.5%), indicating significant investment in education systems. This is followed by the European Union (18.8%) and Eastern and Southern Africa (17.7%). However, Sub-Saharan Africa (mean: 9.49%) and Western and Central Africa (8.46%) have low literacy rates, highlighting the challenges of access to education. This trend correlates with economic disparities and unequal access to basic services in these regions.

International Tourism

Regions such as the Middle East and North Africa (mean: 12.8%) and Sub-Saharan Africa (mean: 12.5%) rely heavily on tourism for export earnings, reflecting their strategic position in global travel. The European Union (mean: 4.53%) and East Asia and the Pacific (mean: 2.11%) have a relatively low reliance on tourism as part of their export mix, reflecting their diverse and more robust industrial base. The variability within the Middle East & North Africa (standard deviation: 12.9%) suggests that some countries within the region are more dependent on tourism than others.

GDP Growth

Eastern and Southern Africa has the highest average GDP growth rate (7.26%), reflecting the region's fast-growing economies, while OECD members (mean: 2.51%) and the European Union (mean: 1.43%) have more stable but slower growth. Sub-Saharan Africa's higher average growth (5.45%) is in line with the continent's development potential, although it faces the challenge of higher variability (standard deviation: 4.49%).

International Tourism, Number of Arrivals

The European Union leads in tourism arrivals, reflecting its long-established tourism infrastructure. East Asia and the Pacific and OECD members also report significant tourism arrivals. Sub-Saharan Africa, with only 432,101 arrivals, highlights the region's limited role in global tourism despite its natural attractions.

GDP

OECD members have the highest average GDP, followed by East Asia and Pacific, while Sub-Saharan Africa has the lowest GDP (US$432,101 million). This highlights the significant economic disparities between developed and developing regions, with developed economies having far greater financial resources.

CO_2 Emissions

CO_2 emissions per capita vary widely, with OECD members leading the way at 15.7 metric tons, reflecting higher levels of industrialization and energy consumption. Sub-Saharan Africa has the lowest (average: 0.153 tons), reflecting its minimal contribution to global emissions. This disparity underscores the uneven environmental footprint of different regions, with developed countries contributing more to climate change despite global environmental goals.

Renewable Energy Consumption

Sub-Saharan Africa has the highest reliance on renewable energy (mean: 84.5%), likely due to limited access to traditional energy sources. In contrast, Central Europe and the Baltics (15.8%) and the European Union (10.7%) have lower percentages, although these regions have invested in renewable energy infrastructure. The wide range within the East Asia and Pacific region (standard deviation: 20.6) indicates that countries are at different levels of renewable energy adoption.

Public and Publicly Guaranteed Debt Service

Regions such as Eastern and Southern Africa (mean: 2.89%) and Latin America and the Caribbean (mean: 2.72%) have significant debt burdens. The European Union and Central Europe and the Baltics report zero debt service, indicating more stable financial systems. Sub-Saharan Africa (mean: 2.09%) faces moderate debt service levels, reflecting the ongoing challenges of public debt management in the region.

Correlation Matrix of Economic, Technological and Environmental Indicators

The correlation matrix in Table 2 provides a comprehensive view of the relationships between key economic and sustainability variables in this study, allowing for a deeper understanding of the interplay between FDI, digital transformation, sustainable tourism, and post-pandemic economic resilience. The matrix is based on Pearson's r and Spearman's rho to assess linear and rank-order correlations, respectively.

Foreign Direct Investment (FDI) and Digital Connectivity

FDI is positively correlated with the percentage of individuals using the Internet (Pearson's $r = 0.101$, $p < .001$), indicating that as FDI inflows increase, Internet use tends to increase. This relationship could mean that foreign investment contributes to infrastructure improvements and technological development. However, the correlation with mobile phone subscriptions is weaker and negative (Pearson's $r = -0.057$, $p = 0.07$), although Spearman's rho shows a modest positive relationship (rho = 0.090, $p < .01$). This suggests that while mobile infrastructure may not grow directly in line with FDI, there is still some association in terms of rank order.

Literacy and Sustainable Tourism

Literacy has a modest positive correlation with both Internet use (Pearson's $r = 0.108$, $p < .001$) and FDI (Pearson's $r = 0.095$, $p < .01$), suggesting that improvements in educational outcomes are linked to technological advances and investment. The positive correlation between literacy and tourism receipts

(Pearson's r = 0.004, insignificant) is small, but Spearman's rho shows a slightly stronger association (rho = 0.029, p > .05), suggesting that literacy may indirectly influence tourism performance in terms of ranking, although the relationship is weak.

Tourism and Economic Growth

Tourism receipts show a significant positive correlation with GDP growth (Pearson's r = 0.208, p < .001), highlighting the role of tourism in driving economic expansion. Similarly, the number of international tourist arrivals is positively associated with GDP (Pearson's r = 0.491, p < .001), reinforcing the economic importance of tourism in boosting GDP. The negative association with CO_2 emissions (Pearson's r = -0.173, p < .001) suggests that as tourism grows, efforts may be made to mitigate environmental impacts. Interestingly, renewable energy consumption is also positively correlated with tourism revenues (Pearson's r = 0.151, p < .001), suggesting the potential for sustainable tourism to increase the adoption of renewable energy.

Digital Transformation and CO_2 Emissions

Digital transformation, as reflected in internet usage and mobile phone subscriptions, shows an interesting relationship with CO_2 emissions. While internet usage is positively correlated with CO_2 emissions (Pearson's r = 0.287, p < .001), mobile subscriptions have a minimal association (Pearson's r = 0.033, p = 0.286). These results suggest that the expansion of Internet infrastructure may be associated with higher environmental costs, possibly due to the energy consumption of digital infrastructure, while mobile usage has a relatively neutral effect on emissions.

Renewable Energy and Public Debt Service

There is a strong negative correlation between renewable energy consumption and CO_2 emissions (Pearson's r = -0.581, p < .001), reinforcing the important role of renewable energy in reducing carbon emissions. Furthermore, the inverse relationship between public and publicly guaranteed debt service and CO_2 emissions (Pearson's r = -0.442, p < .001) suggests that countries with higher debt service levels tend to have lower emissions, possibly due to economic constraints limiting industrial expansion. Interestingly, renewable energy consumption is also negatively correlated with public debt service (Pearson's r = 0.295, p < .001), suggesting that investment in green energy may alleviate the economic pressures of debt service.

Table 2. Correlation Matrix of Economic, Technological and Environmental Indicators

		Foreign direct investment, net inflows (% of GDP)		Individuals using the Internet (% of population)		Mobile cellular subscriptions (000)		Literacy rate, adult total (% of people ages 15 and above)		International tourism, receipts (% of total exports)		GDP growth (annual %)		International tourism, number of arrivals		GDP (current US Million)		CO2 emissions (metric tons per capita)		Renewable energy consumption (% of total final energy consumption)		Public and publicly guaranteed debt service (% of GNI)	
Foreign direct investment, net inflows (% of GDP)	Pearson's r	—																					
	df	—																					
	p-value	—																					
	Spearman's rho	—																					
	df	—																					
	p-value	—																					
Individuals using the Internet (% of population)	Pearson's r	0.101	**	—																			
	df	1022		—																			
	p-value	0.001		—																			
	Spearman's rho	0.230	***	—																			
	df	1022		—																			
	p-value	< .001		—																			
Mobile cellular subscriptions(000)	Pearson's r	-0.057		0.261	***	—																	
	df	1022		1022		—																	
	p-value	0.070		< .001		—																	
	Spearman's rho	0.090	**	0.733	***	—																	
	df	1022		1022		—																	
	p-value	0.004		< .001		—																	
Literacy rate, adult total (% of people ages 15 and above)	Pearson's r	0.095	**	0.108	***	0.047		—															
	df	1022		1022		1022		—															
	p-value	0.002		< .001		0.130		—															
	Spearman's rho	0.129	***	0.116	***	0.192	***	—															
	df	1022		1022		1022		—															
	p-value	< .001		< .001		< .001		—															

International tourism, receipts (% of total exports)		Pearson's r		0.075	*	-0.115	***	-0.125	***	0.004		—														
		df		1022		1022		1022		1022		—														
		p-value		0.016		<.001		<.001		0.892		—														
		Spearman's rho		0.151	***	0.135	***	0.132	***	0.029		—														
		df		1022		1022		1022		1022		—														
		p-value		<.001		<.001		<.001		0.358		—														
GDP growth (annual %)		Pearson's r		0.289	***	-0.155	***	0.065	*	0.029		0.208	***	—												
		df		1022		1022		1022		1022		1022		—												
		p-value		<.001		<.001		0.036		0.362		<.001		—												
		Spearman's rho		0.347	***	-0.120	***	-0.045		0.045		0.144	***	—												
		df		1022		1022		1022		1022		1022		—												
		p-value		<.001		<.001		0.148		0.148		<.001		—												
International tourism, number of arrivals		Pearson's r		-0.062	*	0.319	***	0.368	***	0.083	**	-0.026		-0.054		—										
		df		1022		1022		1022		1022		1022		1022		—										
		p-value		0.047		<.001		<.001		0.008		0.401		0.086		—										
		Spearman's rho		0.121	***	0.508	***	0.582	***	0.137	***	0.357	***	-0.069	*	—										
		df		1022		1022		1022		1022		1022		1022		—										
		p-value		<.001		<.001		<.001		<.001		<.001		0.027		—										
GDP (current US$Million)		Pearson's r		-0.147	***	0.331	***	0.620	***	-0.064	*	-0.109	***	-0.073	*	0.491	***	—								
		df		1022		1022		1022		1022		1022		1022		1022		—								
		p-value		<.001		<.001		<.001		0.039		<.001		0.020		<.001		—								
		Spearman's rho		-0.154	***	0.535	***	0.727	***	0.053		-0.096	**	-0.255	***	0.537	***	—								
		df		1022		1022		1022		1022		1022		1022		1022		—								
		p-value		<.001		<.001		<.001		0.092		0.002		<.001		<.001		—								
CO_2 emissions (metric tons per capita)		Pearson's r		-0.026		0.287	***	0.033		-0.131	***	-0.173	***	-0.177	***	0.191	***	0.278	***	—						
		df		1022		1022		1022		1022		1022		1022		1022		1022		—						
		p-value		0.406		<.001		0.286		<.001		<.001		<.001		<.001		<.001		—						
		Spearman's rho		-0.053		0.326	***	0.176	***	-0.105	***	-0.005		-0.289	***	0.442	***	0.492	***	—						
		df		1022		1022		1022		1022		1022		1022		1022		1022		—						
		p-value		0.088		<.001		<.001		<.001		0.872		<.001		<.001		<.001		—						
Renewable energy consumption (% of total final energy consumption)		Pearson's r		0.037		-0.396	***	-0.149	***	-0.042		0.151	***	0.225	***	-0.304	***	-0.270	***	-0.581	***	—				
		df		1022		1022		1022		1022		1022		1022		1022		1022		1022		—				
		p-value		0.236		<.001		<.001		0.184		<.001		<.001		<.001		<.001		<.001		—				
		Spearman's rho		0.124	***	-0.277	***	-0.289	***	0.020		0.108	***	0.251	***	-0.225	***	-0.533	***	-0.641	***	—				
		df		1022		1022		1022		1022		1022		1022		1022		1022		1022		—				
		p-value		<.001		<.001		<.001		0.531		<.001		<.001		<.001		<.001		<.001		—				
Public and publicly guaranteed debt service (% of GNI)		Pearson's r		-0.032		-0.326	***	-0.131	***	0.041		0.078	*	0.055		-0.229	***	-0.252	***	-0.442	***	0.295	***	—		
		df		1022		1022		1022		1022		1022		1022		1022		1022		1022		1022		—		
		p-value		0.306		<.001		<.001		0.190		0.013		0.078		<.001		<.001		<.001		<.001		—		
		Spearman's rho		0.043		-0.365	***	-0.203	***	0.132	***	0.108	***	0.208	***	-0.220	***	-0.469	***	-0.563	***	0.375	***	—		
		df		1022		1022		1022		1022		1022		1022		1022		1022		1022		1022		—		
		p-value		0.174		<.001		<.001		<.001		<.001		<.001		<.001		<.001		<.001		<.001		—		

Note. * p < .05, ** p < .01, *** p < .001

In a nutshell, the correlation matrix provides valuable insights into the dynamics between economic variables, digital transformation, and sustainability efforts in the context of post-pandemic economic resilience. Strong correlations between FDI, digital infrastructure, and tourism highlight the interconnectedness of these sectors, while inverse relationships between renewable energy consumption and CO_2 emissions underscore the importance of sustainable practices in supporting long-term economic growth.

Regression Analysis on GDP

The linear regression model was designed to predict GDP (current US$ millions) using several independent variables. The

model in Table 1 shows a robust fit with an R^2 value of 0.638 and an adjusted R^2 value of 0.619. This indicates that approximately 63.8% of the variance in GDP is explained by the independent variables in the model. The F-statistic of 34.3, with a p-value of less than 0.001, confirms the statistical significance of the model, suggesting that the predictors together provide a strong explanation for the variance in GDP.

Table 3. Model Fit Measures

				Overall Model Test			
Model	R	R^2	Adjusted R^2	F	df1	df2	p
1	0.799	0.638	0.619	34.3	50	973	< .001

Model Coefficients - GDP (current US$ Million)

Foreign Direct Investment

The coefficient is negative (-90528.41) and statistically significant ($p < 0.001$), indicating that an increase in FDI is associated with a decrease in GDP. This unexpected result reflects capital outflows or inefficient use of foreign investment.

Individuals Using the Internet

The positive coefficient of 15628.72 with a significant t-value ($p < 0.001$) indicates that higher Internet usage is associated with higher GDP, underscoring the role of digital connectivity in driving economic growth.

Mobile Cellular Subscriptions

The coefficient of 8.13, which is highly significant ($p < 0.001$), shows that mobile subscriptions have a positive impact on GDP. This result highlights the importance of technological expansion in promoting economic development.

Literacy Rate

A negative coefficient of -4448.64 with a p-value of 0.028 suggests a slight decrease in GDP with higher literacy rates. This indicate a lag effect, where the economic benefits of improved literacy take time to materialize.

International Tourism, Receipts

Although not statistically significant ($p = 0.087$), the positive coefficient of 14383.64 suggests a modest positive impact of tourism receipts on GDP.

International Tourism, Number of Arrivals

The positive and highly significant coefficient of 0.0198 ($p < 0.001$) indicates that an increase in tourist arrivals is associated with an increase in GDP, consistent with the understanding of tourism as a driver of economic growth.

Renewable Energy Consumption

The coefficient of -3227.22 with a p-value of 0.401 indicates that renewable energy consumption is not statistically significant in explaining GDP variations in this model.

Public and Publicly Guaranteed Debt Service (% of GNI)

This variable shows a significant negative relationship with GDP, as evidenced by a coefficient of -100030.23 and a p-value of 0.011. This suggests that higher debt service obligations may constrain economic growth.

Table 4. Model Coefficients - GDP (current US$ Million)

Predictor	Estimate	SE	t	p
Intercept [a]	998222.1534	454803.93480	2.1948	0.028
Foreign direct investment, net inflows (% of GDP)	-90528.4140	26831.97092	-3.3739	< .001
Individuals using the Internet (% of population)	15628.7238	3770.79579	4.1447	< .001
Mobile cellular subscriptions (000)	8.1250	0.43092	18.8548	< .001
Literacy rate, adult total (% of people ages 15 and above)	-4448.6423	2021.84324	-2.2003	0.028
International tourism, receipts (% of total exports)	14383.6407	8385.97546	1.7152	0.087
International tourism, number of arrivals	0.0198	0.00197	10.0643	< .001

Renewable energy consumption (% of total final energy consumption)	-3227.2193	3837.88001	-0.8409	0.401
Public and publicly guaranteed debt service (% of GNI)	-100030.2273	39114.92943	-2.5573	0.011
Global Regions and Economies:				
Africa Western and Central – Africa Eastern and Southern	-129963.1915	269333.44616	-0.4825	0.630
Central Europe and the Baltics – Africa Eastern and Southern	-989538.4388	354952.80960	-2.7878	0.005
East Asia & Pacific – Africa Eastern and Southern	218032.9999	327278.48832	0.6662	0.505
Europe & Central Asia – Africa Eastern and Southern	-99999.3299	323702.20197	-0.3089	0.757
European Union – Africa Eastern and Southern	-1.06e−6	367649.86649	-2.8868	0.004
Latin America & Caribbean – Africa Eastern and Southern	-329862.2587	295972.50267	-1.1145	0.265
Middle East & North Africa – Africa Eastern and Southern	-647294.7105	337581.28940	-1.9174	0.055
OECD Members – Africa Eastern and Southern	2.78e+6	365351.97469	7.6010	< .001
Sub-Saharan Africa – Africa Eastern and Southern	32155.3248	291395.06236	0.1103	0.912
Year:				
1991 – 1990	21355.1769	471949.74022	0.0452	0.964
1992 – 1990	36003.5626	472171.18336	0.0763	0.939
1993 – 1990	132124.5104	472882.89109	0.2794	0.780
1994 – 1990	219747.1335	472966.47880	0.4646	0.642
1995 – 1990	-188305.6707	479571.28822	-0.3927	0.695
1996 – 1990	-323507.8296	481042.56170	-0.6725	0.501
1997 – 1990	-379186.7638	483067.37832	-0.7850	0.433
1998 – 1990	-297259.3717	484196.05677	-0.6139	0.539
1999 – 1990	-328998.7926	485108.93274	-0.6782	0.498
2000 – 1990	-288012.6715	488578.11807	-0.5895	0.556
2001 – 1990	-474414.4478	490451.65300	-0.9673	0.334
2002 – 1990	-539463.9043	489651.98865	-1.1017	0.271
2003 – 1990	-560515.0103	491220.60191	-1.1411	0.254
2004 – 1990	-669218.0503	497972.04216	-1.3439	0.179
2005 – 1990	-747514.9172	504220.84764	-1.4825	0.139
2006 – 1990	-777063.9544	511624.45737	-1.5188	0.129
2007 – 1990	-743249.0628	522292.62170	-1.4231	0.155
2008 – 1990	-832922.4576	516935.54408	-1.6113	0.107
2009 – 1990	-1.01e−6	516851.30811	-1.9626	0.050
2010 – 1990	-965231.8907	523855.90799	-1.8426	0.066

2011 – 1990		-930604.9263		525955.41628		-1.7694		0.077	
2012 – 1990		-1.08e−6		528211.44322		-2.0467		0.041	
2013 – 1990		-1.17e−6		530722.49921		-2.2110		0.027	
2014 – 1990		-1.20e−6		534644.75488		-2.2454		0.025	
2015 – 1990		-1.40e−6		538579.07933		-2.6064		0.009	
2016 – 1990		-1.42e−6		545548.60008		-2.5983		0.010	
2017 – 1990		-1.42e−6		549336.39483		-2.5793		0.010	
2018 – 1990		-1.42e−6		554900.34581		-2.5633		0.011	
2019 – 1990		-1.44e−6		561319.67687		-2.5653		0.010	
2020 – 1990		-901676.0300		555456.35383		-1.6233		0.105	
2021 – 1990		-306814.1714		561830.71288		-0.5461		0.585	
2022 – 1990		-26131.9573		524980.15338		-0.0498		0.960	
2023 – 1990		-1.64e−6		1.90e+6		-0.8614		0.389	
[a] **Represents reference level**									

Global Regions and Economies

The dummy variables representing different world regions reveal notable regional differences in GDP. OECD members have a significant positive effect on GDP, with an estimate of ($p < 0.001$), indicating that membership in developed regions correlates with higher GDP. The European Union shows a negative relationship with GDP, with an estimate of ($p = 0.004$), suggesting that EU countries perform worse relative to the reference region (Eastern and Southern Africa). Central Europe and the Baltics shows a negative coefficient of -989538.44 with significance ($p = 0.005$), indicating lower GDP levels compared to Africa Eastern and Southern.

These results highlight regional disparities, with developed economies such as the OECD countries showing significantly higher GDP, while regions such as Central Europe and the Baltics and the European Union show lower relative performance.

Yearly Effects

The year variables show notable shifts in GDP over time, with years from 2015 to 2019 showing consistently negative and significant estimates. This indicates a decline in GDP relative to 1990 levels. The period after 2010 appears to be particularly challenging, with many coefficients negative and significant, suggesting continued economic difficulties.

Assumption Checks

Table 5 shows that most of the Variance Inflation Factor (VIF) values are below 2, indicating that there are no major multicollinearity problems. The tolerance levels also confirm that the independent variables are sufficiently independent of each other.

Table 5. Collinearity Statistics

	VIF	Tolerance
Foreign direct investment, net inflows (% of GDP)	1.16	0.862
Individuals using the Internet (% of population)	2.11	0.475
Mobile cellular subscriptions(000)	1.28	0.781
Literacy rate, adult total (% of people ages 15 and above)	1.10	0.908
International tourism, receipts (% of total exports)	1.25	0.797
International tourism, number of arrivals	1.43	0.701
Renewable energy consumption (% of total final energy consumption)	2.02	0.495
Public and publicly guaranteed debt service (% of GNI)	1.31	0.764
Global Regions and Economies	1.17	0.858
Year	1.03	0.969

Summary

The linear regression model provides valuable insights into the factors influencing GDP, highlighting the importance of technological variables such as Internet use and mobile phone subscriptions. The negative relationship between foreign direct investment and GDP is unexpected and may indicate inefficiencies or capital outflows. Regional effects are pronounced, with developed economies such as OECD countries showing stronger GDP performance than others.

Regression Analysis on GDP Growth

The linear regression analysis as shown in Table 6 yields an R-squared value of 0.383, indicating that approximately 38.3% of the variability in GDP growth can be explained by the model. The adjusted R-squared is slightly lower at 0.351, indicating a slight reduction in explanatory power when the number of predictors in the model is taken into account. The overall model fit is statistically significant ($F(50, 973) = 12.1$, $p < .001$), confirming that the set of independent variables significantly predicts GDP growth.

Table 6. Model Fit Measures

				Overall Model Test			
Model	R	R^2	Adjusted R^2	F	df1	df2	p
1	0.619	0.383	0.351	12.1	50	973	< .001

GDP Growth

The results in Table 7 show that certain predictors have a significant impact on GDP growth. Foreign direct investment, net inflows has a strong positive relationship with GDP growth (estimate = 0.38814, t = 8.01, p < .001). This suggests that higher FDI inflows contribute significantly to GDP growth, possibly due to increased capital formation, technology transfer and job creation. Individuals using the Internet shows a negative relationship with GDP growth (estimate = -0.03496, t = -5.13, p < .001). This unexpected result may suggest that the expansion of Internet use has not yet translated into direct economic benefits in some regions, or that there are lags in the economic returns of digital transformation. International tourism receipts have a positive and significant impact on GDP growth (estimate = 0.04004, t = 2.64, p = 0.008). This underscores the importance of tourism in driving economic expansion, especially in countries that rely heavily on tourism export earnings. Renewable energy consumption also contributes positively to GDP growth (estimate = 0.02826, t = 4.07, p < .001), suggesting that a higher share of renewable energy in the energy mix promotes economic growth, likely through improvements in sustainability and energy security.

Several variables were statistically insignificant. Mobile phone subscriptions had no significant effect on GDP growth (p = 0.123), which may reflect the saturation of mobile technology in some economies. Literacy rate and publicly guaranteed debt service also showed no significant relationship with GDP growth, suggesting that other factors may moderate their economic impact.

Regional Effects

The analysis also considered regional effects. Compared to Africa Eastern and Southern: East Asia and Pacific had the largest positive effect (estimate = 3.38905, t = 5.73, p < .001), highlighting the region's rapid economic growth driven by industrialization and export-oriented policies. Middle East and North Africa and OECD members also significantly outperformed Eastern and Southern Africa in terms of GDP growth, with positive coefficients (p < .001 and p = 0.015, respectively). These regions benefit from stronger institutional frameworks, higher levels of human capital, and diversified economies.

In contrast, regions such as Sub-Saharan Africa and Latin America and the Caribbean did not show significant deviations from Africa Eastern and Southern, indicating comparable growth patterns.

Temporal Trends

Several year-specific effects were statistically significant, in particular: 2020 saw a significant decline in GDP growth relative to 1990 (estimate = -3.92076, t = -3.91, p < .001), reflecting the economic contraction due to the global COVID-19 pandemic. In contrast, 2021 showed a strong positive rebound (estimate = 3.93458, t = 3.88, p < .001), suggesting that recovery efforts and adaptive measures helped restore growth. 2009, another year of significant contraction, likely due to the global financial crisis (estimate = -3.39328, p < .001). 2010 and 2022 both show positive effects on GDP growth, indicating periods of economic recovery and growth acceleration.

Table 7. Model Coefficients - GDP growth (annual %)

Predictor	Estimate	SE	t	p
Intercept [a]	0.62184	0.82183	0.75666	0.449
Foreign direct investment, net inflows (% of GDP)	0.38814	0.04849	8.00542	< .001
Individuals using the Internet (% of population)	-0.03496	0.00681	-5.13007	< .001
Mobile cellular subscriptions(000)	1.20e-6	7.79e-7	1.54531	0.123
Literacy rate, adult total (% of people ages 15 and above)	0.00112	0.00365	0.30589	0.760
International tourism, receipts (% of total exports)	0.04004	0.01515	2.64223	0.008
International tourism, number of arrivals	4.47e-9	3.55e-9	1.25653	0.209
Renewable energy consumption (% of total final energy consumption)	0.02826	0.00694	4.07490	< .001
Public and publicly guaranteed	-0.01193	0.07068	-0.16884	0.866

debt service (% of GNI)								
Global Regions and Economies:								
Africa Western and Central – Africa Eastern and Southern		0.9242 3		0.4866 8		1.8990 3		0.05 8
Central Europe and the Baltics – Africa Eastern and Southern		0.7012 8		0.6414 0		1.0933 6		0.27 5
East Asia & Pacific – Africa Eastern and Southern		3.3890 5		0.5913 9		5.7306 3		< .00 1
Europe & Central Asia – Africa Eastern and Southern		1.3038 1		0.5849 3		2.2290 0		0.02 6
European Union – Africa Eastern and Southern		0.3535 2		0.6643 4		0.5321 4		0.59 5
Latin America & Caribbean – Africa Eastern and Southern		0.3243 2		0.5348 2		0.6064 0		0.54 4
Middle East & North Africa – Africa Eastern and Southern		2.7558 3		0.6100 1		4.5176 9		< .00 1
OECD Members – Africa Eastern and Southern		1.6045 5		0.6601 9		2.4304 3		0.01 5
Sub-Saharan Africa – Africa Eastern and Southern		0.9799 1		0.5265 5		1.8610 1		0.06 3
Year:								
1991 – 1990		-2.5752 1		0.8528 1		-3.0196 7		0.00 3
1992 – 1990		-3.2013 1		0.8532 1		-3.7520 6		< .00 1
1993 – 1990		-1.8494 9		0.8545 0		-2.1644 1		0.03 1
1994 – 1990		-1.7405 2		0.8546 5		-2.0365 3		0.04 2
1995 – 1990		-0.4573 8		0.8665 8		-0.5277 9		0.59 8
1996 – 1990		0.8196 4		0.8692 4		0.9429 4		0.34 6
1997 – 1990		0.5487 5		0.8729 0		0.6286 5		0.53 0
1998 – 1990		-0.9374 9		0.8749 4		-1.0714 9		0.28 4
1999 – 1990		-0.7667 3		0.8765 9		-0.8746 7		0.38 2
2000 – 1990		0.9040 2		0.8828 6		1.0239 7		0.30 6
2001 – 1990		-0.4447 8		0.8862 4		-0.5018 7		0.61 6
2002 – 1990		0.0016 3		0.8848 0		0.0018 4		0.99 9
2003 – 1990		0.5316 1		0.8876 3		0.5989 1		0.54 9
2004 – 1990		1.9376 4		0.8998 3		2.1533 4		0.03 2
2005 – 1990		1.4525 6		0.9111 3		1.5942 5		0.11 1
2006 – 1990		2.2483 5		0.9245 0		2.4319 6		0.01 5
2007 – 1990		1.5378 4		0.9437 8		1.6294 5		0.10 4
2008 – 1990		0.0770 2		0.9341 0		0.0824 5		0.93 4
2009 – 1990		-3.3932 8		0.9339 5		-3.6332 6		< .00 1
2010 – 1990		2.0129 1		0.9466 1		2.1264 5		0.03 4
2011 – 1990		1.7755 0		0.9504 0		1.8681 6		0.06 2
2012 – 1990		0.7996 2		0.9544 8		0.8377 6		0.40 2
2013 – 1990		0.9809 4		0.9590 1		1.0228 6		0.30 7
2014 – 1990		1.1776 4		0.9661 0		1.2189 6		0.22 3
2015 – 1990		0.9542 8		0.9732 1		0.9805 5		0.32 7
2016 – 1990		0.5187 7		0.9858 0		0.5262 4		0.59 9
2017 – 1990		1.7375 3		0.9926 5		1.7504 0		0.08 0
2018 – 1990		1.4763 9		1.0027 0		1.4724 1		0.14 1
2019 – 1990		1.0879 5		1.0143 0		1.0726 1		0.28 4
2020 – 1990		-3.9207 6		1.0037 1		-3.9062 8		< .00 1
2021 – 1990		3.9345 8		1.0152 3		3.8755 7		< .00 1
2022 – 1990		2.1711 2		0.9486 4		2.2886 7		0.02 2
2023 – 1990		-1.1603 9		3.4301 3		-0.3382 9		0.73 5
[a] Represents reference level								

Assumption Checks

Collinearity, as shown in Table 8, does not appear to be a significant problem, with VIF values below 2 for all predictors, indicating no severe multicollinearity.

Table 8. Collinearity Statistics

	VIF	Tolerance
Foreign direct investment, net inflows (% of GDP)	1.16	0.862
Individuals using the Internet (% of population)	2.11	0.475
Mobile cellular subscriptions(000)	1.28	0.781

Table 8. Collinearity Statistics

	VIF	Tolerance
Literacy rate, adult total (% of people ages 15 and above)	1.10	0.908
International tourism, receipts (% of total exports)	1.25	0.797
International tourism, number of arrivals	1.43	0.701
Renewable energy consumption (% of total final energy consumption)	2.02	0.495
Public and publicly guaranteed debt service (% of GNI)	1.31	0.764
Global Regions and Economies	1.17	0.858
Year	1.03	0.969

Summary

The regression model identifies key drivers of GDP growth, particularly FDI, tourism, and renewable energy consumption, while highlighting challenges related to digital transformation and economic shocks such as the COVID-19 pandemic.

Regression Analysis on CO_2 emissions

The linear regression model as shown in Table 9 shows a good fit, as indicated by an R^2 value of 0.746, indicating that 74.6% of the variability in CO_2 emissions is explained by the predictors in the model. The adjusted R^2 of 0.733, which takes into account the number of predictors, remains robust and confirms the goodness of fit of the model. The F-statistic of 57.1, with a p-value < .001, further confirms that the overall model is statistically significant. The F-test indicates that the model provides a significantly better fit than a model without any predictors.

Table 9. Model Fit Measures

				Overall Model Test			
Model	R	R^2	Adjusted R^2	F	df1	df2	p
1	0.864	0.746	0.733	57.1	50	973	< .001

Foreign Direct Investment (FDI)

The positive coefficient ($\beta = 0.16994$, $p < .001$) indicates that increased FDI leads to higher CO_2 emissions. This finding indicates that foreign investment, especially in carbon-intensive sectors, contributes to higher emissions, highlighting a potential trade-off between attracting FDI and achieving sustainable development.

Literacy Rate

The negative coefficient ($\beta = -0.00992$, $p = 0.006$) indicates that higher literacy rates are associated with lower CO_2 emissions. This suggests that a more educated population may be better able to implement environmentally friendly practices, or that increased education correlates with a societal shift towards sustainability.

GDP

Despite the common belief that GDP drives emissions through industrial activity, the coefficient ($\beta = 3.51e\text{-}8$, $p = 0.472$) is not statistically significant. This indicates that GDP alone does not significantly explain variations in CO_2 emissions in this dataset.

GDP Growth

The coefficient on GDP growth ($\beta = -0.01365$, $p = 0.661$) is also statistically insignificant, suggesting that short-term fluctuations in economic growth do not have a strong impact on CO_2 emissions in this model.

Renewable Energy Consumption

This predictor has a significant negative effect on CO_2 emissions ($\beta = -0.10551$, $p < .001$). This result supports the argument that increasing the share of renewable energy in the energy mix is effective in reducing carbon emissions, underscoring its critical role in mitigating climate change.

International Tourism Receipts

The negative coefficient ($\beta = -0.18072$, $p < .001$) indicates that higher tourism receipts are associated with lower CO_2 emissions. This may suggest that, despite tourism's association with environmental impacts, tourism-dependent economies export lower-emitting services relative to industrial production.

Public and Publicly Guaranteed Debt Service (% of GNI)

The strong negative association ($\beta = -1.01797$, $p < .001$) suggests that higher debt service obligations reduce CO_2 emissions. This may be because countries with high debt burdens may reduce economic activity or adopt austerity measures, thereby limiting industrial production and emissions.

Regional Effects

There are notable regional differences in CO_2 emissions when compared to Eastern and Southern Africa (the reference category): OECD members and regions such as East Asia and

the Pacific have significantly higher CO_2 emissions. OECD countries, with their advanced industrial base, emit 5.47 metric tons more per capita than Africa Eastern and Southern, while East Asia and Pacific emits 4.33 metric tons more. On the other hand, regions such as Latin America and the Caribbean and Central Europe and the Baltic have lower emissions than Africa Eastern and Southern, suggesting that regional development strategies and environmental policies may be driving these differences.

Temporal Trends

The years after 2020 have a noticeable negative impact on CO_2 emissions. For example, the year 2021 shows a $\beta = -7.91$ and 2022 shows an even larger drop ($\beta = -10.81$). These results likely reflect the economic disruptions caused by the COVID-19 pandemic, which drastically reduced industrial activity, transportation, and consequently emissions. The dramatic reduction continues through 2023, with $\beta = -18.69$, indicating a sustained decline in emissions.

Table 10. Model Coefficients - CO_2 emissions (metric tons per capita)

Predictor	Estimate	SE	t	p
Intercept [a]	13.16443	0.80435	16.367	< .001
Foreign direct investment, net inflows (% of GDP)	0.16994	0.04947	3.435	< .001
Literacy rate, adult total (% of people ages 15 and above)	-0.00992	0.00361	-2.751	0.006
GDP (current US Million)	3.51e-8	4.88e-8	0.720	0.472
GDP growth (annual %)	-0.01365	0.03116	-0.438	0.661
Renewable energy consumption (% of total final energy consumption)	-0.10551	0.00690	-15.301	< .001
International tourism, receipts (% of total exports)	-0.18072	0.01464	-12.344	< .001
International tourism, number of arrivals	-2.62e−9	3.65e-9	-0.718	0.473
Public and publicly guaranteed debt service (% of GNI)	-1.01797	0.06985	-14.573	< .001
Global Regions and Economies:				
Africa Western and Central – Africa Eastern and Southern	-2.85015	0.48066	-5.930	< .001
Central Europe and the Baltics – Africa Eastern and Southern	-2.40542	0.59446	-4.046	< .001
East Asia & Pacific – Africa Eastern and Southern	-4.33209	0.56436	-7.676	< .001
Europe & Central Asia – Africa Eastern and Southern	-1.05796	0.55638	-1.902	0.058
European Union – Africa Eastern and Southern	-4.63770	0.62655	-7.402	< .001
Latin America & Caribbean – Africa Eastern and Southern	-3.08032	0.51329	-6.001	< .001
Middle East & North Africa – Africa Eastern and Southern	1.82146	0.58521	3.112	0.002
OECD Members – Africa Eastern and Southern	5.46671	0.61452	8.896	< .001
Sub-Saharan Africa – Africa Eastern and Southern	0.77933	0.52005	1.499	0.134
Year:				
1991 – 1990	0.30867	0.84462	0.365	0.715
1992 – 1990	-0.37090	0.84709	-0.438	0.662
1993 – 1990	-0.85552	0.84450	-1.013	0.311
1994 – 1990	-0.36266	0.84447	-0.429	0.668
1995 – 1990	1.13138	0.85402	1.325	0.186
1996 – 1990	1.19831	0.85635	1.399	0.162
1997 – 1990	0.68132	0.85917	0.793	0.428
1998 – 1990	0.60530	0.86084	0.703	0.482
1999 – 1990	0.67946	0.86056	0.790	0.430
2000 – 1990	0.51244	0.86280	0.594	0.553
2001 – 1990	0.32527	0.86440	0.376	0.707
2002 – 1990	0.48320	0.86071	0.561	0.575
2003 – 1990	0.55632	0.86051	0.646	0.518
2004 – 1990	0.19623	0.86794	0.226	0.821
2005 – 1990	0.17990	0.87091	0.207	0.836
2006 – 1990	-0.22703	0.87958	-0.258	0.796
2007 – 1990	-0.51482	0.89007	-0.578	0.563
2008 – 1990	-0.54841	0.87750	-0.625	0.532
2009 – 1990	-0.82546	0.88387	-0.934	0.351
2010 – 1990	-0.59915	0.87497	-0.685	0.494
2011 – 1990	-0.68743	0.87223	-0.788	0.431
2012 – 1990	-0.79193	0.86970	-0.911	0.363
2013 – 1990	-0.74020	0.86866	-0.852	0.394
2014 – 1990	-0.83346	0.86836	-0.960	0.337
2015 – 1990	-0.74981	0.86820	-0.864	0.388
2016 – 1990	-0.72859	0.87094	-0.837	0.403
2017 – 1990	-0.49729	0.86895	-0.572	0.567
2018 – 1990	-0.28811	0.86928	-0.331	0.740

2019 – 1990	-0.35388	0.87051	-0.407	0.684
2020 – 1990	-1.61376	0.87357	-1.847	0.065
2021 – 1990	-7.90676	0.86034	-9.190	< .001
2022 – 1990	-10.80704	0.87791	-12.310	< .001
2023 – 1990	-18.69174	3.37996	-5.530	< .001
[a] **Represents reference level**				

Assumption Checks

Variance Inflation Factors (VIF) as shown in Table 11 for all predictors are below 10, with most well below 2, indicating no multicollinearity issues.

Table 11. Collinearity Statistics

	VIF	Tolerance
Foreign direct investment, net inflows (% of GDP)	1.20	0.833
Literacy rate, adult total (% of people ages 15 and above)	1.10	0.907
GDP (current US$ Million)	1.42	0.705
GDP growth (annual %)	1.26	0.797
Renewable energy consumption (% of total final energy consumption)	2.04	0.491
International tourism, receipts (% of total exports)	1.23	0.814
International tourism, number of arrivals	1.49	0.672
Public and publicly guaranteed debt service (% of GNI)	1.31	0.762
Global Regions and Economies	1.16	0.861
Year	1.02	0.983

Moderation Analysis

Moderating Effect of Literacy Rate on the Relationship Between Renewable Energy Consumption and CO_2 Emissions

The moderation analysis has shown in Table 12 reveals a significant interaction between renewable energy consumption and literacy rate on CO_2 emissions. The negative coefficient for Renewable Energy Consumption (β = -0.1212, $p < .001$) suggests that higher renewable energy consumption consistently leads to a reduction in CO_2 emissions. This effect is significant because renewable energy serves as a key factor in mitigating environmental impacts by replacing carbon-intensive energy sources.

Similarly, the literacy rate also has a significant negative impact on CO_2 emissions (β = -0.0278, $p < .001$). This suggests that as literacy rates increase, emissions tend to decrease, possibly due to increased public awareness, better implementation of environmental policies, or a shift in societal values towards sustainability.

The interaction between renewable energy consumption and literacy rate is statistically significant ($\beta = 0.000639$, $p = 0.001$), meaning that the relationship between renewable energy consumption and CO_2 emissions is moderated by literacy rates. Specifically, as literacy rates increase, the effect of renewable energy consumption on reducing CO_2 emissions becomes less pronounced. This could be explained by the idea that highly literate populations may already have other mechanisms in place to reduce emissions, such as advanced technologies or stricter environmental regulations, which reduce reliance on renewable energy alone as a key driver.

Table 12. Moderation Estimates

	Estimate	SE	Z	p
Renewable energy consumption (% of total final energy consumption)	-0.1212	0.00523	-23.18	< .001
Literacy rate, adult total (% of people ages 15 and above)	-0.0278	0.00503	-5.53	< .001
Renewable energy consumption (% of total final energy consumption) ✻ Literacy rate, adult total (% of people ages 15 and above)	6.39e-4	1.95e-4	3.28	0.001

The simple slope analysis shown in Table 13 further disaggregates the moderation effect and illustrates how the effect of renewable energy consumption on CO_2 emissions varies by literacy level. At the average level of literacy, the effect of renewable energy consumption on reducing CO_2 emissions remains strong (β = -0.121, $p < .001$). This reflects the general trend that increasing renewable energy consumption leads to a reduction in emissions. At low literacy levels (-1 standard deviation), the effect is even stronger (β = -0.141, $p < .001$). In societies with lower literacy rates, reliance on renewable energy plays a more important role in reducing emissions, likely because other mitigating factors such as technological advances or environmental policies may be less

developed. At high literacy levels (+1 standard deviation), the effect of renewable energy consumption on emissions is still significant, but weaker (β = -0.101, p < .001). This suggests that in more literate societies, other factors such as environmental awareness, better policy enforcement, or technological innovation may already be contributing to lower emissions, reducing the sole impact of renewable energy.

This moderating effect highlights the nuanced interplay between education and renewable energy consumption in shaping environmental outcomes. It suggests that while renewable energy is critical to reducing emissions globally, its impact is most pronounced in regions with lower literacy rates, where other supportive mechanisms for reducing emissions may be less prevalent.

Table 13. Simple Slope Estimates

	Estimate	SE	Z	p
Average	-0.121	0.00527	-23.0	< .001
Low (-1SD)	-0.141	0.00772	-18.3	< .001
High (+1SD)	-0.101	0.00849	-11.9	< .001

Note. shows the effect of the predictor (Renewable energy consumption (% of total final energy consumption)) on the dependent variable (CO_2 emissions (metric tons per capita)) at different levels of the moderator (Literacy rate, adult total (% of people ages 15 and above))

Moderating Effect of Foreign Direct Investment on the Relationship Between Renewable Energy Consumption and CO2 Emissions

The moderation analysis examines the interaction between renewable energy consumption and foreign direct investment (FDI) in influencing CO_2 emissions. The results as shown in Table 14 indicate that renewable energy consumption significantly reduces CO_2 emissions (β = -0.1217, p < .001). This confirms that as countries increase their reliance on renewable energy sources, emissions decrease, which is consistent with global efforts to mitigate climate change through sustainable energy transitions.

However, FDI does not have a statistically significant effect on CO_2 emissions (β = -0.0118, p = 0.855), suggesting that net inflows of foreign investment are not directly related to changes in emissions in this context. This result may suggest that FDI as a stand-alone factor may not have a significant impact on environmental outcomes without taking into account the nature of the investments (whether they are directed towards green technologies or more traditional, emission-intensive sectors).

Interestingly, the interaction between renewable energy consumption and FDI is also insignificant (β = -0.000285, p = 0.904), suggesting that FDI does not significantly moderate the relationship between renewable energy use and CO_2 emissions. This lack of moderation suggests that the environmental benefits of renewable energy use in reducing emissions are relatively independent of the level of FDI. In other words, whether a country receives high or low levels of FDI, the reduction in CO_2 emissions due to renewable energy consumption remains consistent.

Table 14. Moderation Estimates

	Estimate	SE	Z	p
Renewable energy consumption (% of total final energy consumption)	-0.1217	0.00535	-22.770	< .001
Foreign direct investment, net inflows (% of GDP)	-0.0118	0.06484	-0.182	0.855
Renewable energy consumption (% of total final energy consumption) ✻ Foreign direct investment, net inflows (% of GDP)	-2.85e−4	0.00236	-0.121	0.904

The simple slope analysis as shown in Table 15 examines the effect of renewable energy consumption on CO_2 emissions at different levels of FDI (low, average, and high): At the average level of FDI, renewable energy consumption significantly reduces CO_2 emissions (β = -0.122, p < .001). This suggests that in economies with moderate FDI inflows, renewable energy continues to play a central role in reducing emissions. For countries with low FDI (-1 standard deviation), the effect of renewable energy on emissions is still significant, but slightly weaker (β = -0.121, p < .001). This suggests that even at low levels of foreign investment, renewable energy remains an effective tool for reducing carbon emissions. At high levels of FDI (+1 standard deviation), the impact of renewable energy consumption on emissions remains stable and significant (β = -

0.122, p < .001). This further supports the notion that the positive environmental impact of renewable energy is robust regardless of the level of FDI.

These results indicate that renewable energy consistently leads to a reduction in CO_2 emissions, regardless of the level of FDI. The lack of a significant interaction effect suggests that FDI neither enhances nor diminishes the role of renewable energy in reducing emissions. This finding highlights the independent and essential contribution of renewable energy to environmental sustainability, regardless of the dynamics of foreign investment.

The moderation analysis provides an important insight into the relationship between renewable energy, FDI and environmental sustainability. Despite expectations that FDI might influence the impact of renewable energy on emissions, the results show no such interaction. This suggests that the positive environmental effects of renewable energy are robust and consistent across different levels of FDI, making it an important strategy for reducing emissions in both high and low investment scenarios.

These findings emphasize the need for targeted investments in renewable energy infrastructure and policies, irrespective of the magnitude of foreign capital inflows. Furthermore, it highlights that while FDI is important for economic growth, it may not always correlate with positive environmental outcomes unless specifically directed towards green technologies or sustainable industries.

Table 15. Simple Slope Estimates

	Estimate	SE	Z	p
Average	-0.122	0.00535	-22.8	< .001
Low (-1SD)	-0.121	0.00763	-15.9	< .001
High (+1SD)	-0.122	0.00829	-14.8	< .001

Note. shows the effect of the predictor (Renewable energy consumption (% of total final energy consumption)) on the dependent variable (CO_2 emissions (metric tons per capita)) at different levels of the moderator (Foreign direct investment, net inflows (% of GDP))

Moderating Effect of Public and Publicly Guaranteed Debt Service on the Relationship Between Renewable Energy Consumption and CO_2 Emissions

The moderation analysis examines how public and publicly guaranteed debt service (% of GNI) affects the relationship between renewable energy consumption and CO_2 emissions. The results as shown in table 16 show a significant negative relationship between renewable energy consumption and CO_2 emissions (β = -0.1046, p < .001), indicating that increased reliance on renewable energy sources significantly reduces emissions. This finding is consistent with global patterns of renewable energy adoption, which reduce carbon emissions as countries move away from fossil fuels. However, public and publicly guaranteed debt service has a significant and much stronger negative effect on CO_2 emissions (β = -1.3023, p < .001). This implies that countries with higher debt service tend to have lower emissions. One possible interpretation is that countries with high debt obligations may limit certain investments or industrial activities, which could indirectly lead to lower emissions. Alternatively, countries with high debt may prioritize debt repayment over high-emissions economic activities, which may contribute to this effect. The interaction term between renewable energy consumption and public and publicly guaranteed debt service is also significant (β = 0.0261, p < .001), suggesting that debt service moderates the relationship between renewable energy consumption and emissions. The positive interaction coefficient indicates that the reduction in emissions from renewable energy consumption becomes less pronounced as debt service increases. This could mean that while renewable energy consumption still reduces emissions, the financial constraints imposed by high debt service may limit the extent of this reduction.

Table 16. Moderation Estimates

	Estimate	SE	Z	p
Renewable energy consumption (% of total final energy consumption)	-0.1046	0.00477	-21.9	< .001
Public and publicly guaranteed debt service (% of GNI)	-1.3023	0.07432	-17.5	< .001
Renewable energy consumption (% of total final energy consumption) ✻ Public and publicly guaranteed debt service (% of GNI)	0.0261	0.00224	11.7	< .001

The simple slope analysis from Table 17 provides a more nuanced view of the effect of renewable energy consumption on CO_2 emissions at different levels of public and publicly guaranteed debt service: At the average level of debt service, renewable energy consumption significantly reduces CO_2 emissions (β = -0.1046, p < .001). This reflects the general trend that renewable energy adoption contributes to emission reductions in economies with moderate levels of debt service.

At low levels of debt service (-1 standard deviation), the reduction in emissions due to renewable energy consumption is even stronger (β = -0.1553, p < .001). This suggests that countries with lower debt burdens are better positioned to maximize the environmental benefits of renewable energy. In such scenarios, the absence of significant financial constraints may allow for more efficient and widespread deployment of renewable technologies, leading to greater emissions reductions. Conversely, at high levels of debt service (+1 standard deviation), the effect of renewable energy on emissions is still significant, but significantly weaker (β = -0.0539, p < .001). This suggests that countries with high debt burdens experience a diminished impact of renewable energy consumption on reducing emissions. The financial pressures associated with high debt service may limit the scope for renewable energy projects, making it more difficult for these countries to fully reap the environmental benefits of renewable energy.

The moderation analysis highlights the complex relationship between renewable energy consumption, debt service, and CO2 emissions. While renewable energy consumption consistently reduces emissions, the magnitude of this effect depends on a country's level of debt service. Countries with lower debt service can more effectively use renewable energy to reduce emissions, while countries with higher debt service face constraints that reduce the impact of renewable energy on environmental outcomes. The interaction between debt service and renewable energy consumption suggests that financial burdens may hinder a country's ability to fully realize the benefits of renewable energy. In high debt scenarios, governments may struggle to invest in the necessary infrastructure or technology to transition to cleaner energy sources, thereby weakening potential emission reductions. This finding underscores the importance of fiscal health in enabling sustainable energy transitions and suggests that addressing debt-related issues could be a critical factor in maximizing the environmental benefits of renewable energy.

Table 17. Simple Slope Estimates

	Estimate	SE	Z	p
Average	-0.1046	0.00502	-20.82	< .001
Low (-1SD)	-0.1553	0.00713	-21.79	< .001
High (+1SD)	-0.0539	0.00632	-8.53	< .001

Table 17. Simple Slope Estimates

	Estimate	SE	Z	p

Note. shows the effect of the predictor (Renewable energy consumption (% of total final energy consumption)) on the dependent variable (CO_2 emissions (metric tons per capita)) at different levels of the moderator (Public and publicly guaranteed debt service (% of GNI))

In conclusion, while renewable energy consumption is a powerful tool for reducing CO_2 emissions, the extent of its effectiveness is moderated by a country's public debt obligations. Countries with lower debt service can use renewable energy more effectively, while countries with higher debt service face challenges that limit the environmental benefits of renewable energy investments.

Moderating Effect of International Tourism Receipts on the Relationship Between Renewable Energy Consumption and CO_2 Emissions

The moderation analysis examines the interaction between renewable energy consumption and international tourism receipts in influencing CO_2 emissions. The main effect of renewable energy consumption on CO_2 emissions as shown on Table 18 is significantly negative (β = -0.12078, p < .001), indicating that higher renewable energy consumption is correlated with lower CO_2 emissions. This supports the general understanding that renewable energy helps reduce greenhouse gas emissions by displacing fossil fuels.

International tourism receipts also have a significant negative effect on CO_2 emissions (β = -0.09692, p < .001). This result suggests that as the share of tourism in exports increases, CO_2 emissions decrease. One interpretation could be that tourism receipts reflect economic activities that, while potentially having a carbon footprint, may also be associated with investments in sustainable practices or cleaner technologies within the tourism sector.

The interaction term between renewable energy consumption and international tourism receipts is positive and significant (β = 0.00235, p < .001). This indicates that the impact of renewable energy on CO_2 emissions is moderated by the level of international tourism receipts. Specifically, the positive interaction suggests that the reduction in emissions due to renewable energy consumption is less pronounced in countries with higher international tourism receipts.

Table 18. Moderation Estimates

Table 18. Moderation Estimates

	Estimate	SE	Z	p
Renewable energy consumption (% of total final energy consumption) ✻ International tourism, receipts (% of total exports)	-0.12078	0.00528	22.86	< .001
Renewable energy consumption (% of total final energy consumption)	-0.09692	0.01844	-5.25	< .001
International tourism, receipts (% of total exports)				

The simple slope analysis from Table 19 provides additional insight into how the effect of renewable energy consumption on CO_2 emissions varies with different levels of international tourism receipts: At the average level of international tourism receipts, the effect of renewable energy consumption on CO_2 emissions is significantly negative ($\beta = -0.121$, $p < .001$). This confirms that, on average, increased consumption of renewable energy is effective in reducing CO_2 emissions. At low levels of international tourism receipts (-1 standard deviation), the effect of renewable energy consumption on CO_2 emissions is stronger ($\beta = -0.141$, $p < .001$). This suggests that the environmental benefits of renewable energy are more pronounced in countries with relatively lower tourism receipts. It may be that these countries are more focused on using renewable energy to reduce emissions without the potential diversion of resources that may accompany higher tourism receipts. At high levels of international tourism receipts (+1 standard deviation), the effect of renewable energy consumption on CO_2 emissions is weaker ($\beta = -0.100$, $p < .001$). This suggests that in countries with significant tourism receipts, the reduction in CO_2 emissions due to renewable energy consumption is less effective. High tourism receipts may be associated with increased overall economic activity, which could offset some of the emission reductions achieved through renewable energy.

The moderation analysis shows that the effectiveness of renewable energy consumption in reducing CO_2 emissions is influenced by the level of international tourism receipts. While renewable energy generally contributes to lower emissions, this effect is moderated by tourism receipts. Countries with higher international tourism receipts may experience a dilution of the emission reduction benefits of renewable energy. This could be due to increased economic activities or investments related to tourism that offset the positive impacts of renewable energy. In contrast, countries with lower tourism receipts appear to benefit more directly from renewable energy consumption in terms of emission reductions.

Table 19. Simple Slope Estimates

	Estimate	SE	Z	p
Average	-0.121	0.00532	-22.7	< .001
Low (-1SD)	-0.141	0.00713	-19.8	< .001
High (+1SD)	-0.100	0.00633	-15.8	< .001

Note. shows the effect of the predictor (Renewable energy consumption (% of total final energy consumption)) on the dependent variable (CO_2 emissions (metric tons per capita)) at different levels of the moderator (International tourism, receipts (% of total exports))

Overall, the analysis highlights the importance of considering the economic context when assessing the impact of renewable energy on emissions. Countries with different levels of tourism revenue may need tailored strategies to maximize the environmental benefits of renewable energy, while ensuring that tourism-related activities do not undermine efforts to reduce carbon emissions.

Discussion

This study provides an integrated examination of the economic, technological, and environmental dynamics shaping global development, examining critical indicators such as foreign direct investment (FDI), Internet usage, mobile subscriptions, literacy rates, and renewable energy consumption, and revealing significant regional disparities. The study reveals show that regions such as the OECD and the European Union have higher levels of Internet usage and mobile subscriptions, reflecting their advanced digital infrastructure. In contrast, Sub-Saharan Africa highlights development gaps with significantly lower figures. This observation is consistent with previous research highlighting the digital infrastructure gap between developed and developing regions (Myovella et al., 2020). The key findings from the correlation matrix reinforce the interconnectedness of these factors. Positive relationships were observed between FDI, digital connectivity (internet usage and mobile phone subscriptions), literacy rates and economic growth, underscoring the role of digital transformation in driving economic expansion. These findings are consistent with the literature that highlights the importance of digital connectivity and FDI in driving economic growth (Ndlovu &

Haabazoka, 2024; Mukupa et al., 2016). In addition, tourism emerged as a significant factor with a positive impact on GDP growth, especially in regions where international tourism plays a central role in the economy. This finding supports previous studies that have highlighted the contribution of tourism to economic growth (Erdoğan et al., 2022). The study also highlights the interaction between renewable energy consumption and CO_2 emissions, demonstrating the environmental benefits of sustainable practices. Increased use of renewable energy significantly reduces CO_2 emissions, supporting global decarbonization efforts. This finding is consistent with the literature, which highlights the effectiveness of renewable energy in reducing emissions (Bhattacharya et al., 2016; Saidi & Omri, 2020).

Foreign Direct Investment (FDI) and Economic Performance

The regression analysis provides nuanced insights into the role of FDI in shaping economic outcomes. On the one hand, FDI has a positive impact on GDP growth, reinforcing its importance for economic expansion. This is consistent with global patterns, where foreign capital inflows often stimulate investment, production and job creation, especially in emerging and developing economies. However, as highlighted by Ndlovu and Haabazoka (2024), the impact of FDI is context dependent, with different outcomes across regions. In the case of Zambia, FDI had a positive impact on economic growth mainly by reducing inflation, although its impact on savings, interest rates and unemployment was limited. Similarly, Zekarias (2016) found a positive correlation between FDI and economic growth in East African countries, highlighting the need for an improved investment climate and regional cooperation to maximize benefits.

Digital Transformation and Economic Growth

The role of Internet usage and mobile phone subscriptions in driving economic growth is complex. While the study shows that higher Internet usage is positively correlated with FDI and economic expansion, the regression analysis reveals an unexpected negative relationship between Internet usage and GDP growth. This suggests that in some regions, technological progress has not yet fully translated into growth benefits. This finding is at odds with the literature, which generally portrays digital transformation as a key driver of economic growth (Myovella et al., 2020; Feng & Qi, 2024). This paradox can be attributed to several factors, including the digital divide, where some regions lack the infrastructure or digital literacy to reap the economic benefits of Internet use. The literature highlights the need to address the digital divide through investments in infrastructure and education to fully realize the benefits of technology (Shofawati, 2019; Xun et al., 2020).

Renewable Energy and Environmental Sustainability

The relationship between renewable energy consumption and CO_2 emissions is a central focus of the study. The regression analysis confirms that renewable energy consumption significantly reduces CO_2 emissions, supporting the view that transitioning to greener energy sources is crucial for mitigating climate change. This finding is consistent with the literature that highlights the role of renewable energy in reducing emissions (Bhattacharya et al., 2016; Saidi & Omri, 2020). The moderation analysis further examines how literacy rates, FDI, public debt, and tourism receipts affect this relationship.

Higher literacy rates are associated with lower CO_2 emissions, suggesting that education plays an important role in promoting environmental awareness and the adoption of sustainable practices. Educated populations may be more likely to use energy-efficient technologies and engage in less carbon-intensive behaviors. This observation supports findings in the literature that education promotes environmental sustainability (Ndlovu & Haabazoka, 2024). However, the interaction between renewable energy consumption and literacy rate suggests that the emission-reducing effect of renewable energy is somewhat less pronounced in more educated regions. This may indicate that more educated societies may already be taking additional measures to mitigate emissions, reducing the relative impact of renewable energy consumption alone.

Foreign direct investment, while generally considered a catalyst for economic growth, does not significantly moderate the relationship between renewable energy consumption and CO_2 emissions. This suggests that foreign capital inflows, regardless of their volume, do not amplify the positive environmental effects of renewable energy. Instead, the impact of renewable energy on reducing emissions remains consistent across different levels of FDI, further underscoring the independent value of renewable energy investments in decarbonizing economies. This finding provides a nuanced perspective compared to the literature suggesting that FDI can improve environmental outcomes through technology transfer (Zekarias, 2016).

Public Debt and Environmental Sustainability

The interaction between renewable energy consumption and public debt service highlights an important consideration for countries facing fiscal constraints. While renewable energy consumption significantly reduces CO_2 emissions, countries with high debt service obligations tend to experience a weaker emissions-reducing effect. This is likely due to fiscal constraints that limit the scale of renewable energy investment. This finding is consistent with the literature, which argues that fiscal soundness is critical to the use of renewable energy for environmental sustainability (Saidi & Omri, 2020).

International Tourism and Emissions

International tourism, often thought to be environmentally harmful because of the travel and infrastructure demands it generates, has a nuanced relationship with CO_2 emissions. While tourism revenues are negatively associated with emissions, suggesting that tourism-dependent economies tend to have lower emissions than industrial economies, the moderation analysis shows that increased tourism revenues slightly reduce the effectiveness of renewable energy in mitigating emissions. This result is consistent with the literature suggesting that tourism-related emissions may offset some of the benefits of renewable energy (Erdoğan et al., 2022).

Policy Implications and Recommendations

The study on the interplay between foreign direct investment (FDI), digital transformation, renewable energy and sustainable tourism provides valuable insights into their impact on economic growth and environmental sustainability. Based on the findings, the following policy implications and recommendations are outlined, with special attention to the regions and countries involved in the study.

Policy Implications

Enhancing Digital Connectivity

Governments in developing regions need to prioritize investments in digital infrastructure to close the digital divide. This includes expanding internet access, increasing mobile coverage, and improving digital literacy. Effective policies could include public-private partnerships to build infrastructure and international aid to support digital inclusion initiatives.

Supporting Renewable Energy Transition

Developing countries need targeted support to accelerate the deployment of renewable energy. Policy recommendations include creating an enabling regulatory environment for renewable energy investment, providing financial incentives, and facilitating technology transfer. International cooperation and financing should be leveraged to help these countries scale up renewable energy projects.

Promoting Sustainable Tourism Development

Policymakers in developing regions should focus on sustainable tourism strategies, including infrastructure development, capacity building and environmentally sound practices. Governments should also work with international organizations to improve tourism infrastructure and promote best practices in sustainable tourism.

Attracting and Utilizing FDI Effectively

To attract FDI, countries should improve their investment climate by streamlining regulatory processes, increasing transparency, and investing in infrastructure. Special economic zones and investment incentives could be introduced to attract foreign investors and stimulate economic growth.

Addressing Regional Disparities

Policymakers should develop region-specific strategies that address the unique needs and challenges of each area. Tailored policies can ensure that interventions are effective in promoting economic growth and sustainability, while taking into account local contexts and priorities.

Recommendations

Invest in Digital Infrastructure

In regions such as Sub-Saharan Africa and West and Central Africa, governments should prioritize investments in digital infrastructure. This includes expanding broadband networks, increasing mobile connectivity, and improving digital literacy programs. International organizations and private sector partnerships can play a critical role in supporting these initiatives.

Facilitate Renewable Energy Projects

Countries such as Zambia, Uganda and other developing countries should receive targeted support for renewable energy projects. Policies should include financial incentives for renewable energy investment, support for technology transfer, and the establishment of favorable regulatory frameworks. Cooperation with developed countries and international institutions can help facilitate these efforts.

Develop Sustainable Tourism Policies

Developing regions such as Zambia and Kenya should implement policies that promote sustainable tourism. This includes investing in tourism infrastructure, improving local services, and adopting environmentally friendly practices. Governments should work with international tourism organizations to attract investment and improve tourism management.

Improve Investment Climate

Emerging economies such as China and Brazil should continue to improve their investment climates to attract and retain FDI. This includes maintaining regulatory stability, improving transparency, and investing in infrastructure. Developing countries should also focus on creating an investment-friendly environment to promote economic development through FDI.

Implement Region-Specific Strategies

Policymakers should design and implement strategies that address the specific needs and conditions of each region. For example, digital transformation strategies in Africa should focus on improving connectivity and digital literacy, while renewable energy policies in developing countries should prioritize technology adoption and capacity building. Tailored approaches can help bridge regional disparities and promote more equitable development outcomes.

Limitations of the Study

Despite the comprehensive nature of this study, several limitations must be acknowledged. First, the analysis relies on aggregate data from the World Bank database, which may obscure sector-specific dynamics and variations within countries. This limitation may affect the granularity of the results and the ability to draw nuanced conclusions about specific sectors or regions. Finally, the aggregation of data across regions may mask significant regional differences, limiting insights into local conditions and specific nuances.

Future Recommendations

Future research should focus on longitudinal studies to assess the long-term impact of FDI, digital transformation, renewable energy and sustainable tourism on economic growth and environmental sustainability. This approach would provide a deeper understanding of how these factors interact over time. In addition, examining these dynamics in specific regional contexts can provide insights into how local conditions and cultural factors influence their effectiveness, leading to more tailored and effective strategies.

It is also important to explore the impact of emerging technologies, such as artificial intelligence and blockchain, on the relationships between FDI, digital transformation, renewable energy, and sustainable tourism. Understanding these impacts will inform future policy development. Sector-specific analyses could show how different industries are affected by these dynamics, facilitating targeted strategies for different sectors.

Finally, assessing the effectiveness of existing policies and strategies in integrating these factors will provide valuable insights into best practices and areas for improvement. Addressing these limitations and pursuing these avenues of research will improve our understanding of the complex interactions between economic growth and sustainability, leading to more informed and effective policy and strategy development.

Conclusion

This study offers a comprehensive analysis of the interactions between foreign direct investment (FDI), digital transformation, renewable energy, and sustainable tourism in shaping economic growth and environmental sustainability across global regions. The findings reveal that although FDI stimulates growth, its advantages are not distributed equally. Digital expansion contributes to economic output, but it also puts a strain on the environment. Renewable energy offers a promising path toward decarbonization, and sustainable tourism supports inclusive development. These interdependencies underscore the need for integrated policy frameworks that align economic growth with environmental and social objectives in the post-pandemic world.

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