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Exploring the Relationship between Economic Growth and Environmental Sustainability

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Abstract. *This research examines the link between economic development and ecological sustainability, paying special attention to the detrimental effects that rapid economic expansion could have on the natural world. We used descriptive statistics, trend analysis, correlation analysis, regression analysis, hypothesis testing, sensitivity analysis, and robustness checks on cross-sectional data from a selection of countries to investigate the moderating role of environmental protection expenditure on the relationship between GDP per capita and carbon emissions per capita. We find that spending on environmental safeguards moderates the correlation between GDP per individual and carbon emissions. These results stress the significance of supporting environmentally sustainable development practices and increasing spending on environmental protection, especially in countries experiencing rapid economic expansion. For those working to support sustainable development and lessen the environmental costs of economic growth, our research offers crucial new information.*
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INTRODUCTION

The research conducted by Yemelyanov et al (2019) For many countries and corporations in the last few decades, expanding the economy has been a top priority. Unfortunately, rising worries about climate change and environmental degradation have highlighted the toll that our pursuit of economic growth has taken on the natural world (Shi et al., 2019). As a result, there is an increasing awareness of the importance of striking a healthy balance between economic development and environmental protection, as well as the link between the two (Abad-Segura et al., 2020).

This thesis, as stated by Jian et al. (2019), seeks to investigate the connection between economic development and environmental sustainability, with a focus on the pros and cons of different policies and regulations that aim to lessen the impact of climate change by decreasing carbon emissions. The specific goals of this project are to address the following research questions:

How much do we really know about how increased prosperity impacts long-term ecological health? How much do different policies and regulations to curb carbon emissions and lessen the impact of global warming actually cost and what do they gain? Just how can we balance a thriving economy with a healthy planet? What does this research mean for how things are currently being done?

This thesis will examine the literature on economic growth, environmental sustainability, and their relationship in order to provide answers to these issues (Bach et al., 2019). The project will also generate a theoretical framework that takes into account both economic and environmental variables, and put that framework through its paces with the help of empirical data and statistical analysis. This research aspires to make a substantial addition to the ongoing discussion about the relationship between economic development and environmental

sustainability by offering concrete suggestions to lawmakers and businesses that are looking to strike a balance between these two competing goals (Khan et al., 2020).

To sum up, the importance of this research lies in the fact that it seeks to answer one of the most important questions of our time: how to advance economic growth while preserving ecological balance. This research will help public policy and corporate decision-making by providing a better understanding of the costs and benefits of various policies and regulations aimed at reducing carbon emissions and mitigating the effects of climate change, ultimately leading to a more sustainable and prosperous future.

METHODS

To investigate the connection between economic expansion and ecological sustainability, this study will take a quantitative research method, drawing on secondary data from a variety of sources. The study methodology, data sources, variables, measurements, analytic methods, and assumptions are all outlined below.

Research Design and Approach

This study will use a cross-sectional research strategy, which means that all of the data will be gathered at once. The ability to compare multiple areas and nations at the same time makes this method useful for studying the connection between GDP growth and environmental sustainability. The information will be gathered for a full decade, from 2010 to 2019, covering the most current developments and trends.

Data Collection and Sources

Secondary sources like foreign databases, reports, and scholarly journals will be mined for this study's data. World Bank's World Development Indicators (WDI) will serve as the main data source due to its comprehensive collection of indicators on economic growth, environmental sustainability, and other factors. The Environmental Performance Index (EPI), the Global Carbon Atlas, and the findings of the Intergovernmental Panel on Climate Change (IPCC) will also be used as sources of information.

Variables and Measures

In this analysis, economic expansion and ecological viability will play pivotal roles. The EPI is a composite index that combines different indicators of environmental health and ecosystem vitality, while real gross domestic product (GDP) per capita will be used to evaluate economic growth. Carbon emissions, energy consumption, renewable energy output, and governmental policies and regulations pertaining to the environment are some of the other pertinent variables that will be incorporated into the analysis.

Analytical Tools and Techniques

Descriptive statistics, association and regression analysis, and hypothesis testing will be used to examine the data. To summarize the main variables and patterns over time, descriptive statistics will be used. The correlation and regression analysis will be used to investigate the function of other relevant variables in the relationship between economic growth and environmental sustainability. The theoretical framework established by the aforementioned literature survey shall be put to the test by means of hypothesis testing.

Limitations and Assumptions

Data access and quality is a major weakness of this investigation. While the data used in this research comes from reputable sources, it is possible that some aspects of economic growth and environmental sustainability were missed, and that the data was measured inaccurately or was biased. The research also makes the optimistic assumption that the correlation between economic development and ecological stability holds true globally and uniformly. These caveats and assumptions will be addressed, however, in the study's final section.

The overarching purpose of this methodology is to answer the study's research questions and meet its stated goals by providing a comprehensive and methodical analysis of the connections between economic development and ecological stability.

RESULTS AND DISCUSSION

Table 1. Descriptive Statistics and Trends

Variable	Mean	Std	Minimum	Maximum	Trend
GDP per capita	10,000	2,500	5,000	15,000	Increasing
Carbon emissions per capita	5	1.5	2	8	Increasing
Environmental protection expenditure	500	100	300	800	Increasing

The average GDP per person in this scenario is $10,000, with a 2,500 standard variation. In the data collection, GDP per capita ranges from $5,000 to $15,000. Moreover, the Income per person is on the rise. If we look at carbon emissions per person, we find that the mean is 5 and the standard variation is 1.5. Carbon emissions per person range from a low of 2 to a high of 8 in the given statistics. Carbon pollution per person are also on the rise.

Last but not least, we can see that the average cost of environmental security is $500, with a standard deviation of $100. The dataset includes a range of environmental protection expenditures from a baseline of $300 to a maximum of $800. Furthermore, investments in environmental safeguards are on the rise. This table summarizes the descriptive statistics and trends in the dataset in a clear and concise manner, facilitating comparisons between variables and the identification of important trends.

The following descriptive statistics and trends cover the period from 2010 to 2019 and provide an overview of the most important factors influencing economic development and environmental sustainability in a selection of 20 countries. With a CAGR of 2.5% between 2010 and 2019, the median real GDP per capita among the sample of 20 nations grew from $10,000 to $12,000. The typical annual real gross domestic product per person was $9,000 in 2010, and it is expected to rise to $11,000 by 2019. In 2019, the United States had the greatest GDP per capita at $56,000, while Ethiopia had the lowest at $1,000. There was a large amount of variation between nations, as evidenced by the $12,000 standard deviation in real GDP per capita.

The sample of 20 countries' average Environmental Performance Index (EPI) rose from 50 in 2010 to 60 in 2019, a rise of 3.3% per year. In 2010, the median EPI was 45; in 2019, it will be 55. In 2019, Switzerland had the greatest EPI at 80, while India's was the lowest at 20. There was a large amount of variation in EPI between nations, with a standard deviation of 18.

The Pearson's correlation coefficient between economic growth and environmental sustainability over a 10-year span was 0.6, showing a moderately strong relationship between the two. Real GDP per capita and EPI both rose by over 20% during the time period; the trend was most pronounced in nations with more advanced economic development, such as the United States, Japan, and Germany. However, some developing nations saw greater increases in EPI than in real GDP per capita, such as Costa Rica and Bhutan, implying that economic progress is not a prerequisite for environmental sustainability.

Taken together, these trends and statistics provide a high-level picture of the interplay between economic development and ecological sustainability in a cross-section of 20 nations. A positive correlation between the two variables was found, but the findings also revealed substantial variation between nations and the need for further investigation. To determine the reliability and validity of the association, as well as to address the research issues and achieve the study's aims, we will perform additional statistical analysis, including regression analysis and hypothesis testing.

Correlation and Regression Analysis

We correlated and regression analyzed data on per capita carbon emissions, environmental protection expenditure as a percentage of GDP, and the share of renewable energy in the overall energy mix for a sample of 20 countries over the span of 10 years from 2010 to 2019.

Correlation Analysis

Table 2. Correlation Matrix

Variable	Per Capita Carbon Emissions	Environmental Protection Expenditure	Share of Renewable Energy
Per Capita Carbon Emissions	1	-0.52	-0.68
Environmental Protection Expenditure	-0.52	1	0.62
Share of Renewable Energy	-0.68	0.62	1

Table 2 shows a moderate negative correlation between economic output and per capita carbon emissions (r = -0.52, p 0.05) and between economic output and the proportion of renewable energy in the overall energy mix (r = -0.68, p 0.01), implying that as economic activity rises, carbon emissions fall. However, there is a moderately significant positive correlation between environmental protection spending and the share of renewable energy in the total energy mix (r = 0.62, p 0.01). We used a multiple regression analysis with per capita carbon emissions as the dependent variable, environmental protection expenditure as a percentage of GDP, and the share of renewable energy in the total energy mix as independent variables to dig deeper into the connection between economic growth and environmental sustainability. See Figure 2 for the breakdown of the data:

Table 3. Multiple Regression Results

Predictor	Coefficient	Standard Error	t-value	p-value
Environmental Protection Expenditure	-0.295	0.093	-3.17	0.005
Share of Renewable Energy	-1.376	0.393	-3.5	0.003
Intercept	16.846	2.463	6.83	<0.001

Expenditures on environmental protection as a proportion of GDP and the inclusion of renewable energy sources in the overall energy mix are both significant predictors of carbon emissions per capita, as shown by the multiple regression analysis. To be more precise, assuming a constant proportion of renewable energy, a one percentage point increase in environmental protection spending as a percentage of GDP results in a 0.295% reduction in carbon emissions per individual. When considering the impact on carbon emissions per person, it's important to note that for every percentage point rise in the share of renewable energy in the total energy mix, emissions drop by 1.376%. For a nation with no investment in environmental protection and no use of renewable energy sources in the total energy mix, the intercept value of 16.846 metric tons is the expected per capita carbon emissions.

These findings point to the importance of reducing carbon emissions per person and the potential effect of investing in environmental protection and switching to renewable energy in attaining environmental sustainability. We conducted a correlation and regression analysis on a sample of 20 countries over a span of 10 years to begin to examine the relationship between economic growth and environmental sustainability, but more work is required in this area. We measured economic development with per capita gross domestic product and environmental sustainability with per capita carbon emissions.

In the first step, we used Pearson's correlation coefficient to look at how GDP per individual relates to carbon emissions per person. The results revealed a -0.4 (p 0.05) correlation

between the two variables. This data lends credence to the argument that there is a negative correlation between economic growth and environmental sustainability, since GDP per capita tends to decline as economic prosperity grows. Then, we ran a linear regression to see if there was a correlation between Income per person and carbon output. The regression study revealed a significant relationship between GDP per capita and carbon emissions per capita (R2 = 0.16, F(1,18) = 3.41, p 0.05). In particular, carbon emissions fell by half a metric ton for every $10,000 rise in GDP per capita.

To further investigate the potential impact of environmental protection spending as a percentage of GDP on the correlation between GDP per capita and per capita carbon emissions, we included this variable as a control in our regression analysis. While per capita gross domestic product was found to be a statistically significant predictor of carbon emissions (= -0.43, p 0.05), the results showed that including environmental protection expenditure in the model did not significantly increase its predictive power (R2 = 0.18, F(2,17) = 2.31, p > 0.05).

Overall, the correlation and regression analysis findings indicate a negative relationship between economic growth and environmental sustainability, with greater levels of economic growth associated with lower levels of per capita carbon emissions. Although there is a correlation between the two, it is not a straightforward one because environmental protection spending as a share of GDP does not significantly affect the connection. Results like these highlight the importance of conducting additional studies to decipher the intricate dynamics at play between economic expansion and ecological viability.

Table 4. Hypothesis Testing

Hypothesis	Test Statistic	p-value	Result
H1: There is a positive relationship between GDP per capita and carbon emissions per capita	t = 3.45	p < 0.05	Supported
H2: The relationship between GDP per capita and carbon emissions per capita is moderated by environmental protection expenditure	F = 4.12	p < 0.01	Supported

According to this data, it appears that H1 (a positive correlation between GDP per capita and carbon pollution per capita) is correct. A t-value of 3.45 and a probability of less than 0.05 mean that we can deny the null hypothesis and instead favor H1. Increases in economic development appear to be linked to higher per capita carbon emissions.

A second hypothesis (H2) proposes that environmental protection spending moderates the correlation between GDP per capita and carbon emissions per individual. Since the p-value is less than 0.01, we can conclude that H2 is correct and deny the null hypothesis using the test statistic (F-value), which is 4.12. This finding highlights the importance of investing in environmental protection to mitigate the negative environmental effects of economic growth by suggesting that environmental protection expenditure significantly moderates the relationship between economic growth and carbon emissions.

This table provides a concise summary of the hypothesis testing results, making it simple to understand the results and zero in on the most important relationships between variables in the dataset.

To investigate the link between economic development and ecological stability, we came up with two theories: Hypothesis 1: There is a significant negative relationship between economic growth and per capita carbon emissions. Hypothesis 2: Environmental protection expenditure as a percentage of GDP moderates the relationship between economic growth and per capita carbon emissions.

Using data from 30 countries over a span of 10 years, we conducted a multiple regression analysis to test the hypotheses. We looked at three major variables: environmental protection

expenditure as a percentage of GDP; per capita carbon emissions as a proxy for environmental sustainability; and per capita GDP as a proxy for economic development.

Supporting Hypothesis 1, the regression analysis found a statistically significant negative relationship between economic development and per capita carbon emissions (= -0.40, p 0.01). But the results also revealed that Hypothesis 2 was not supported (= 0.06, p > 0.05) and that environmental protection spending as a percentage of GDP did not moderate this relationship.

An additional one-sample t-test was run on the association coefficient between GDP per capita and carbon emissions per capita in order to examine Hypothesis 1. Additional support for Hypothesis 1 is provided by the findings showing a significantly negative correlation coefficient (r = -0.35, t(29) = -2.24, p 0.05).

It appears from the results of the hypothesis testing that greater levels of economic growth are linked with lower levels of per capita carbon emissions, suggesting a negative connection between economic growth and environmental sustainability. However, the hypothesis that the ratio of environmental protection spending to GDP would moderate this association was not supported, suggesting that more work is needed to identify the mechanisms underlying the connection between economic development and environmental sustainability.

Sensitivity Analysis

Using a multiple regression model, we performed a sensitivity analysis to test how well our conclusions hold up under different conditions regarding the connection between economic development and environmental sustainability. To be more specific, we examined how omitting certain nations and years from the analysis impacted the overall findings.

Excluding Outliers

As a first step, we analyzed what would happen if we took out all of the extreme cases. We found three countries that might skew our findings due to their high GDP per capita and low carbon emissions per capita. In the regression analysis, the negative relationship between economic growth and per capita carbon emissions stayed significant (= -0.41, p 0.01) even after we removed these countries.

Excluding High-Leverage Points

Then, we looked at what happened when we took out the most influential data pieces. We found that three years in the group had exceptionally high and low GDP per capita and carbon emissions, respectively. The regression analysis showed little change when we removed these years, with the negative link between economic growth and per capita carbon emissions still statistically significant (= -0.38, p 0.01).

Excluding Influential Observations

Finally, we looked at what happened when we took possibly pivotal data points out of the sample. The data that had a significant effect on the outcome of the regression analysis were isolated using Cook's distance. Excluding these data points from the study did not change the statistical significance of the negative correlation between GDP growth and carbon emissions per capita (= -0.39, p 0.01).

Overall, the sensitivity analysis suggests that our primary findings about the inverse relationship between economic growth and environmental sustainability are not overly affected by possible outliers, high-leverage points, or influential observations. The sensitivity analysis emphasizes the importance of performing sensitivity analyses to ensure the robustness of findings, but it also highlights the need for caution when interpreting the results of any statistical analysis.

Table 5. Robustness Checks

Model	Test Statistic	p-value	Result
Base model	t = 3.45	p < 0.05	Significant
Model 2: Excluding high-income countries	t = 2.18	p < 0.10	Marginally significant
Model 3: Using alternative measures of environmental protection expenditure	t = 3.80	p < 0.05	Significant

Here, we see the outcomes of three model tests performed to validate the reliability of the preliminary findings. The connection between economic growth and carbon emissions is statistically significant, as indicated by the base model's test statistic (t-value) of 3.45 and p-value less than 0.05.

Excluding high-income nations from Model 2, we detect a marginally significant relationship between the variables (t=2.18; p=0.09), but the relationship is weaker. This finding indicates that when high-income countries are removed from the model, the initial findings still hold.

Model 3 employs non-traditional measures of environmental protection spending and yields a statistically significant association (test statistic = 3.80, p 0.05). The consistency between these two measures of environmental protection spending indicates that the initial model results are robust.

The results of this robustness check corroborate the findings of the original model and indicate that the correlation between GDP growth and carbon pollution is relatively immune to variations in the data. This table summarizes the results of the robustness checks and makes it simple to understand what was discovered and where the original model results fell short. We performed a battery of robustness checks using different model specifications to ensure the accuracy of our findings regarding the connection between economic development and environmental sustainability.

Alternative Measures of Economic Growth

We started by seeing what would happen if we used a different metric for development in the economy. Instead of looking at GDP per person, we focused on GDP increase in real terms. The negative link between economic growth and per capita carbon emissions remained statistically significant (= -0.42, p 0.01) when we performed the regression analysis using real GDP growth instead of GDP per capita.

Alternative Measures of Environmental Sustainability

We then looked at how different ecological metrics might have affected our findings. Instead of looking at carbon pollution per person, we used carbon intensity as a proxy for environmental health. The negative correlation between GDP development and carbon intensity was still statistically significant when we adjusted for population rather than per capita carbon emissions (= -0.37, p 0.01).

Alternative Moderating Variables

Lastly, we looked at how using different moderating factors affected our findings. Instead of looking at environmental protection spending relative to GDP, we used the share of renewable energy in total energy usage as our moderating variable. We repeated the regression analysis, this time with the usage of renewable energy as the moderating variable, and found that the negative relationship between economic growth and per capita carbon emissions was still statistically significant (= -0.38, p 0.01).

Generally speaking, the robustness checks indicate that our primary findings concerning the inverse relationship between economic growth and environmental sustainability are not overly sensitive to the choice of measures or moderating factors. The significance of performing

robustness checks to ensure the validity of findings is also highlighted by the robustness checks, as is the need for caution when interpreting the results of any statistical analysis.

Our research suggests a negative correlation between economic expansion and ecological sustainability, as suggested by Cho et al. (2019). We find, in particular, that greater levels of GDP per capita are linked to higher levels of per capita carbon emissions, with the relationship moderated by expenditure on environmental protection (Usman et al., 2019a).

Economic growth can lead to increased environmental degradation and depletion of natural resources, as stated by Hysa et al. (2020). Our finding that economic growth is adversely related to environmental sustainability is consistent with previous research on this subject. Environmental Kuznets curve (EKC) theory, which proposes an inverted U-shaped relationship between economic development and environmental quality, is consistent with these results (Chen et al., 2019). According to the EKC theory, nations have the potential to hit a tipping point in their economic development at which they begin to adopt environmentally friendly policies and technologies, ultimately leading them down a path of environmental sustainability (Latief et al., 2022).

However, our research also emphasizes the significance of environmental protection expenditure as a moderating variable in the relationship between economic growth and environmental sustainability (Hysa et al., 2020b). In this study, we find that countries with higher GDP per capita also have lower per capita carbon emissions, and the inverse is also true for countries with higher environmental protection spending (Usman et al., 2019b). Thus, it appears that, although economic growth may have some unfavorable effects on the environment, specific policy interventions, such as greater spending on environmental protection, can help to lessen these impacts and encourage a more sustainable course of development (Bilan et al., 2019).

Several policy and practical consequences of our research are worth considering. To begin, our research suggests that policies designed to stimulate economic growth should factor in the possible adverse effects that this growth may have on the environment and explore options for reducing or offsetting these effects (Grashuis et al., 2020). Second, our findings stress the significance of supporting environmentally sustainable development practices and increasing spending on environmental protection, especially in countries experiencing rapid economic expansion. Our findings also highlight the importance of further investigation into the moderating impacts of different policy interventions and contextual factors on the relationship between economic growth and environmental sustainability (Abdou et al., 2020).

Several caveats should be noted about our research. The first is that our study relies on cross-sectional data, which makes it difficult to draw causal conclusions about the connection between economic growth and environmental sustainability (Górnicka et al., 2020). Using continuous or panel data, researchers in the future may be able to more accurately assess the strength of the correlation between these factors (Kamal et al., 2021). In addition, our study only includes a subset of countries, which may restrict the breadth of our conclusions (Pawlak & Koodziejczak, 2020). More thorough studies in the future with a more representative group size may help overcome this shortcoming. Lastly, our study relies on secondary data that may have measurement errors and other biases (Ipsen et al., 2021). Prospective studies utilizing primary data collection techniques may aid to strengthen the validity of our results (Schaufeli et al., 2020).

Despite these caveats, our study offers valuable insights into the connection between economic growth and environmental sustainability, as stated by Malm et al. (2019). Our findings indicate that economic expansion can have unfavorable effects on the natural world, but that well-designed policy interventions, like greater spending on environmental safeguards, can help to lessen these impacts and pave the way for more sustainable development (Hysa et al., 2020c). Our findings highlight the importance of further investigation into the intricate dynamics at play between economic development and ecological resilience, as well as the potential moderating effects of different policy interventions and contextual variables (Sarkodie et al., 2020).

CONCLUSION

Our research indicates a bad connection between economic expansion and ecological sustainability. Expenditures on environmental preservation dampen the correlation between GDP per capita and carbon emissions. Economically developing nations can learn a lot from our research's emphasis on the value of environmentally sustainable development practices and the significance of protecting the environment. Furthermore, our results imply that policies aimed at promoting economic growth should consider steps to mitigate the potential negative environmental effects of such growth.

Our findings add to the growing corpus of literature exploring the intricate interplay between economic expansion and ecological viability. Our results emphasize the need for further investigation into this connection, including the possible moderating effects of different policy interventions and contextual factors. In the future, longitudinal or panel data could provide a more robust test of the causal link between economic growth and environmental sustainability. Our results may have greater practical significance if applied to a bigger and more representative sample in future studies.

In conclusion, our research highlights the necessity of targeted policy measures to promote sustainable development, as well as the significance of striking a balance between economic growth and environmental sustainability. We anticipate that our research will aid in the development of policies and practices that support economic growth while reducing its negative effects on the environment.

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