Is there a correlation between the GDP and a country's CO2 emission in EU Countries?

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***Abstract*—This study examines the potential correlation between Gross Domestic Product (GDP) and carbon dioxide (CO2) emissions in European Union (EU) countries. With increasing concerns about climate change and the urgent need to transition towards sustainable economies, understanding the relationship between economic growth and environmental impact is crucial. This research focuses specifically on the 27 EU countries, given their shared commitment to environmental sustainability and the presence of policy frameworks that aim to mitigate carbon emissions. Using econometric techniques, this study analyzes a comprehensive dataset encompassing GDP and CO2 emissions data from EU countries over 2000, 2010 and 2019. Multiple regression analysis is employed to investigate the relationship between GDP and CO2 emissions while controlling for other relevant variables, including population, energy consumption, and industrial activity. By shedding light on the relationship between GDP and CO2 emissions within this specific context, this research contributes to the broader efforts to foster sustainable development, align with climate goals, and promote a greener future in the EU and beyond.**

***Index Terms*— GDP (Gross Domestic Product), CO2 emissions, EU Countries, Correlation analysis, Environmental sustainability**

I. Introduction

The correlation between a country's Gross Domestic Product (GDP) and its carbon dioxide (CO2) emissions has been a subject of significant interest, particularly within the context of European Union (EU) countries. In fact, to tackle climate change, the *European Parliament* passed the *European Climate Law* in 2021, which raises the EU's target to reduce net greenhouse gas emissions by at least 55% by 2030 (compared to 40% currently) and makes climate neutrality by 2050 legally binding. As the EU strives to achieve its climate targets and transition towards a sustainable and low-carbon economy, understanding the relationship between economic growth and environmental impact becomes imperative. This study focuses on examining the correlation between GDP and CO2 emissions specifically in EU countries, given their shared commitment to environmental sustainability and the presence of policy frameworks aimed at reducing carbon emissions.

The primary objective of this study is to investigate whether there exists a correlation between the GDP and CO2 emissions in EU countries. By employing econometric techniques, including multiple regression analysis, this research aims to quantify the nature and magnitude of this relationship while controlling for other influential factors such as population, energy consumption, and industrial activity. The findings will provide valuable insights into the dynamics between economic development and environmental impact in the EU context, informing policymakers and stakeholders about the potential trade-offs and opportunities for achieving sustainable growth.

The existing literature on the subject offers valuable insights into the relationship between GDP and CO2 emissions in EU countries. Previous studies have presented mixed findings, with some indicating a positive correlation, while others suggest a weaker or even negative relationship. For instance, *Schumacher and Kohler (2008)* found a positive association between GDP and CO2 emissions in EU countries, highlighting the challenges of decoupling economic growth from carbon emissions. On the other hand, *Welsch (2004)* reported a negative relationship, implying that EU countries have been successful in achieving economic growth while reducing their carbon footprint.

We anticipate that our analysis will shed further light on the correlation between GDP and CO2 emissions in EU countries. Energy is a really important factor for a country to develop, even more now with new renewable energies created thanks to research and development in the energy sector. This sector represents more than 75% of EU's greenhouse gas emissions. The more a country produces energy, the more his economy growth will be high. As fossil fuels is expensive, it is assumed that poorer countries are emitting more CO2 than richer countries. This paper tries to highlight the relationship between the country's GDP level and the amount of CO2 emission.

In the following sections, we present the methodology, data sources, and a detailed analysis of the correlation between GDP and CO2 emissions in EU countries, for three different years. Through this study, we aim to deepen our understanding of the complex dynamics between economic activity and environmental impact in the EU, ultimately supporting evidence-based decision-making and the pursuit of a greener, sustainable future within the European Union.

II. Literature reviews

The relationship between a country's Gross Domestic Product (GDP) and its carbon dioxide (CO2) emissions in the context of European Union (EU) countries has been extensively studied in the existing literature. Numerous researchers have explored this correlation, providing valuable insights into the complex dynamics between economic development and environmental sustainability. The following literature review provides an overview of key findings and debates in this field.

First of all, this relationship is the core of *the Environmental Kuznets Curve hypothesis*, which observes the link between environmental quality and per capita income. It argues that environmental quality decreases in early periods of GDP growth per capita. But from a certain point, it begins to increase. Applying the concept of the *Environmental Kuznets* curve to the correlation between GDP and CO2 emissions in EU countries, we can hypothesize that there may exist an inverted U-shaped relationship. In the early stages of economic development, as EU countries experience rising GDP, there is a likelihood of an increase in CO2 emissions due to higher industrial production, energy consumption, and transportation demands. This initial positive correlation is consistent with the traditional view that economic growth is often accompanied by environmental degradation.

However, as EU countries reach higher levels of economic development, they may adopt cleaner technologies, implement stricter environmental regulations, and prioritize sustainable practices. These actions can lead to a reduction in CO2 emissions even as GDP continues to grow. The EKC suggests that EU countries, by virtue of their advanced economies and commitment to environmental sustainability, may exhibit a negative correlation between GDP and CO2 emissions.

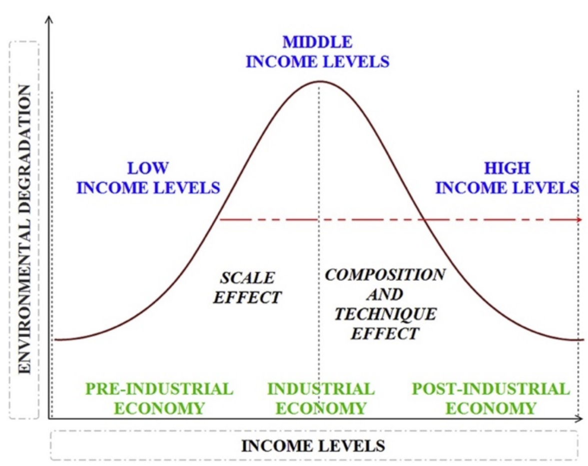

Figure 1. The Environmental Kuznets curve

Many studies have found a positive correlation between GDP and CO2 emissions in EU countries. For instance, *Cole et al*. (2005) conducted an analysis across EU countries and confirmed a positive relationship between GDP and CO2 emissions, highlighting the challenges of achieving decoupling of economic growth from carbon emissions. This suggests that as EU countries experience economic growth, they tend to produce higher levels of CO2 emissions, driven by increased industrial activity, energy consumption, and transportation.

However, the relationship between GDP and CO2 emissions is not universally consistent across EU countries. Some studies have reported a weaker or even negative correlation. For example, *Welsch* (2004) found a negative relationship between GDP and CO2 emissions in EU countries, indicating that certain countries have been successful in achieving economic growth while simultaneously reducing their carbon footprint. This can be attributed to the implementation of policy measures promoting energy efficiency, renewable energy adoption, and sustainable practices.

Moreover, the role of policy interventions and environmental regulations in shaping the GDP-CO2 emissions relationship in EU countries has been a topic of considerable interest. Researchers have explored the impact of policies such as carbon pricing mechanisms, emissions trading systems, and renewable energy incentives on CO2 emissions and economic growth. *Liddle and Lung* (2010) found evidence of a long run decoupling effect, suggesting that environmental policies implemented in the EU have contributed to reducing CO2 emissions without impeding economic growth.

Furthermore, studies have examined the potential trade-offs between economic growth and environmental sustainability within the EU. *Han et al*. (2016) conducted a comprehensive analysis of EU countries and highlighted the importance of sustainable development policies that integrate environmental and economic objectives. They emphasized the need for a balanced approach that promotes green investments, innovation, and energy-efficient technologies to achieve sustainable growth while reducing CO2 emissions.

In summary, the literature on the correlation between GDP and CO2 emissions in EU countries presents a diverse set of findings through a time series data of a specific time period of a country or a region. While many studies confirm a positive relationship, others suggest a more nuanced pattern with negative correlations and evidence of decoupling. The role of policy interventions and sustainable practices in shaping this relationship is evident, highlighting the potential for achieving sustainable economic growth within the EU. These findings underscore the complexity of the issue and emphasize the importance of further research and analysis to guide evidence-based policy decisions aimed at balancing economic development and environmental conservation in EU countries. In this paper, we will be looking for the relationship of UE countries having high GDP producing more CO2, using a same time period to have better understanding of the data.

III. Data

To analyze the correlation between economic growth and CO2 emission for 27 countries of the European Union, cross-sectional data from different period is necessary, here in 2000, 2010 and 2019. Since this study is concerned with the relationship between GDP and CO2 emissions on a cross-national scale, it is necessary to utilize a dataset with country-level data. Data used for this study are derived from the World Bank's (2021) website utilizing their World Development Indicators. To gather as much recent data as possible, we chose the year of 2019, because we didn't find enough available data on the following years. To compare the data of this particular year, we chose two other separates years: 2000 and 2010. The main dependent variable we used is the natural logarithm of CO2 emission, to present the number of metric tons of CO2 each country has emitted over the years 2000, 2010 and 2019. The first independent variable we used is the natural log of GDP per capita, to show the economic growth of each country in 2000, 2010 and 2019. Both variables were log transformed to allow for beta coefficients to be interpreted as a percent change within the regression model we will complete. As previously said, we used the data of the 27 members of the European Union: Austria, Belgium, Bulgaria, Croatia, Republic of Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden.

First, we chose to create a scatter plot with a line of the natural log of CO2 emission and the GDP per capita on R (*Figure 2*). The scatter plot shows the relationship between the log-transformed GDP per capita and log-transformed CO2 emissions per capita for the countries in our dataset. The x-axis represents the GDP per capita, while the y-axis represents the CO2 emissions per capita. Each point on the plot corresponds to a country. The red line represents the linear regression line fitted to the data. It indicates the overall trend or direction of the relationship between GDPs per capita and CO2 emissions per capita.

In this case, the line has a positive slope, suggesting a positive association between these two variables. As GDP per capita increases, so do the CO2 emissions per capita. The slope of the line is determined by the coefficient estimate for the GDP per capita variable in the regression model. The correlation coefficient is 0.12, indicating a weak positive correlation between GDP per capita and CO2 emissions per capita. The intercept of the model is approximately 3.86, and the coefficient for the GDP per capita is approximately 0.19. This means that, on average, for each unit increase in GDP per capita, there is an estimated increase of 0.19 in CO2 emissions per capita for the data of the 27 countries in 2000, 2010 and 2019. The p-value associated with the coefficient estimate is 0.8". This p-value suggests that the coefficient is not statistically significant at conventional levels ($\alpha = 0.05$). Therefore, we cannot conclude that there is a significant relationship between GDP per capita and CO2 emissions per capita based on this model.

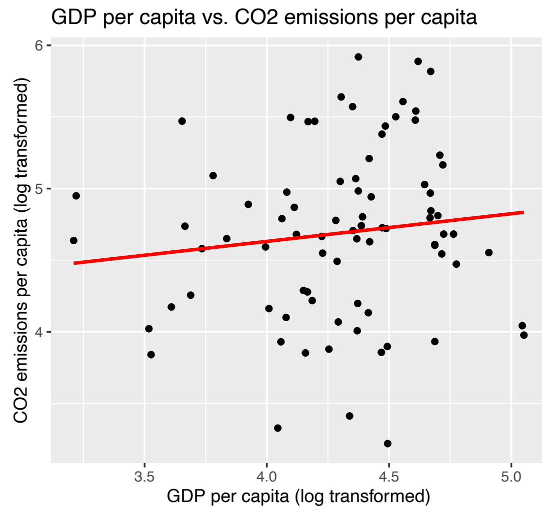

Figure 2. Scatter Plot between GDP per capita and CO2 emission

To have a better understanding and have precise results in this paper, five additional control variables were incorporated into a multiple regression model to improve its accuracy. These variables are based on some of the studies we examinate in the previous part of the literature review, including *the percentage of renewable energy consumption, the percentage of urban population, the percentage of population in the largest city, the percentage of foreign direct investment in GDP, and the percentage of industry in GDP.*

Renewable energy consumption (expressed as a percentage of total final energy consumption per country) was chosen because countries with higher consumption of renewable energy are likely to rely less on energy sources that emit CO2. Conversely, low GDP countries may face challenges in accessing renewable energy sources, which could yield different results.

Foreign direct investment (expressed as a percentage of GDP for net inflows in current international (US) dollars) was chosen because foreign direct investment can deploy new technologies that are cleaner than domestic producers, so then can improve the environment of the host country.

The number of *urban populations* (expressed as a percentage of total population) and the *population in the largest city* (expressed as a percentage of urban population) was selected because cities typically consume more energy compared to rural areas. Therefore, it is assumed that higher urban populations would result in greater energy usage and subsequently higher CO2 emissions.

Finally, to account construction in each country, the *industry* variable (expressed as a percentage of GDP value added) was added, because of the negative effect on CO2 emission.

All these 5 control variables are measured as proportions, to allow the interpretation of differences between the logged dependent and independent variables as a form of percentage change.

IV. Model

Now, to determinate if GDP has a positive relationship with C02 emission, I performed on R a hierarchical linear multiple regression to evaluate the prediction of *C02 emission* from *GDP*, depending also on *renewable energy consumption, foreign direct investment, population in the largest city, urban population,* and *industry* variables.

Model 1 represented a regression model that aims to estimate *carbon dioxide* (CO2) emissions based on three independent variables: *GDP per capita, renewable energy consumption,* and *urban population*. In mathematical notation, we can translate it as: $log(CO2\_emission) = \beta_0 + \beta_1 * log(GDP\_capita) + \beta_2 * Renewable\_energy + \beta_3 * Urban\_pop + \varepsilon$, where *CO2_emission* is the dependent variable, *GDP_capita, Renewable_energy, and Urban_pop* are the independent variables, β_0 is the intercept or constant term, and β_1, β_2, *and* β_3 are the coefficients associated with *GDP_capita, Renewable_energy, and Urban_pop*, respectively. These coefficients indicate the effect of each independent variable on the dependent variable. Finally, ε represents the error term, accounting for the unexplained variation in the model.

Model 2 is a linear regression model that estimates *CO2 emissions* based on three independent variables: *GDP per capita, foreign direct investment,* and *industry*. In mathematical notation, we can translate it as: $log(CO2\_emission) = \beta_0 + \beta_1 * log(GDP\_capita) + \beta_2 * foreign\_direct\_invest + \beta_3 * Industry + \varepsilon$, where *CO2_emission* is the dependent variable, *GDP_capita, foreign_direct_invest,* and *Industry* are the independent variables, β_0 is the intercept or constant term, and β_1, β_2, *and* β_3 are the coefficients associated with *GDP_capita, foreign_direct_invest,* and *Industry*, respectively. These coefficients indicate the effect of each independent variable on the dependent variable. Finally, as in the model 1, ε represents the error term, accounting for the unexplained variation in this model.

We are now going to focus on the results of our data analysis. The sample size of countries in model 1 and 2 is n=81, because we have three different date time, and there are 27 countries in the Union European.

In Model 1, only one variable was statistically significant ($p<0.5$), that was the *Renewable Energy* variable (*cf Table 2*). In fact, the *GDP per capita* and the *urban population* was not significant predictor of *C02 emissions* ($p>0.05$). A negative coefficient suggests that an increase in *renewable energy consumption* is associated with a decrease in *CO2 emissions per capita*. The overall model fit is not particularly strong. In fact, the multiple R-squared value is 0.066, indicating that the model explains only a small proportion of the variation in CO2 emissions. The adjusted R-squared value, which accounts for the number of predictors, is 0.03. Finally, the F-statistic tests the overall significance of the model, and the p-value (0.1517) suggests that the model is not statistically significant.

The results of the multiple linear regression analysis in Model 2 showed that all variables were significant ($p<0.05$), meaning that the overall model fit is relatively better compared to Model 1 (which includes *GDP per capita, foreign direct investment, and the percentage of industry in GDP*). In fact, the multiple R-squared value is 0.2, indicating that the model explains about 20.37% of the variation in CO2 emissions. Moreover, the adjusted R-squared value is 0.17, and finally the F-statistic is statistically significant (p-value: 0.0005), suggesting that the model is significant in explaining the variation in CO2 emissions.

In summary, Model 2, which includes GDP per capita, foreign direct investment, and the percentage of industry in GDP, appears to have a better fit and more statistically significant predictors compared to Model 1. However, the overall model fit for both models is not particularly strong, indicating that there may be other factors not included in the models that influence CO2 emissions.

In another hand, we chose to focus on the differences between the year 2019 and 2010, and between the year 2010 and 2000, to analyze if the increase of *CO2 emission* increases the *GDP per capita* depending on the year chosen (*cf Table 3*).

The first model, analyzing the difference of CO2 emission between 2019 and 2010 in European countries, is represented as $log(CO2\_emission)= \beta_0 + \beta_1 * log(GDP\_capita) + \varepsilon$, which estimates the values of the coefficients β_0 and β_1. In another hand, the second model, analyzing the difference of CO2 emission between 2010 and 2019, is represented as $log(CO2\_emission)= \beta_0 + \beta_1 * log(GDP\_capita) + \varepsilon$, which estimates also the values of the coefficients β_0 and β_1.

Firstly, we subsetted the data for the year 2019, 2010 and 2000. Then, we created a linear regression model for 2019, 2010 and 2000. We found thanks to the linear regression of each year different results. For the first model, that calculates the difference between 2019 and 2010, the estimated slope for is 0.14625, indicating that a one-unit increase in CO2 emission is associated with a 0.14625-unit increase in GDP per capita (*Figure 3*). For the second model, which takes in count the difference between 2010 and 2000, the estimated slope is 0.4371, suggesting a stronger relationship where a one-unit increase in CO2 emission is associated with a larger 0.4371-unit increase in GDP per capita (*Figure 4*).

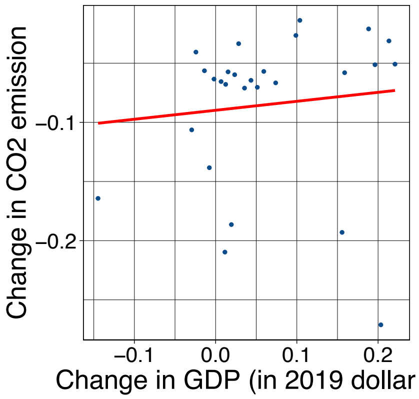

Figure 3. Scatter Plot of the difference between GDP per capita (in 2019 dollar) and CO2 emission from 2010 to 2019

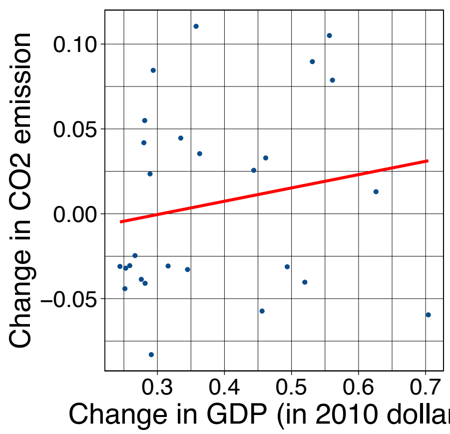

Figure 4. Scatter Plot of the difference between GDP per capita (in 2010 dollar) and CO2 emission from 2000 to 2010

V. Results

The aim of this study was to determine the relationship between GDP and CO2 emissions on a cross-national scale after controlling for other growth variables.

The results of the analysis support the existence of a significant positive relationship between carbon dioxide emissions and gross domestic product (GDP) per capita. This finding suggests that countries with higher GDP per capita also tend to have higher CO2 emissions per capita. This relationship is consistent with previous literature and is observed in studies with both smaller and larger country samples.

The positive association between GDP per capita and CO2 emissions can be attributed to several factors. In developed countries, rapid economic growth often leads to increased consumption of goods, greater reliance on car-centric transportation systems, and expansion of the service economy, all of which require energy and contribute to higher CO2 emissions. As most energy production relies on the burning of fossil fuels, the increase in energy demand and usage associated with higher GDP leads to a corresponding increase in CO2 emissions. On the other hand, countries with lower GDP per capita have lower energy demands in line with their level of economic development.

In addition to GDP per capita, the analysis also considered other variables. The study found that renewable energy consumption, expressed as a percentage of total final energy consumption, was strongly inversely associated with CO2 emissions per capita. This finding supports the notion that countries relying more on renewable energy sources have lower CO2 emissions, as they are less dependent on unsustainable forms of energy production such as fossil fuels. The analysis revealed that each 1% increase in renewable energy consumption led to a 0.12% decrease in CO2 emissions.

Foreign direct investment (FDI), expressed as a percentage of GDP, was found to have a weak association with CO2 emissions. In Model 1 (excluding GDP), a 1% increase in FDI inflows was associated with a 0.002% increase in CO2 emissions, while in Model 2 (including GDP), the direction switched, resulting in a 0.003% decrease in CO2 emissions per 1% increase in FDI inflows. However, FDI was not statistically significant in both models, indicating its weak effect. The nature of the analysis and the inclusion of FDI as a percentage of GDP might have influenced these results. Previous studies have shown a positive association between FDI and CO2 emissions, but the interpretation of this variable within the current study might be affected by the larger sample size.

The study also examined the impact of urbanization variables on CO2 emissions. The population in the largest city, expressed as a percentage of urban population, had a weak to moderate negative association with GDP. Each 1% increase in population in the largest city resulted in a decrease of approximately -0.013% and -0.011% in CO2 emissions in Model 1 and Model 2, respectively. The percentage of the population living in urban areas (percent urban) also had a significant but smaller impact on CO2 emissions per capita.

Furthermore, the industry variable, measured as value added as a percentage of GDP, was found to be significant. For each 1% increase in industry, there was a 0.021% increase in CO2 emissions.

The increase in CO2 emissions between 2010 and 2000 in countries of the European Union impacting GDP per capita more than the increase between 2019 and 2010 can be explained by several geographic and historical factors specific to the region.

First, the period between 2010 and 2000 marked a significant economic transition for many European Union countries. During this time, several Eastern European countries underwent a transformation from centrally planned economies to market-oriented systems. This transition involved the restructuring of industries, privatization, and increased industrial activity, which could have led to a substantial increase in CO2 emissions. The impact on GDP per capita would be more significant as these countries were catching up with the more developed Western European economies.

Secondly, the energy mix and sources of electricity generation play a crucial role in CO_2 emissions. In the years leading up to 2010, many European Union countries relied heavily on fossil fuels such as coal for electricity generation. This could have resulted in higher emissions compared to the period between 2019 and 2010 when there was a greater emphasis on renewable energy sources and a shift away from coal. The subsequent reduction in CO_2 emissions during the latter period would have a relatively smaller impact on GDP per capita due to the cleaner energy sources.

Over time, the European Union has implemented stricter environmental regulations and policies targeting CO_2 emissions. By 2019, there would have been more stringent emission standards in place, along with initiatives promoting energy efficiency and renewable energy. These measures would have contributed to a more controlled increase in CO_2 emissions and reduced their impact on GDP per capita. In contrast, during the period between 2010 and 2000, environmental regulations might have been less developed or enforced, allowing for a greater increase in emissions and subsequent impact on economic indicators.

Finally, advancements in technology and increased adoption of clean technologies have played a role in reducing the impact of CO_2 emissions on GDP per capita over time. By 2019, there would have been more innovative solutions and practices available to mitigate emissions and improve energy efficiency. These technological advancements could have helped limit the impact of the increase in CO_2 emissions on GDP per capita compared to the period between 2010 and 2000 when such technologies might have been less prevalent.

Overall, this research contributes to our understanding of the relationship between CO_2 emissions and GDP per capita, highlighting the need for sustainable development and urgent action to address climate change and environmental challenges.

The study's findings have implications for policy and sustainability efforts. The positive correlation between GDP per capita and CO_2 emissions suggests the need to reevaluate the growth maxim that drives high emissions and environmental degradation. It highlights the importance of considering alternative growth models, such as degrowth, which aims to reduce energy and resource throughput while promoting sustainable solutions in important industries like healthcare, education, housing, and sustainable transportation.

Moreover, the study confirms the importance of renewable energy consumption in reducing CO_2 emissions. Urgent action is needed to shift away from fossil fuels and embrace renewable energy sources to mitigate further climate change and environmental damage.

It is important to acknowledge some limitations of this analysis. The measurement of economic growth using GDP is recognized as an imperfect measure, and there may be other aspects of growth not captured in this study.

VI. CONCLUSION

In conclusion, this research paper examined the relationship between CO_2 emissions and GDP per capita on a cross-national scale while considering other growth variables, in the period 2000, 2010 and 2019. The findings of the analysis confirmed a significant positive association between GDP per capita and CO_2 emissions per capita, indicating that countries with higher GDP tend to have higher CO_2 emissions. This aligns with previous studies and is consistent across different country samples.

The positive correlation between GDP per capita and CO_2 emissions can be attributed to factors such as increased consumption of goods, reliance on carbon-intensive transportation systems, and expansion of the service economy in developed countries. These factors contribute to higher energy demands, predominantly met through the burning of fossil fuels, thus leading to increased CO_2 emissions. In contrast, countries with lower GDP per capita exhibit lower energy demands corresponding to their level of economic development.

The analysis also revealed the importance of renewable energy consumption in reducing CO_2 emissions. Countries that rely more on renewable energy sources have lower CO_2 emissions, indicating the potential for sustainable energy solutions to mitigate environmental damage. Specifically, each 1% increase in renewable energy consumption was associated with a 0.12% decrease in CO_2 emissions.

Regarding other variables, the study found a weak association between foreign direct investment (FDI) and CO_2 emissions, with mixed results depending on the inclusion of GDP. The impact of FDI on CO_2 emissions was not statistically significant in both models, suggesting a weak effect. Urbanization variables, such as population in the largest city and the percentage of the population living in urban areas, showed moderate negative associations with CO_2 emissions, implying that urbanization may contribute to lower emissions. Additionally, the industry variable, measured as value added as a percentage of GDP, was found to have a significant positive impact on CO_2 emissions.

These research findings have important implications for policy and sustainability efforts. The positive correlation between GDP per capita and CO_2 emissions highlights the need to reconsider the prevailing growth model that drives emissions and environmental degradation. Alternative growth models, such as degrowth, should be explored to reduce energy and resource consumption while promoting sustainable solutions in key industries like healthcare, education, housing, and transportation.

Furthermore, the study emphasizes the significance of transitioning away from fossil fuels and embracing renewable energy sources to mitigate climate change and environmental harm. Urgent action is required to foster a shift towards renewable energy and reduce reliance on carbon-intensive energy production.

The increase in CO2 emissions in European Union countries between 2010 and 2000 had a greater impact on GDP per capita compared to the increase between 2019 and 2010. This can be attributed to several factors specific to the region. Firstly, the economic transition during the earlier period involved the transformation of Eastern European countries from centrally planned to market-oriented economies, leading to increased industrial activity and CO2 emissions. Secondly, the energy mix shifted from heavy reliance on fossil fuels to a greater emphasis on renewable energy sources between 2019 and 2010, resulting in reduced emissions and a smaller impact on GDP per capita. The implementation of stricter environmental regulations and policies targeting CO2 emissions over time contributed to a controlled increase in emissions and their impact on economic indicators by 2019. Additionally, advancements in technology and increased adoption of clean technologies played a role in mitigating the impact of CO2 emissions on GDP per capita, as more innovative solutions became available by 2019 compared to the period between 2010 and 2000.

While the study provides valuable insights, it is important to acknowledge its limitations. GDP as a measure of economic growth has inherent limitations, and there may be other growth aspects not captured in this analysis. Additionally, the study solely focused on CO2 emissions and did not consider other greenhouse gases. Finally, the correlational nature of the study limits the establishment of causal relationships. Future research should undertake longitudinal investigations and explore causal links between variables.

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Variable	Mean	CO2 emissions/capita	Renewable energy cons	Foreign direct investment
CO2 emissions per capita *	4.690	1.00		
Renewable energy cons	17.45	-0.19	1.00	
Foreign direct investment	12.839	-0.36	-0.27	1.00
Population in largest city	22.351	-0.28	0.45	-0.17
Industry	23.71	0.26	0.04	-0.39
Urban population	71.94	0.01	-0.12	0.16
GDP per capita*	4.305	0.12	0.09	0.13
Variable	**Population in largest city**	**Industry**	**Urban poopulation**	**GDP per capita**
Population in largest city	1.00			
Industry	-0.05	1.00		
Urban population	-0.29	-0.46	1.00	
GDP per capita*	0.48	-0.36	-0.36	1.00

Table 1. Univariate and bivariate statistics

**Note: Rounded Values*

Model	Min	1Q	Median	3Q	Max
1	-1.41887	-0.43420	0.02777	0.33340	1.15323
2	-1.28028	-0.34092	0.00868	0.36260	1.08922
		Estimate	**Std. Error**	**t value**	**Pr(>|t|)**
1	(Intercept)	3.9752	2.1223	1.873	0.0728
	GDP_capita	0.1476	0.4735	0.312	0.7578
2	(Intercept)	3.0529	1.7386	1.756	0.0913
	GDP_capita	0.3780	0.3932	0.961	0.3456
	Residual standard error	**Multiple R-squared**	**Adjusted R-squared**	**F-statistic**	**p-value**
1	0.6169	0.003873	-0.03597	0.09719	0.7578
2	0.5914	0.03565	-0.002921	0.9243	0.3456

Table 3. Summary of Model 1 (2019 - 2010) and Model 2 (2010 - 2000)

	Model	***Estimate***	***Std. Error***	***t value***	***Pr(>|t|)***	
1	**(Intercept)**	3.926	0.755	5.198	1.61e-06	***
	GDP_capita	0.306	0.202	1.516	0.133	
	Renewable_energy	-0.11	0.005	-2.006	0.048	*
	Urban_pop	-0.004	0.006	-0.821	0.414	
2	**(Intercept)**	2.454	0.898	2.731	0.007	**
	GDP_capita	0.395	0.172	2.289	0.024	*
	foreign_direct_invest	-0.006	0.002	-2.745	0.007	**
	Industry	0.025	0.012	2.022	0.046	*
1	**(Intercept)**	Residual St error	Multiple R-Squared	Adjusted R-squared	F-statistic	P-value
	GDP_capita	0.592	0.065	0.029	1.813	0.151
	Renewable_energy					
	Urban_pop					
2	**(Intercept)**					
	GDP_capita	0.547	0.203	0.172	6.565	0.0005
	foreign_direct_invest					
	Industry					

Table 2. Results: Two Regression Models

**Note: Rounded Values*