Carbon neutrality and net zero goals in the context of sustainable development. Measuring the reverse impact on economy among E.U. countries

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Abstract

Economic development represents a goal for all countries across the globe, however, maybe now more than ever there is a very important need to consider the implications that this can bring on environmental and climate change. Thus, carbon neutrality and net zero goals represent important and current subjects that have gained more interest among all countries in the recent period, especially considering the targets that were set up until 2050. Some of the developing countries are in line or have even completed the actions to become carbon neutral, which can be extremely relevant in today's context. However, many other actions need to be considered before considering these goals achieved globally. The current research focuses on highlighting the importance of carbon neutrality in the current economic environment, by studying if there is indeed a significant correlation between the economic development of a country and the climate-related economic losses that it faces. The dataset used to create the linear regression model includes 24 E.U. countries and the value of the indicators between 2020 and 2022. The study identifies that there is a direct impact of the carbon emissions of a country and its economic losses triggered by climate-related events, which means that the price for evolution and development is paid later by countries if they do not consider greener alternatives. This conclusion can help facilitate future discussions regarding the need to focus future research on the carbon neutrality subject, as sustainable development represents a very much-needed future for all countries.

Keywords

Carbon neutrality, net zero, sustainable development, carbon emissions

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Introduction

The escalating threat of climate change necessitates a global transition towards carbon neutrality and the pursuit of net zero goals. This paper conducts a comprehensive literature review to understand carbon neutrality, exploring its importance in mitigating climate change, and examining the strategies and technological innovations aimed at achieving net zero emissions. It delves into the different approaches to carbon neutrality, the definition and implications of net zero goals, and the role of policy frameworks and initiatives in fortifying this transition. Ultimately, this paper synthesizes current knowledge to provide a roadmap for policymakers, industry leaders, and stakeholders to navigate the challenges posed by a warming planet.

Achieving carbon neutrality stands as a linchpin for the economy and sustainable living, holding profound implications across various realms. At its core, carbon neutrality plays a pivotal role in combating climate change, a pressing global challenge exacerbated by escalating greenhouse gas emissions. By striving for net-zero emissions, we endeavor to mitigate the adverse effects of climate change, including extreme weather patterns, sea level rise, and ecological disruptions. This concerted effort not only safeguards our environment but also fortifies human health and economic stability, underscoring the critical need for sustainable practices in the modern era.

In the global arena, carbon neutrality assumes paramount significance as countries strive to honor their international commitments under accords like the Paris Agreement. By attaining carbon neutrality, nations not only fulfill their pledges but also exhibit leadership on the world stage, inspiring collaborative action and nurturing a culture of shared responsibility in addressing climate change. Through proactive measures towards carbon neutrality, countries forge partnerships, foster cooperation, and champion a sustainable, resilient future for the global community.

Considering the relevance of the subject, there are some recent researches performed on this field (Gore et al, 2024, Krishnan, M. et al, 2023, Saraji, M. Streimikiene, D. 2023) in which the authors highlight the main challenges to the low carbon energy transition, the effects of the net-zero transition in countries and regions and the main methods and technologies utilized in the process of achieving carbon neutrality. However, by consulting the previous research performed in this area, a gap was identified related to the lack of research regarding the correlation between the economic development of a country and the climate-related economic losses it faces. Therefore, the current paper aims to highlight the importance of carbon neutrality in the current economic environment, by studying if there is indeed a significant correlation between the economic development of a country and the climate-related economic losses, by using a linear regression model utilizing a database including 24 European countries. By implementing this research, the current paper contributes significantly to filling the existing gaps related to the carbon neutrality subject. The research methodology used to create the study implies the use of a quantitative method, by creating a linear regression model in which climate-related economic losses are considered to be the dependent variable, and GDP per capita and total carbon emissions are considered the independent variables. The database was created by including the evolution of each variable between the years 2020-2022 for 24 European countries. The study identifies that when the independent variables represented in the model by the country's economic development level (GDP per capita) and the carbon emissions level increase, there will be a direct and significant increase in the climate-related economic losses of the country. In this case, the value of the current research lies in the importance of the problem related to the potential price that we as a global population have to “pay” for development, as the study manages to quantify the impact that economic development might have on our environment. In this context, even if there is a significant tendency towards sustainable development, there is a continuous need to improve the existing actions in this direction, and the current study supports this statement.

The structure of the paper will contain firstly a literature review related to the subject of carbon neutrality in which the problem is going to be outlined by highlighting the net zero goals and implications, the implications of carbon neutrality and sustainable development, and the main strategies used to achieve carbon neutrality as well as the technological innovations supporting carbon neutrality. The second part of the paper will focus on presenting the practical part of the research by discussing the data and methodology used and the main hypothesis considered for the study. The last part will include the main results of the research, discussions, and the final outlined conclusions.

Literature review

1.1. Understanding carbon neutrality in a sustainable economy

Peer-reviewed studies evaluate the efficacy of these methods, offering insights into their potential and limitations (Gore et al, 2024). Comparative analyses identify the most cost-effective and sustainable practices for different contexts, whether they be nations, industries, or individual organizations. The literature identifies technological, economic, political, and social barriers, such as the high initial cost of renewable energy technologies, lack of political will, regulatory hurdles, and public skepticism (Saraji and Streimikiene, 2023). Furthermore, this review and another similar research (Lienhard, N. et al, 2023) discuss the ethical concerns related to carbon offsetting, such as the potential for "greenwashing" and the socio-environmental consequences of large-scale afforestation projects on local communities.

A recent study performed by Xu Zhenci (2024) discusses the importance of sustainable land use in achieving Carbon Neutrality goals in China, emphasizing the need for a systematic approach to analyze land use sustainability and carbon neutrality potential across different scales. The study presents China's first multi-scale spatiotemporal optimization pathway for sustainable land use to improve carbon neutrality potential, highlighting as well the implications for policy, cooperation with cross-regional pathways, and cooperation with other development policies. Hao, Li, and Murshed (2023) conducted similar studies as well, focusing on the innovation that China is bringing to the carbon neutrality sector. Their research indicates also a positive correlation between economic development and environmental regulations focused on reducing CO2 emissions. Another study corresponding to Zheng and Hou (2024) highlights the importance of integrating different sectors and technologies to achieve carbon neutrality, with a specific focus on sectoral integration, carbon removal technologies, and CCS.

According to a recent article published by the European Parliament (2023), carbon emissions contribute to climate change in various ways, primarily through the release of greenhouse gases into the atmosphere. Also, based on a study performed by Ghosh (2019), during 1965 and 2017, there were 20 companies worldwide, which were responsible for most (35%) global carbon emissions. Out of these 20 companies, 12 are state-owned, cumulating 58% of the carbon emissions, and only 8 are private. The country with the highest number of companies included in this top is the U.S. with 4 companies all of them private (representing 24% of the total carbon emissions from the top). In addition, manufacturing processes, particularly in heavy industries such as cement, steel, and chemicals, can be energy-intensive and produce large amounts of emissions (Majova, A., et al, 2022).

1.2. Understanding Net Zero goals and implications

A publication by the Institute for Sustainability Leadership at the University of Cambridge (2021) presents a strategic blueprint for businesses to progress towards achieving net zero emissions by 2050. This framework entails ten interconnected tasks to be undertaken by business, government, and financial leaders within the upcoming decade. The objective is to assist companies in transitioning to a sustainable economy that is in harmony with the UN Sustainable Development Goals and strives to limit global warming to 1.5°C. Furthermore, the framework urges businesses to strategically plan, initiate measures to decarbonize operations and products, integrate net zero objectives into decision-making processes, assign accountabilities, align incentives, and cultivate the necessary capabilities and resources to realize net zero emissions (Wang, Z. et al, 2023).

According to the theoretical framework provided by the University of Oxford (2022), the concept of net zero involves lowering greenhouse gas emissions to a level where any residual emissions are counterbalanced by an equal amount of carbon removal or offsetting. In countries such as Australia, there is a high awareness of zero-carbon housing, as shown in a recent study (Li, H.X., et al, 2022), financial incentives are extremely important to achieve development in this sector. Additionally, even if financial implications are important, the support of builders and legislation represent also aspects, that need to support the orientation toward carbon housing.

1.3. Strategies for achieving Carbon neutrality and Net Zero goals. The forecasted economic impact

The European Union has set ambitious targets and regulations related to carbon neutrality and net zero as part of its efforts to combat climate change. One of these regulations represented by the European Green Deal, is a set of policy initiatives by the European Commission with the overarching goal of making the EU climate-neutral by 2050. This includes targets for reducing greenhouse gas emissions, increasing renewable energy use, and promoting sustainable growth. There is also an action plan in place at the E.U. level (European Council, 2024), The Circular Economy Action Plan, which aims to promote sustainable resource, use and reduce waste generation. This includes measures to reduce the carbon footprint of products and encourage recycling and reuse (Riemer, M, et al, 2023).

At a global level, 137 countries have committed to achieving the Net Zero goals stated by the Energy and Climate Intelligence Unit until 2050. However, based on the most recent data published by Wallach (2021), there are some specific countries, which, based on their actions, either achieved the targets (for example: Bhutan and Suriname) or are set up to achieve the targets earlier (example: Uruguay in 2030, Finland in 2035, Austria and Iceland in 2040, Germany and Sweden in 2045). On the other hand, the evolution regarding carbon neutrality targets is slower, as based on the same publication only six countries (Denmark, France, Hungary, New Zealand, and the U.K.) have translated the carbon neutrality targets into their legislation, and almost 72% of the 137 countries have ongoing discussions regarding this possibility. Another study (Li, W. et al, 2023) indicates that Sichuan Province will achieve a peak regarding carbon emissions in 2028 and will be able to achieve neutrality in 2058. Another significant factor to consider is the EU ETS (Emissions Trading System), which plays a crucial role in emissions reduction efforts and the pursuit of carbon neutrality. Furthermore, the Renewable Energy Directive establishes mandatory goals for boosting the proportion of renewable energy within the EU's energy portfolio (European Commission, 2023). At an E.U. level, there are some specific countries, which are more engaged in achieving carbon neutrality and net zero goals, by implementing specific regulations and actions with a focus on a greener environment (European Council, 2024).

In other regions, such as China for example, a recent research (Ren, F., et al, 2023) evaluates the emission efficiency of energy, CO2, and atmospheric pollutants in the Yangtze River Economic Belt (YEB) and Yellow River Ecological Economic Belt (YREB) under the carbon neutrality target. The study applies a Meta-frontier DN-DEA model to assess the emission efficiencies of 19 regions in YEB and YREB from 2011 to 2017. The results show that the overall efficiencies of both economic belts improve significantly when subject to a carbon reduction factor. Moreover, a document published by the U.K. Government in September 2022 guides promoting

sustainability and achieving net zero carbon emissions in construction projects. The document outlines the policy context, scope, and key strategies for achieving sustainability goals in construction projects. The UK government has legislated to achieve at least a 100% reduction in greenhouse gas emissions by 2050, known as the Net Zero Target, which is why the authors highlight the importance of decarbonization and sustainability in public infrastructure and construction projects. One of the main strategies proposed relates to supply chain decarbonization, digital technologies, waste reduction, and resource efficiency to achieve net zero carbon emissions

A study written by Wand et al (2022), approaches the subject of the Covid-19 impact on the collaborations for carbon neutrality actions between the U.S. and China. Both the U.S. and China have made commitments to carbon neutrality and have been engaging in research and cooperation on various aspects of climate change mitigation, including clean energy technologies, renewable energy, carbon capture and storage, and more. While the pandemic may have initially disrupted some collaborative efforts due to travel restrictions and other logistical challenges, the overall commitment to addressing climate change and achieving carbon neutrality will likely continue to drive cooperation between countries like the US and China. The Climate Action Tracker publication (2024) highlights issues with the International Civil Aviation Organization's (ICAO) target of 'carbon neutral growth from 2020' and the insufficiency of current strategies in addressing emissions from international aviation. The document also mentions specific commitments and strategies from countries like the EU, the US, the UK, and China regarding their aviation emissions reductions. Furthermore, it outlines the weaknesses in the CORSIA offsetting scheme introduced by ICAO and the lack of environmental integrity in current rules.

Regarding the economic transformation needed in the net-zero transition, according to a report published by the McKinsey Global Institute (2022), the total amount is estimated to be $275 trillion required capital spending on assets between 2021 and 2050. Moreover, the transition would be front-loaded, with spending needing to rise to almost 9% of GDP between 2026 and 2030 before falling. The impact across sectors, geographic areas, and communities, will be uneven, presenting challenges for some specific countries. In this regard, an analysis published states that developing countries and regions focused on fuel production would invest more relative to GDP in this transition, compared to other countries. Thus, the total amount necessary for the transition in developing countries represents on average 9.8% of their GPD, in fuel-producing regions it increases up to 18%, while in other countries it is only 5.9%. Regarding the pricing evolution of some other specific gases, research published in 2022 (Bouacida, I. et al, 2022) highlights the possibility that methane price will rise soon, as a result of the higher focus on low-carbon gases.

1.4. Technological innovations and solutions supporting carbon neutrality

Energy storage technologies are also emerging as crucial enablers of the transition to carbon neutrality. Innovations in batteries, pumped hydro storage, and other storage solutions are instrumental in overcoming the intermittency of renewable energy sources, ensuring a reliable and resilient energy supply while bolstering the integration of renewables into the grid (Worku, M., 2022).

Continued advancements in renewable energy technologies such as solar, wind, hydroelectric, and geothermal power can significantly increase the share of clean energy in the overall energy mix. These technologies produce electricity with minimal or no greenhouse gas emissions, helping to reduce reliance on fossil fuels (Raghutla and Chittedi, 2023). The report published by the International Energy Agency (2023) provides a perspective regarding the annual investment in power generation based on the allocated technology during 2020-2023 focusing on solar PV, wind, hydro, nuclear energy, coal, and gas power. Moreover, within a study written by Perdana et al (2023), the next-generation energy storage had the highest potential among examined technologies to be able to facilitate the transition towards net zero. Also, in a study written by Matalebi et al (2022), the subject of the trade between the U.S. and Canada is approached, as it plays a significant role in North American decarbonization pathways. Both countries have interconnected electricity grids that allow for the exchange of electricity across the border. This cross-border trade can help to balance supply and demand, improve grid reliability, and support the integration of renewable energy sources.

Data and methodology

The current research aims to identify the correlation between three important indicators: GDP per capita, total carbon emissions, and climate-related economic losses. Also, through the regression model used, the research is going to indicate the main relation that exists between the three variables included in the model and the proportion from the fluctuation of the dependent variable (climate-related economic losses) that can be explained by the

variance of the independent variables (GDP per capita and total carbon emissions). Because the research is going to focus on creating a linear regression model, the formula that is going to be used is the following:

Climate-related economic losses = $\alpha + \beta_1 *$ GDP per capita + $\beta_2 *$ carbon emissions annual value

In the current context of green development and in line with the 17 objectives of sustainable development adopted by the U.N. member states, it is important to understand how each European country contributes to creating a greener future. The database contains the evolution of all the indicators in 2020, 2021, and 2022 based on the reports provided by Eurostat, the European Commission, and the International Monetary Fund for 24 E.U. countries.

Research findings serve as vital benchmarks for assessing progress toward carbon neutrality objectives over time. Monitoring changes in GDP per capita, carbon emissions, and climate-related economic losses allows policymakers to gauge the effectiveness of mitigation and adaptation measures. Flexibility in strategy adjustment ensures alignment with evolving needs on the path to carbon neutrality. Promoting sustainable economic development emerges as a cornerstone in the journey towards carbon neutrality. Encouraging the decoupling of economic growth from carbon emissions entails investments in green technologies, fostering innovation in clean energy, and supporting green job creation. A sustainable economic model can be cultivated through these initiatives, prioritizing environmental stewardship, social equity, and economic prosperity. Building resilience to climate impacts is imperative for achieving carbon neutrality. Understanding the economic repercussions of climate change informs adaptation measures to mitigate vulnerabilities. Investment in climate-resilient infrastructure, disaster preparedness, and nature-based solutions fosters resilience, reducing the risk of future economic losses.

The methodology used to identify the correlation between the data and to quantify the impact of the independent variables (GDP per capita and total carbon emissions) on the dependent variable (climate-related economic losses) uses a linear regression model. The preliminary expectations in terms of the research results are based on the following assumptions presented together with their alternative hypothesis:

H1: Countries with higher GDP per capita often have more resources to invest in technological advancements, infrastructure, and environmental conservation measures, which can influence carbon emissions and resilience to climate-related economic losses.

H2: There is no correlation between the country's GDP per capita, total annual carbon emissions, and climate-related economic losses in the last three years.

H3: As GDP per capita increases, there tends to be a corresponding increase in carbon emissions due to higher levels of consumption, industrialization, and urbanization.

H4: There is no actual impact of the increase in GDP per capita on the carbon emission value of an E.U. country.

H5: Countries with higher carbon emissions are often more vulnerable to climate change events due to factors like increased exposure, inadequate infrastructure, and limited adaptive capacity. Consequently, they may experience greater economic losses in terms of property damage, agricultural losses, healthcare costs, and disruptions to supply chains and economic activities.

H6: There is no correlation between the carbon emission value of an E.U. country and climate-related economic losses.

Research methodology

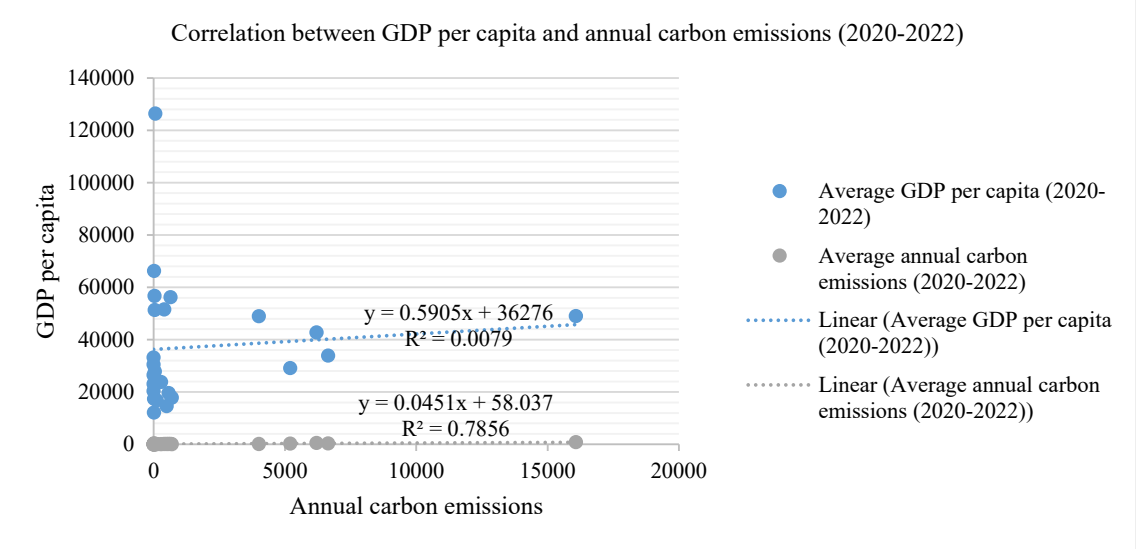
Using the correlation function based on the adapted data set, I can affirm that there is a positive but very weak correlation between the GDP per capita and climate-related economic losses (0.08). A similar result is obtained for the dataset in which it was studied the correlation between the GDP per capita and annual carbon emissions (0.012). However, the study indicated that there is indeed a strong positive correlation between the GDP per capita and climate-related economic losses (0.88).

The regression statistics obtained based on the linear regression model indicate that about 88.9% of the fluctuation of the dependent variable is explained by the fluctuation of the independent variables. Therefore, the variation of the climate-related economic losses is explained in about 89% of the cases by the fluctuation of the GDP per capita and the carbon emissions within the 24 E.U. countries considered in the analysis. The level of significance of the regression model (significance F level) indicates that the model is representative of the research. Also, based on the value of the F statistic (39.9) compared with the F calculated (3.44) statistic (with 2 and 23 degrees of freedom) the null hypothesis for the model can be rejected and the alternative hypothesis can be considered as

verified. The value of the β_1 coefficient of the model (β_1= 0.01) indicates that at an increase of 1 u.m. of the GDP per capita value, the climate-related economic losses will increase by 0.01 u.m. Also, the value of the β_2 coefficient (β_2= 17.4) highlights when the carbon emissions annual value increases by 1 u.m., the value of the climate-related economic losses increases by 17.4 u.m.

Research results and discussion

Based on the performed research, it can be concluded that there is a significant, strong, and positive impact on the GDP per capita, therefore of the economic power and development of a country on the climate-related economic losses that it faces. Based on the data obtained in the first regression model, the H1 hypothesis can be validated, while the H2 hypothesis can be rejected. Also, the model indicates a weak but positive correlation between the GDP per capita and annual carbon emissions in the 24 considered E.U. countries, therefore the H3 hypothesis can be validated (and the H4 hypothesis rejected) but with some constraints and limitations which can be analyzed more in-depth in future researches. Moreover, based on the correlation model, H6 is rejected and H5 validated, as there is a very strong direct impact between carbon emissions and climate-related economic changes.



Graphic no. 1 Correlation between GDP per capita and annual carbon emissions (2020-2022)
Source*: by the authors using Excel Microsoft*

However, the model limitations include the potential impact of other independent variables which might contribute to the increase of the climate-related economic losses of the E.U. countries included in the research. Therefore, a future study can include the focus on adding even more complexity to the model, by considering other indicators related to sustainable development areas (maybe the investment in the biofuel area or biofuel usage in the transportation sector).The data considered for the model are very relevant, as it contains both pandemic and post-pandemic years, which can help highlight the impact that this global event had on the environmental and economic aspects.

Conclusions

The literature on carbon neutrality is vast and diverse, reflecting the complexity of the subject. Overall, it can be concluded that achieving carbon neutrality requires a collaborative effort that encompasses scientific innovation, economic restructuring, and policy reform. The reviewed literature underscores the urgency of the climate crisis and the necessity for immediate action. It also highlights the importance of continued research and dialogue to refine strategies that can lead to a sustainable, carbon-neutral future. In terms of the countries that can be considered to be the top offenders when it comes to pollution and carbon emissions, based on the most recent studies, the U.S. contributes significantly, followed by Saudi Arabia and Russia. Of course, this impact is triggered by sectors of the economy that are the most developed in these countries. The future in achieving carbon neutrality and net zero goals relies on using the most advanced technologies in terms of renewable energy and alternative fuels (while also increasing the potential and efficiency of these solutions).

As validated through the linear regression model, there is a strong correlation and impact between economic development, the level of carbon emissions, and climate-related economic losses among the E.U. countries. In this regard, when the independent variables represented in the model by the economic development level of the country (GDP per capita) and the carbon emissions level, increase, there will be a direct and significant increase in the climate-related economic losses of the country. This means that pollution and carbon emissions are not just affecting the concept of the environment in a general context, but it is demonstrated to affect the economy of the country. This conclusion can help facilitate future discussions regarding the need to focus future research on the carbon neutrality subject, as sustainable development represents a very much-needed future for all countries.

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