Exploring the Correlation Between CO_2 Emissions Per Capita and the Inequality-Adjusted Human Development Index (IHDI)

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Abstract

This study aimed to examine the correlation between CO_2 emissions per capita and the Inequality-Adjusted Human Development Index (IHDI) across 154 countries, with a focus on determining whether the correlation was stronger in developing countries. The study utilized Pearson's correlation test to investigate the relationship between these variables, and the data was divided into four subsets based on the countries' development status: Very High IHDI (>= 0.80), High IHDI (0.70 to 0.79), Medium IHDI (0.55 to 0.69), and Low IHDI (< 0.50). The study found a significant positive correlation globally, with a stronger correlation in developing countries. However, a potentially negative correlation was observed in countries with very high development. These findings offer valuable insights for stakeholders working towards a sustainable future.

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While reducing CO_2 emissions is crucial for climate change mitigation, there has been ongoing discussion about how proposed plans may affect the development standards of developing countries. Due to their limited resources, inadequate investment in innovative technologies, and insufficient funds for adaptation purposes, developing nations are likely to encounter economic repercussions linked to limitation of CO_2 emissions (Pauw et al., 2019). Furthermore, it has been projected that developing nations will heavily depend on fossil fuels to meet their current development needs (Bolin & Kheshgi, 2001). The objective of this study was to investigate the socio-economic impacts of reducing CO_2 emissions on developing countries as compared to developed countries. To achieve this, we conducted a correlation analysis between

CO_2 emissions per capita and overall quality of life, as measured by the Inequality-adjusted Human Development Index (IHDI) across 154 countries.

Literature Review

Measures of Human Development

Previous research focused on the relationship between CO2 emissions and the Human Development Index (HDI), which differs from the IHDI as it doesn't consider inequality. However, both indicators evaluate a country's development based on key factors like life expectancy, education, and GDP per capita at purchasing power parity. These indexes classify human development as *very high* (≥ .80), *high* (.70 to 0.79), *medium* (.55 to 0.69), and *low* (.55 ≤), respectively (Development Programme, 2021).

Correlative Studies

Regarding previous correlative studies on CO_2 emissions and human development, including an analysis of Ethiopia using 2015 data on the top 20 CO_2 emitters and 5 African Nations, found a positive correlation between a country's HDI and per capita CO2 emissions. Teklu (2018) recommended that Ethiopia prioritize industrial development and increase its CO_2 emissions until it reaches a fair emission budget and achieves an HDI of ≥ .8. Moreover, Costa et al. (2011) found a positive correlation between per capita CO_2 emissions and HDI in 147 countries using 2000 data. They also suggested that developing countries aim for HDI scores ≥ 0.80. However, to achieve this and remain within the UN's 2°C warming limit by 2100, they estimated developed nations (HDI ≥ .80) needed to reduce their per capita emissions by 17% and 33% every five years until 2050.

Contrasting the previous study, Simionescu (2021) discovered a negative correlation between HDI/GDP and total greenhouse gas (GHG) emissions in seven EU New Member States

from 1990-2019. The correlation exhibited a stronger negative pattern in countries above a 0.83% GDP growth threshold, and this was attributed to the decline of manufacturing industries and growth of the services sector as countries develop, which promotes pollution reduction.

Causal Relationship Studies

For causal studies, Bieth (2021) conducted research on the impact of GDP and HDI on CO_2 emissions per capita in six ASEAN countries as well as Japan. The study hypothesized a positive relationship between GDP, HDI, and CO_2 emissions per capita based on Kuznets' theory, but the panel data regression from 2007-2018 showed insignificant positive effects of both variables on CO2 emissions per capita. Additionally, using a Two-Stage Least Square (2SLS) regression, Wang et al. (2018) found that for the years 1994-2014 in Pakistan, higher CO_2 emissions were associated with increases in human development, revealing a bidirectional causality between CO_2 emissions and HDI. In line Wang et al.'s findings, Bedir and Yilmaz (2015) established that in 12 out of the 33 OECD countries studied, increases in HDI had a positive effect on CO_2 levels, while in 4 countries there was a bidirectional relationship between the two factors. The data panel approach utilized data collected between 1992 and 2011. Finally, Tran et al. (2019) discovered that in more than 90 countries between 1990 and 2014, increased human development had a negative effect on carbon emissions in the global and developing country samples, but not in developed countries. The study showed that merely increasing carbon emissions may not lead to a higher HDI as the relationship is not two-fold. These results differ from previous causal studies, which showed either positive or insignificant effects on CO_2 emissions, as well as from correlative studies by Teklu (2018) and Costa et al. (2011) that recommended increases in CO_2 emissions to achieve higher development standards having found both variables increase in parallel.

Motivation for Study, Research Questions, Hypothesis, and Prediction

The above studies provided important insights into the relationship between human development and CO_2 emissions per capita. Nevertheless, they are not without limitations. Many of them rely on outdated data and have limited sample sizes, covering only specific regions or countries (see, e.g., Bieth, 2019; Simionescu, 2021; Tran et al., 2019). Although some countries have larger samples, such as Costa et al.'s study, the generalizability of their findings may be limited by changes in climate policy and technological innovation since the data was collected in 2000. Furthermore, the contrasting results within both the correlative and causal studies literature underscore the need for further research. To address these limitations and attempt to find a more generalizable pattern, we used 2021 data across 154 countries. Additionally, we focused on correlative studies as predicting statistically significant causal relationships can be challenging due to their multi-faceted nature. Lastly, we utilized the Inequality-Adjusted Human Development Index (IHDI). In using this more accurate measure of human development, our investigation became more reliable than those based solely on the HDI.

Our study aimed to answer two main questions. Firstly, is there a generalizable correlation between CO_2 per capita emissions and IHDI across all countries? Secondly, is the correlation stronger in developing countries compared to developed countries? Our hypothesis posits a positive correlation between these variables. This prediction is based on results from previous studies (Costa et al., 2011; Teklu, 2018) which showed a positive correlation between CO_2 emissions per capita and HDI. We also predict that the correlation between human development and CO_2 emissions will be stronger in developing countries. This aligns with Kuznets Theory introduced in Bieth (2018), which suggests that in developing countries, pollution levels tend to increase with rising income until a certain level of stable income growth

is achieved, after which they may decrease. Ultimately, we hope to inform global climate action decision-making bodies develop equitable frameworks for CO_2 reductions, particularly in regard to developing countries.

Methods

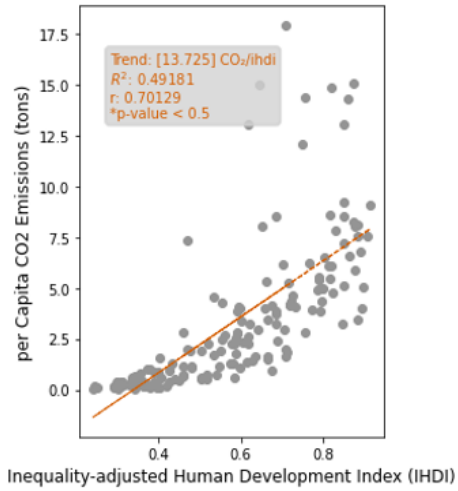
Data on IHDI and CO_2 emissions per capita was collected from trusted sources such as the United Nations Development Program (UNDP) and Our World in Data (Nations, 2023; Ritchie et al., 2020). To ensure accuracy, we utilized Pythonic statistical software to clean the data. Our analysis consisted of a general correlation analysis for all countries in dataset (154), as well as four additional correlations based on specific IHDI thresholds. These thresholds were used to compare correlation strengths between countries with varying levels of development status. Specifically, we focused on countries with very high (≥ .80), high (.70 to 0.79), medium (.55 to 0.69), and low (.55 <) IHDI. The statistical analysis performed was a Pearson's correlation test and it was aided by the Python programming language.

Results

The following graphs present the results of our analysis, focusing on five correlations between IHDI and per capita CO_2 emissions across the different levels of human development.

Figure 1

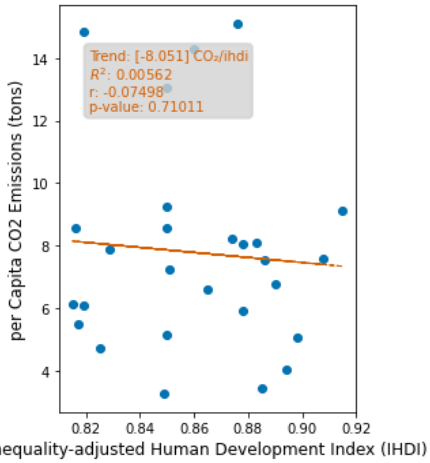
*Correlation for all Countries**



Note. Correlation for countries all countries included in dataset. Sample size (n = 154). See Appendix for full list. Correlation is significant.

Figure 2

Countries with Very High IHDI (≥ .8)

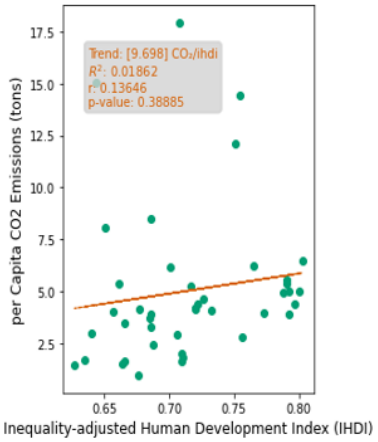


Note. Correlation for countries with IHDI ≥ .8. Sample size (n = 27). See Appendix for list of countries included. Correlation is not significant.

The analysis of all 154 countries (Figure 1) revealed a strong and positive correlation between IHDI and per capita CO_2 emissions. The coefficient of determination (R^2) indicated that around 49% of the data fit the linear trend observed. Moreover, Figure 2 highlights that for countries with *very high* IHDI (≥.8), there was a weak and insignificant negative correlation where CO_2 emissions per capita decreased as IHDI increased.

Figure 3

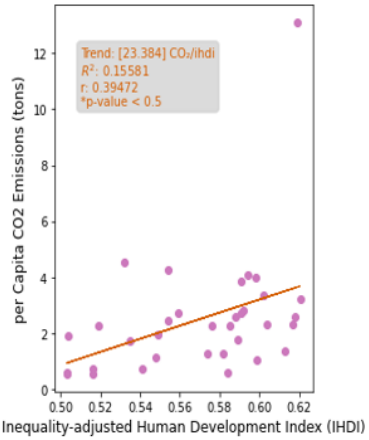
Countries with High IHDI (.70 to 0.79)



Note. Correlation for countries with *high* IHDI (.70 and 0.79). Sample size (n = 42). See Appendix for list of countries included. Correlation is not significant.

Figure 4

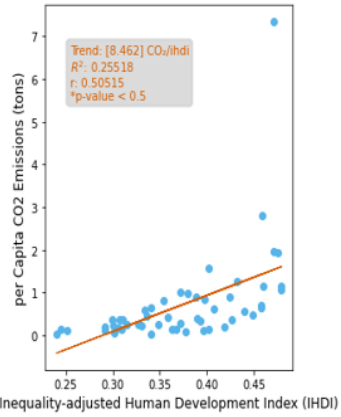
Countries with Medium IHDI (.55 to 0.69)*



Note. Correlation for countries with *medium* IHDI (.55 and 0.69). Sample size (n = 34). See Appendix for list of countries included. Correlation is significant.

Figure 5

Countries with Low IHDI (< 0.55)*



Note. Correlation for countries with *low* IHDI (< .55). Sample size (n = 52). See Appendix for list of countries included. Correlation is significant.

Additionally, Figure 3 revealed a weak and insignificant positive correlation for countries with *high* IHDI (.70 to .79). On the other hand, Figure 4 demonstrated a positive and significant correlation for countries with *medium* IHDI (.55 to .69), with approximately 15% of the data fitting the presented linear trend. Finally, as depicted in Figure 5, a positive and significant correlation was observed in countries with low to medium IHDI (<.55). The coefficient of determination (R^2) estimated that this linear trend is a good fit for approximately 25% of the data.

To summarize, the correlation across all 154 countries revealed a robust and meaningful correlation. Notably, countries with *very high* IHDI displayed a negative correlation while countries with *high* IHDI exhibited a positive correlation, yet these correlations were not statistically significant. Conversely, we found significant results for countries with *medium* and *low* development status. In particular, we observed a stronger correlation in countries with *low* development compared to those of *medium* development.

Discussion

Our study aimed to determine the correlation between CO_2 emissions per capita and IHDI across all countries and whether this correlation is stronger in developing countries. We found a strong positive correlation globally, with a stronger correlation observed in developing countries (low IHDI) than in medium and highly-developed countries (high IHDI). However, an unexpected result emerged, as we found a potentially negative correlation for countries with very high development. Further investigation is required since this portion of the analysis yielded insignificant results. This difference may be due to developing countries prioritizing sustainability and eco-friendly technologies while lower-developed countries prioritize economic growth over environmental concerns, resulting in higher CO_2 emissions per capita. These findings are consistent with Kuznets's theory mentioned in Bieth (2021), where lower-developed countries tend to prioritize economic growth over environmental concerns, resulting in higher CO_2 emissions per capita.

Moving on, the positive correlation between the IHDI and CO_2 emissions per capita at the global level, confirming the findings of previous correlational studies by Teklu (2018) and Costa et al. (2011), as well as causal studies by Wang et al. (2018) and Bedir Yilmaz (2015). These causal studies indicated that CO_2 emissions and HDI are increasing in parallel, which aligns with our own results. However, unlike the causal studies, we were not able to establish causality in our correlation analysis. The causal studies were able to determine a bidirectional relationship between the variables. In contrast, Simionescu's (2021) study that found a negative correlation between HDI and greenhouse gas emissions (GHG). However, our analysis was more robust with a larger sample size of 154 countries and a focus on CO_2 emissions only, which differs from Simionescu's inclusion of all GHG emissions. Additionally, Simionescu's

incorporation of GDP into their analysis may introduce additional sources of error, as measures of human development such as HDI and IHDI already account for GDP. Moreover, our findings were consistent with Costa et al.'s investigation, despite a 20-year gap in data collection. This suggests that the positive correlation between IHDI and CO_2 emissions remains valid in current times. Furthermore, Teklu's more recent research from 2015, albeit conducted on a smaller sample size, supports and reinforces the results of our study.

The existence of a correlation between IHDI and CO_2 emissions per capita, with a stronger correlation for developing countries has important implications for developing countries. These results can inform policies and strategies to address climate change in developing countries with limited resources. Governments and organizations in these countries can use these findings to prioritize sustainable development that balances economic growth with environmental concerns. Additionally, international organizations and developed countries can provide support and resources to assist in the implementation of climate mitigation practices in developing countries.

Limitations

While our study provides valuable insights into the relationship between IHDI and CO_2 emissions per capita, there are several limitations to consider. Firstly, our study only looks at correlation and does not establish causation. Other factors not accounted for in our study, such as political stability, energy policies, and cultural attitudes towards the environment, may also influence CO_2 emissions per capita. Secondly, our study uses cross-sectional data, which does not allow us to examine changes over time. Future studies could benefit from using longitudinal data to better understand how the relationship between IHDI and CO_2 emissions per capita

changes over time. Thirdly, our study only looks at national-level data and does not account for regional differences within countries. Differences in economic development, environmental policies, and cultural attitudes towards the environment may exist at the regional level and affect CO_2 emissions per capita differently. Lastly, the IHDI itself has limitations as a measure of human development, as it only accounts for income, health, and education, and does not consider other important factors such as gender inequality, access to clean water and sanitation, and political freedoms. Overall, while our study provides valuable insights into the relationship between IHDI and CO_2 emissions per capita, future research should consider these limitations to provide a more comprehensive understanding of the complex relationship between economic development and environmental sustainability.

Conclusion

In conclusion, our study reveals a positive correlation between CO_2 emissions per capita and the Inequality-Adjusted Human Development Index (IHDI) across 154 countries, with interesting variations across different levels of human development. These findings suggest the need for policy interventions that balance economic growth and environmental sustainability in developing countries and provides valuable insights for stakeholders working towards a more sustainable future.

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Appendix

1. Data Analysis Script
2. Raw Data Files