Economic Growth, CO_2 Emissions, and Global Temperature Change

A Multi-Scale Data Analysis (1960–2023)

Katherine Jimenez
Department Name
Wentworth Institute of Technology
Boston MA
kathejimenezy@gmail.com

ABSTRACT

This project investigates how economic growth is related to carbon emissions and global warming using long-run data on GDP per capita, CO_2 emissions per capita, and global temperature anomalies from 1960 to 2023. I address four questions: (1) how strongly GDP per capita and CO_2 per capita are related across countries and whether this relationship changes over time, (2) whether CO_2 per capita can be predicted from GDP per capita, (3) whether countries exhibit evidence of an Environmental Kuznets Curve (EKC), and (4) whether global CO_2 emissions can predict global temperature anomalies. The analysis combines annual country-level correlation, power-law regression, quadratic EKC models for selected countries, and linear regression linking global CO_2 to global temperature. The results show a strong and persistent positive relationship between GDP per capita and CO_2 per capita, a highly predictive power-law model for emissions, EKC patterns for several high-income and some emerging economies but not for low-income countries, and a strong linear relationship between global CO_2 emissions and global temperature anomalies. Overall, the findings highlight how economic development shapes emissions and contributes to global warming.

KEYWORDS

GDP per capita; CO_2 emissions; Environmental Kuznets Curve; power-law regression; global temperature anomalies.

1 Introduction

Understanding how economic development affects environmental outcomes is a central topic in both economics and climate science. As countries grow, their energy use and industrial activity tend to increase, leading to higher carbon dioxide (CO_2) emissions—the primary driver of anthropogenic climate change (NASA GISTEMP, 2023). At the same time, global temperatures have been rising steadily, making it crucial to study how economic growth connects to emissions and climate change.

This project investigates long-term data on GDP per capita, CO_2 emissions per capita, and global temperature anomalies to explore how economic activity shapes environmental impact. Specifically, we address four research questions: (1) At the country level, how strongly are GDP per capita and CO_2 per capita related, and how does this relationship evolve over time? (2) Can CO_2 per capita be predicted from GDP per capita using statistical modeling? (3) Do countries exhibit evidence of an Environmental Kuznets Curve (EKC), a hypothesis proposing that environmental degradation first increases and then decreases as economies develop (Kuznets, 1955)? (4) Do global CO_2 emissions help predict changes in global temperature anomalies?

Previous studies provide important context for these questions. The EKC literature suggests that pollution may follow an inverted-U pattern as income rises (Kuznets, 1955). Climate science shows a clear physical relationship between atmospheric CO_2 and global warming (NASA GISTEMP, 2023). Meanwhile, modern datasets such as *Our World in Data* compile long-run historical information on emissions, GDP, and population that enable large-scale empirical analysis (Our World in Data, 2023).

By combining correlation analysis, power-law regression, quadratic EKC modeling, and global linear regression between CO_2 and temperature, this project provides empirical evidence on how economic development influences emissions and climate outcomes across multiple scales.

2 Data

2.1 Source of dataset

This project uses two credible and widely used scientific datasets:

(1) Our World in Data — CO_2 and Greenhouse Gas Emissions Dataset

Downloaded from the official OWID GitHub repository. This dataset is produced using multiple high-quality sources,

including the Global Carbon Project, BP Statistical Review, Maddison Project (GDP), and United Nations population data. It provides annual records for all countries from the 18th century to 2023, including CO_2 emissions, CO_2 per capita, GDP, population, and hundreds of related variables. OWID updates the dataset regularly and provides full methodological transparency, making it a reliable source for global environmental and economic data.

(2) NASA GISTEMP — Global Land–Ocean Temperature Index

Downloaded directly from NASA Goddard Institute for Space Studies (GISS). This dataset contains annual global mean temperature anomalies from 1880 to the present, relative to the 1951–1980 reference baseline. Temperature values are estimated from land-based weather stations and sea-surface temperature measurements using NASA's validated climate modeling pipeline. The dataset is considered the global standard reference for long-term temperature trends. Both datasets are publicly available, scientifically credible, and appropriate

2.2 Characters of the datasets

The OWID CO_2 dataset contains yearly information for every country, including GDP, population, total CO_2 emissions, and CO_2 emissions per capita. For this project, only a small set of variables was used: country name, year, GDP, population, total CO_2, and CO_2 per capita. Using GDP and population, a new variable, **GDP per capita**, was created by dividing GDP by population. All non-country entities or rows with missing values were removed.

The NASA GISTEMP dataset provides annual global temperature anomalies relative to the 1951–1980 baseline. Only the "J–D" (January–December) annual mean temperature value was used. Because some early records included missing or non-numeric values, those rows were also removed.

To combine both datasets, the OWID global CO_2 data for "World" was merged with NASA temperature data using the year variable. All data were restricted to the period 1960–2023 so that the variables would be consistent across analyses.

These cleaning and preprocessing steps ensured a complete and reliable dataset for the correlation analysis, power-law modeling, EKC testing, and temperature prediction models used in this project.

3 Methodology

In this part, you should give an introduction of the methods/model. First, what's the method/model. What's the assumption of this method/model. What's the advantage/disadvantage of this method/model. Why did you choose it. What Python module or function do you apply to apply this method/model. Any optional input/extra work did you adjust to make the results better. If you have multiple methods, feel free to use subsection 3.1, 3.2, 3.3, … to separate them.

3.1 Heading Level 2

3.2 Heading Level 2

…

Example format: The updated template, user manuals, samples, and required fonts, all are available at the URL https://www.acm.org/publications/proceedings-template. It contains said information for all three versions of MS Word (Windows and 2 versions of Mac). There are also separate links to the user guide, which can be referred to by the user. This URL also contains some useful video links, which describe how to add the template, structure the paper, and generate the layout, in different clips. **Display Formula with Number**

$$\sqrt{b^2-4ac}\,\frac{-b\pm\sqrt{b^2-4ac}}{2a} \tag{1}$$

Continuation part of Paragraph Text The user must style this paragraph in **ParaContinue** style, which follows immediately after the **DisplayFormula** (numbered equation). The **DisplayFormula** style is applied only in case of a numbered equation. A numbered equation always has a number to its right. Insert paragraph text here.

Display Formula without Number

$$\sqrt{b^2-4ac}\,\frac{-b\pm\sqrt{b^2-4ac}}{2a}$$

The **DisplayFormulaUnnum** style is applied only in case of an unnumbered equation. An unnumbered display equation never contains an equation number to its right, and this unique property distinguishes it from a numbered equation.

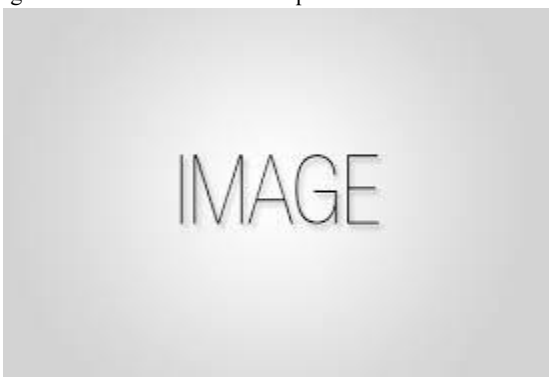

Figure 1: Figure Caption and Image above the caption [In draft mode, Image will not appear on the screen]

Theorem/Proof/Lemma. Insert text here for the enunciation or Math statement. Insert text here for the enunciation or Math statement. Insert text here for the enunciation or Math statement. Insert text here for the enunciation or Math statement. Insert text here for the enunciation or Math statement.

> ....Insert text here for the Quotation or Extract, Insert text here for the Quotation or Extract, Insert text here for the Quotation or Extract, Insert text here for the Quotation or Extract, Insert text here for the Quotation or Extract, Insert text here for the Quotation or Extract.

4 Results

In this part, you need to select a reasonable way to deliver the result of your topic. For example, equation or numerical results, or visualization of your result. You also need to provide a clear explanation of all results and how to understand the results. If there exist any unexpected results, please explain why or possible cause of this special result. You can use subsection 4.1, 4.2, … to separate your results.

4.1 Heading Level 2

Example format: In the below paragraph, it is explained how alt-txt value is placed in **MS Word 2010**. To add alternative text to a picture in Word 2010, follow these steps:

1. In a Word 2010 document, insert a picture.
2. Right click on the inserted picture and select the **Format Picture** option.
3. Select the **Alt Txt** option from the left-side panel options.
4. In the "Title:" and "Description:" text boxes, type the text you want to represent the picture, and then click "Close".

Below are steps to place alt-txt value in **MS Word 2013/2016**. To add alternative text to a picture in Word 2013/2016, follow these steps:

1. In a Word 2013/2016 document, insert a picture.
2. Right click on the inserted picture and select the **Format Picture** option.
3. In the settings at the right side of the window, click on the "Layout & Properties" icon (3rd option).
4. Expand **Alt Txt** option.
5. In the "Title:" and "Description:" text boxes, type the text you want to represent the picture, and then click "Close".

1.1.1 Heading Level 3. Insert paragraph text here. Insert paragraph text here. Insert paragraph text here. Insert paragraph text here. Insert paragraph text here. Insert paragraph text here. Insert paragraph text here. Insert paragraph text here. Insert paragraph text here. Insert paragraph text here.

1.1.1.1 Heading Level 4. Insert paragraph text here. Insert paragraph text here. Insert paragraph text here. Insert paragraph text here. Insert paragraph text here. Insert paragraph text here. Insert paragraph text here. Insert paragraph text here. Insert paragraph text here. Insert paragraph text here.

5 Discussion

Every method/project has its shortage or weakness. Please discuss the unsatisfied results in your project. And discuss the feasible suggestions of future work to revise/improve your result.

6 Conclusion

In this part, you should summarize your project. What important results did you find for your topic and what's the effect of this result on the real-world?

ACKNOWLEDGMENTS

Insert paragraph text here. Insert paragraph text here.

REFERENCES

Use the following ACM Reference format for your citation

FirstName Surname, FirstName Surname and FirstName Surname. 2018. Insert Your Title Here: Insert Subtitle Here. In *Proceedings of ACM Woodstock conference (WOODSTOCK'18). ACM, New York, NY, USA, 2 pages.* https://doi.org/10.1145/1234567890

[1] Patricia S. Abril and Robert Plant, 2007. The patent holder's dilemma: Buy, sell, or troll? *Commun. ACM* 50, 1 (Jan, 2007), 36-44. DOI: https://doi.org/10.1145/1188913.1188915.

[2] Sten Andler. 1979. Predicate path expressions. In *Proceedings of the 6th. ACM SIGACT-SIGPLAN Symposium on Principles of Programming Languages (POPL '79).* ACM Press, New York, NY, 226-236. DOI:https://doi.org/10.1145/567752.567774

[3] Ian Editor (Ed.). 2007. *The title of book one* (1st. ed.). The name of the series one, Vol. 9. University of Chicago Press, Chicago. DOI:https://doi.org/10.1007/3-540-09237-4.

[4] David Kosiur. 2001. *Understanding Policy-Based Networking* (2nd. ed.). Wiley, New York, NY..