Interplay between Environmental Factors and Economic Indicators on Life Expectancy

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Abstract:

The intersection of economic growth, environmental change, and public health is one of the most critical areas for contemporary research, with important implications for policy and global well-being. This study addresses the central question of why life expectancy, as a key public health indicator, varies globally across income levels in response to economic and environmental factors, particularly CO2 emissions.

A major concern is the potential conflict between environmental sustainability and economic growth, as well as how this may ultimately affect health outcomes. To address this conundrum, a robust econometric analysis is conducted using a 60-year panel data set from the World Bank. Fixed-effects models accounting for population costs, mortality, access to electricity, GDP per capita and GDP expenditure based on countries' incomes are used to examine the effect on life expectancy. Then the nonlinear dynamics between CO2 emissions and life expectancy shows a quadratic correlation between CO2 emissions, which can be said clearly, this is a very valuable result of this finding that supports the environmental Kuznets curve theory. This relationship changes based on the income level of countries. In high-income countries, C02__ emissions are decreasing as adverse health effects increase, possibly due to better mitigation strategies. However, in upper-middle-income countries, this is the threshold point at which the negative effects of environmental damage begin to outweigh the benefits of economic growth.

These findings shed light on the critical balance between economic development and environmental policy. They emphasize the need for strategic approaches to promote economic development and maintain environmental integrity to foster sustainable improvements in life expectancy.

Keywords: Economic Growth, Environmental Change, Public Health, Life Expectancy, CO2 Emissions, Income Levels, Environmental Kuznets Curve, Econometric Analysis

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Introduction:

In exploring the delicate interplay between our environment and the economy, this paper dives into how these foundational aspects of our world intertwine to shape health and longevity. Environmental quality—marked by the air we breathe, the water we drink, and the green spaces that provide solace and rejuvenation—is not merely a backdrop of our lives but is central to our well-being. These environmental gifts, however, are increasingly under threat from pollution, deforestation, and the overarching specter of climate change (Beyene & Kotosz, 2021). Simultaneously, the economic landscape—characterized by income levels, employment opportunities, and the distribution of wealth—casts a long shadow over our collective health (Rahman et al., 2022). It's within this context that this study seeks to understand how the convergence of environmental quality and economic prosperity, or lack thereof, impacts life expectancy.

As we stand at a critical crossroads, it becomes imperative to view environmental and economic factors not separately but as intertwined elements that collectively influence public health. The narrative that unfolds from this investigation paints a holistic picture of how these elements collectively dictate access to healthcare, the quality of nutrition, and, ultimately, the quality of life. The pressing need to address how environmental degradation affects our health—from the pollution that fills the air to the loss of natural habitats that once played a crucial role in our ecosystem—illustrates that the environmental challenges we face are as much a health crisis as they are ecological (Rahman et al., 2020).

Conversely, the variables of the economy that form our societies—how wealth is generated and distributed, who gets to access education, and stable employment—also play a critical role in determining health outcomes. This paper navigates through these economic waters, aiming to uncover how these factors intertwine with environmental conditions to either uplift or undermine public health. (Beyene & Kotosz, 2021; Rahman et al., 2022).

The natural environment significantly impacts individual and community health worldwide. Environmental factors such as air and water quality and the availability of green spaces contribute to or detract from overall life expectancy (Stigsdotter et al., 2010). The increasing level of pollution, deforestation, and the depletion of natural resources are pressing concerns that necessitate a focus on environmental sustainability to mitigate their effects (Wang, 2016; Haines et al., 2006). However, health and economic considerations are both separately and often treated as domains in policy-making and public discourse.

Despite their perceived separation, health and economics are deeply intertwined. Improvements in the standard of healthcare not only enhance citizens' well-being but also boost a nation's economic growth. Health indicators such as life expectancy and mortality rates reflect health outcomes and economic progress (Miller & Ruhm, 2009; Ruhm, 2013). Through advancements in science and technology, there causes an increase in life expectancy across the globe. However, these advancements have also led to excessive consumption of natural resources and environmental degradation, indirectly affecting human health and life expectancy (Bloom & Canning, 2004; University of Chicago Press Journals, n.d.). Countries with the most pollution often have the weakest environmental policies, failing to implement measures that could mitigate environmental damage caused by rapid economic growth (Olubusoye & Musa, 2020). Approximately conclusion of all studies in the past about healthier nations tend to have higher per capita productivity and accumulate more wealth compared to countries with poorer health outcomes (Mohsin et al., 2019).

The interplay between economic freedom, education, and CO2 emissions further illustrates the complex relationship between economic indicators, educational attainment, and environmental factors on life expectancy (Rogoz et al., 2022). Moreover, the country's inflation rate's predictive capacity can impact life expectancy, underscoring the importance of economic stability. Social and environmental factors significantly influence life expectancy, highlighting the role of healthcare, social determinants, and lifestyle choices. Environmental policies emerge as potential drivers of growth and health improvements, focusing on the relationship between pollution, environmental quality, and life expectancy (Pautrel, 2009; Beyene & Kotosz, 2021).

According to Rahman et al. (2022), paper the impact of improving economic growth on people's life expectancy is significantly positive. This suggests that although health expenditures are currently at risk from environmental degradation, accessibility to clean water and better sanitation have positive effects on life expectancy in a sample of countries. This analysis of the relationship between healthy human capital and economic growth across 92 countries from 1980 to 2010 suggests that enhanced well-being is consistently associated with economic expansion (Azomahou et al., 2009).

This area has lacked investigation of many evaluations in this field, so because of technology's speed and effect on each side of human life, I became curious to know what economic factors have affected people's life expectancy in the world with different economic conditions. These papers investigate some research gaps in my mind, such as:

- The comprehensive impact of government health policies on life expectancy presents evident gaps in current knowledge. Moreover, the insufficient exploration of external costs related to the health impacts of industrialization is noteworthy.
- Economic fluctuation and life expectancy: There is a discernible lack of extensive research on the nuanced relationship between economic fluctuations and life expectancy on a global scale. The variability in economic conditions and its consequent impact on health outcomes warrant a deeper examination.
- 2. Population Growth's Effect on Life Expectancy: The work currently in publication does not sufficiently address how population dynamics directly affect life expectancy. Considering the possible ramifications for public health and demographic policies, this creates a significant vacuum.
- Socioeconomic Disparities and Health Outcomes: The interaction between socioeconomic status and life expectancy remains insufficiently quantified, especially when evaluating the efficacy of health policies across countries with different income groups.
- The role of environmental factors, such as air pollution (e.g., CO2_emission) and climate change, in the relationship between life expectancy and health outcomes, especially in the face of rapid industrialization.
- The impact of technological advancements and innovation in healthcare on life expectancy has not been fully explored.

This area needs to be investigated more in this field, so because of technology's speed and effect on each side of human life, I became curious to know what economic factors have affected people's life expectancy in the world with different economic conditions.

2. Methodology

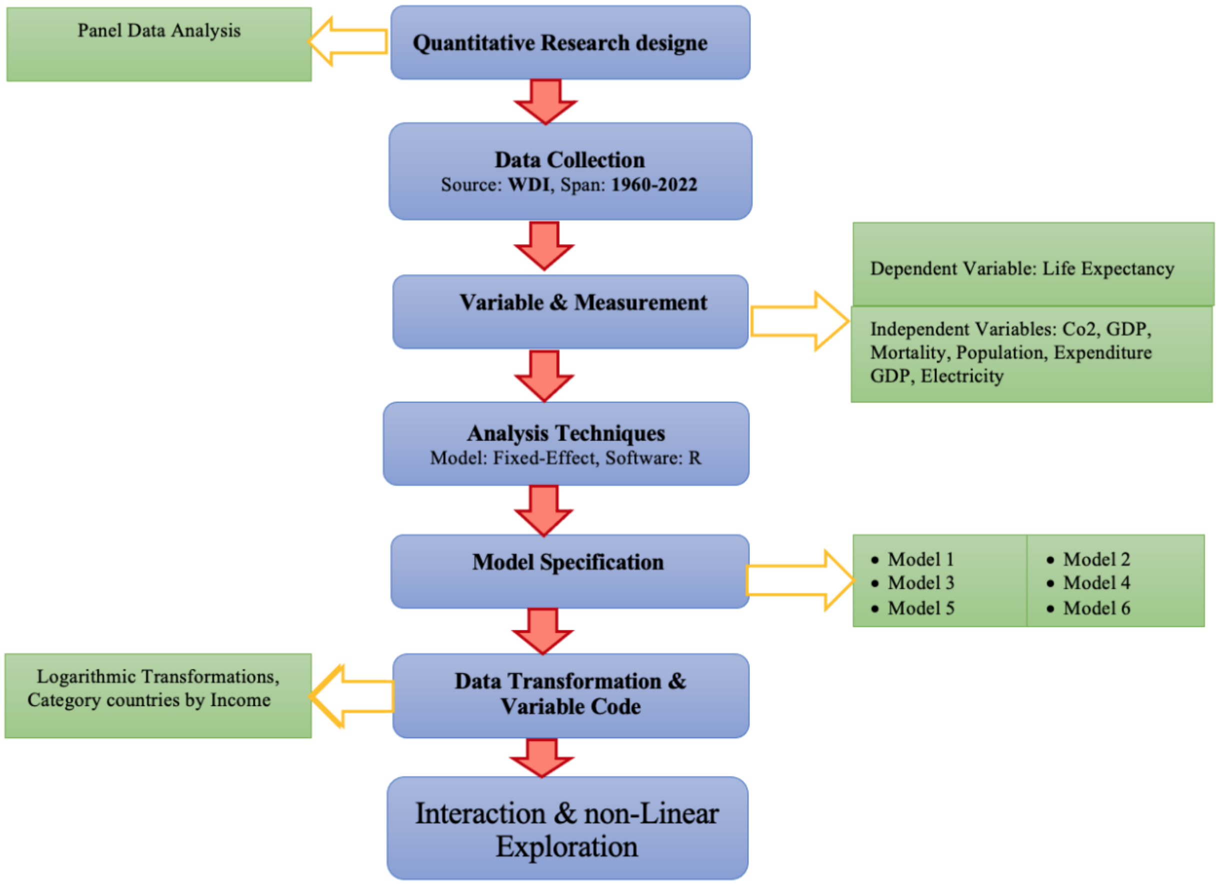

Figure 1 - Methodology_Process

Figure 1 has an overview of the paper's Methodology that continues each part that has been explained.

2-1. Research Design

This study uses panel data models with fixed effect factors to evaluate the connection of economic indicators, such as GDP per capita and healthcare indicators with life expectancy across the world from 1960 to 2022. Due to its robustness in specific trends, this approach expresses potential correlations and causality in extensive numerical data sets by providing a comprehensive temporal analysis of factors affecting life expectancy.

2-2. Data Collection

The data for this research is sourced from the World Bank's comprehensive global databases, snapping 60 years. The longitudinal aspect of this panel data provides a robust framework for assessing temporal dynamics and changes within and between countries over time.

2-3. Variables and Measures

The dependent variable in this study is life expectancy. It also includes independent variables and economic indicators, which are CO2 emissions, GDP per capita, mortality rates, electricity usage, population size, and GDP expenditure on healthcare. These variables were selected because of their potential effect on Life_ Expectancy.

2-4. Analytical Techniques

In this study, Fixed-effect has been employed for the analysis of Panel data models , as these models can control for unobserved heterogeneity among countries. The Hausman test can show us the best choice between a Random or Fixed effect model with determining the suitability of models over the other based on the structure of the data. The analysis uses the "plm" package in R program, which is suited for panel data models. Fixed-effects models are estimated to compare within-country variations against between-country variations. Notice that the fixed effect items of this study are Country_Code and Years.

2-5. Model Specification

Multiple regression models are used to analyze the relationship between life expectancy and a set of independent variables such as CO2 emissions, GDP per capita, mortality rates, electricity, population, and health expenditure. The base model examines the influence of CO2 emissions and GDP per capita on life expectancy across all countries, by considering country code and Years effects as a fixed effect. To evaluate each variable and its combined effects on life expectancy, subsequent models progressively include more variables, such as population, electricity, and health expenditure. The introduction of interaction variables between income group categorizations (e.g., upper medium income, and high income) and CO2 emissions reveals the differential effects it according to a country's economic status. A quadratic term for CO2_emission is included to investigate any non-linea relationships with Life _expectancy, especially for the upper-income and upper-middle-income groups.

2-6. Data Transformation and Variable Coding

Logarithmic transformations are applied to GDP per capita, electricity consumption, population, and CO2 emissions to ensure robust models account for non-normal distributions. Country codes are treated as categorical variables, and years are factored in to control for time trends. The income group variable is derived from the World Bank classification that is used to create dummy variables for specifically high-income and upper-middle-income groups to know which countries are located after the vertex and their Co2_emission and Life_expectancy are different. In table 1, there are 6 models

Table 1 – Equation 1 - Linear Models

Model	Equation	Description
1	life ~ co2_emission | country_code + as.factor(Years)	Models life expectancy as a function of CO2 emissions, adjusted for country and year.
2	life ~ co2_emission + log(gdp_percapita) | country_code + as.factor(Years)	Adds GDP per capita (log-transformed) to the model, considering economic status.
3	life ~ co2_emission + log(gdp_percapita) + (electricity) | country_code + as.factor(Years)	Introduces electricity access as a variable, exploring its impact on life expectancy alongside emissions and GDP.
4	life ~ co2_emission + log(gdp_percapita) + (electricity) + log(population) | country_code + as.factor(Years)	Adds population (log-transformed), examining its effect in the context of emissions, GDP, and electricity access.
5	life ~ co2_emission + log(gdp_percapita) + (electricity) + log(population) + expenditure_GDP | country_code + as.factor(Years)	Incorporates health expenditure as a percentage of GDP, analyzing its influence on life expectancy with other factors.
6	life ~ co2_emission + log(gdp_percapita) + (electricity) + log(population) + expenditure_GDP+ mortality| country_code + as.factor(Years)	Adds mortality rates to the model, offering a comprehensive view by including health expenditure, population, electricity, GDP, and emissions.

In the second Equation model 6 from equation 1 has been replicated, serving as a point of comparison for further specifications. Then according to the hypothesis that observations show a relation between Life Expectancy and Co2 as quadratic, we assume it and we cluster countries according to their Income_group and investigate the interaction of them by choosing Income_group as a binary variable in models then in table 2 shortly describes it.

Table 2 - Quadratic Models

Model	Equation	Description
1	life ~ co2_emission + I(co2_emission^2) + log(gdp_percapita) + electricity + log(population) + expenditure_GDP + mortality | as.factor(country_code) + as.factor(Years)	Adds a quadratic term for CO2 emissions to explore non-linear effects on life expectancy, alongside other factors.
2	life ~ co2_emission:d_highincome + co2_emission + I(co2_emission^2) + I(co2_emission^2):d_highincome + log(gdp_percapita) + electricity + log(population) + expenditure_GDP + mortality | as.factor(country_code) + as.factor(Years)	Introduces interactions between CO2 emissions and the high-income group indicator, both linearly and non-linearly, to assess differential impacts of emissions based on income group.

4- Results

There are four distinct models executed on the 3797 observations which reflect a robust sample size to estimate. Its impact on economic and environmental variables on Life Life_expectancy. Each one added layers of complexity to understand the multifaceted relationship.

4-1. Model Interpretations

In all models, the GDP_Percapita consistently exhibited a positive relationship with life expectancy, suggesting that as per capita income increases, so does life expectancy. The coefficient values between models ranged from 0.356 to 0.542 that were all statistically significant at the 1% level, ($p < 0.01$).

In each model, there was a negative relationship between Mortality and life expectancy correlation ($-1.24 < \beta < -1.26$, $p < 0.01$).

Other control variables such as Electricity and Population did not have a significant impact on life expectancy in none of the models.

After Looking at the graph 2, we know that there is a non-linear interaction between CO2 emissions and life. Therefore, we assume a new hypothesis that there is a quadratic relationship between them, we divide it into 4 groups of high-income, upper-middle-income, lower-middle-income, and low-income in the new equation based on the classification of countries based on income.

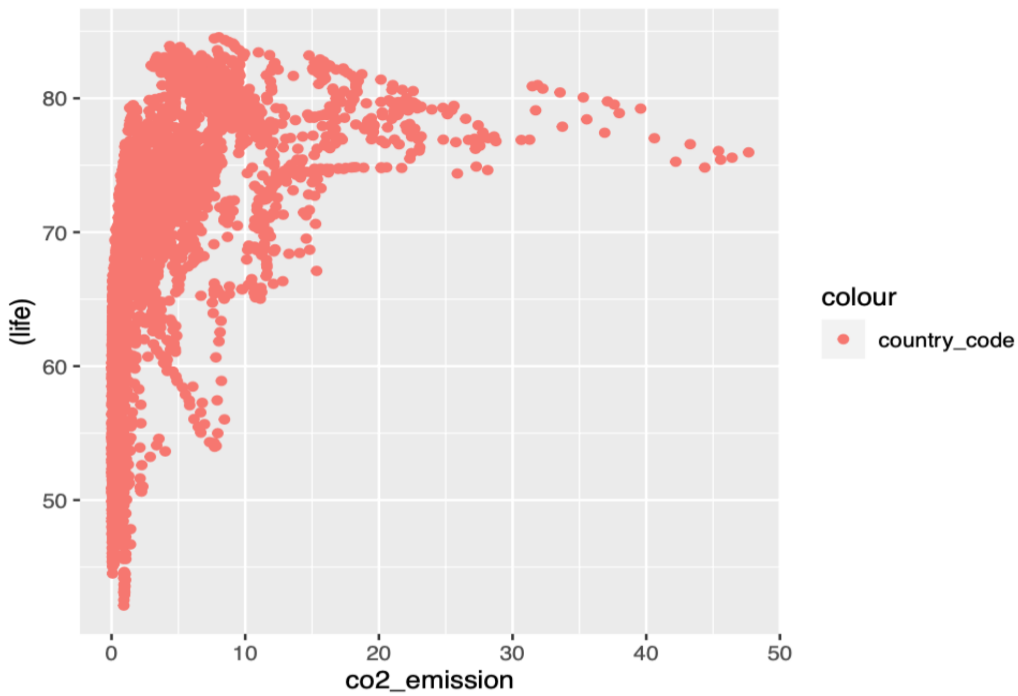

Figure2 - correlation CO2 & life_expectancy

Then we show the CO2 emissions displayed a varied impact across different models. In models (2), and (3), the CO2_emission was positively affected by Life_expectancy, whereas, in model (1), Co2_emission was associated negative impact that has no significant coefficient on the dependent variable. The squared term of CO2 emission was negative and significant in models (2) and (3) which indicate a non-linear relationship where the initial increase in Co2_emission may be associated with higher life expectancy up to a vertex as a threshold that beyond it, the effect reverses.

After inputting the interaction, the relation between CO2 emission and high income (model 3) was negative. This suggests that the life expectancy benefits associated with higher income status diminish as CO2 _emission increase. In addition, the coefficient of quadratic CO2_emission was positive for high-income countries, indicating the effect of increasing CO2 _emission is less pronounced, especially in high-income countries.

Similarly, for countries that are in the upper-middle-income category, the interaction between CO2 emission and upper-middle income (Model 4) was positively associated with life expectancy, with a significant negative quadratic interaction, indicating the complex dynamics between CO2_emission, economic, and health status.

4-2. Modify Fit and Observation

The R-squared Adj values for all models are exceedingly high (0.995) which indicates that the models explained nearly all of the variance in life expectancy across the dataset and fit on the observation.

4-3. Summary of Findings

Table 3 briefly shows the key findings of the models:

Table 3 - Model Summary

	(1)	(2)	(3)	(4)
co2_emission	−0.023	0.204**	0.572***	0.150*
	(0.044)	(0.064)	(0.155)	(0.070)
log(gdp_percapita)	0.542***	0.401**	0.356*	0.393*
	(0.147)	(0.150)	(0.153)	(0.153)
electricity	0.001	0.000	−0.001	0.001
	(0.007)	(0.007)	(0.007)	(0.007)
log(population)	−2.357**	−3.273***	−3.074***	−3.073***
	(0.717)	(0.707)	(0.714)	(0.705)
expenditure_GDP	0.027	0.024	0.022	0.024
	(0.030)	(0.029)	(0.029)	(0.029)
mortality	−1.224***	−1.264***	−1.266***	−1.265***
	(0.054)	(0.052)	(0.052)	(0.052)
I(co2_emission^2)		−0.007***	−0.028***	−0.005***
		(0.001)	(0.008)	(0.001)
co2_emission × d_highincomeTRUE			−0.455**	
			(0.171)	
d_highincomeTRUE × I(co2_emission^2)			0.023**	
			(0.008)	
co2_emission × I(Income_group == "Upper middle income")TRUE				0.538**
				(0.194)
I(Income_group == "Upper middle income")TRUE × I(co2_emission^2)				−0.031***
				(0.009)
Num.Obs.	3797	3797	3797	3797
R2	0.995	0.995	0.995	0.995
R2 Adj.	0.994	0.995	0.995	0.995
R2 Within	0.794	0.802	0.805	0.805
R2 Within Adj.	0.793	0.802	0.804	0.804
AIC	7676.0	7521.6	7470.7	7467.7
BIC	8999.3	8851.2	8812.7	8809.7
RMSE	0.63	0.62	0.61	0.61
Std.Errors	by: country_code	by: country_code	by: country_code	by: country_code
FE: as.factor(Years)	X	X	X	X
FE: as.factor(country_code)		X	X	X
FE: country_code	X			

+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

5- Discussion:

This study announces several important discoveries that expand the study of the factors influencing life expectancy. This discussion interprets these findings in the context of existing literature and explores their implications.

5-1. The Impact of Economic Prosperity

The positive relationship between GDP per capita and life expectancy is consistent with the bulk of economic and public health literature, which posits that higher income levels enable better access to healthcare, nutrition, and living conditions, thereby improving health outcomes (Deaton, 2003; Preston, 1975). The robustness of this relationship across all models underscores the importance of economic growth as a fundamental driver of improved life expectancy.

5-2. Non-Linearity in Environmental Impact

Result Examining the high levels of CO2 emissions in different countries shows a multifaceted scenario that is the basis of industrial activities, dependence on the energy sector, economic structures urbanization, and other factors. As figure 1111 presents, countries such as the United States, Russia, Australia, Qatar, Kuwait, the United Arab Emirates, Luxembourg, Bahrain, Canada, and Kazakhstan, due to their significant industrial sectors, reliance on fossil fuel-based energy production, and greenhouse gas production patterns. They show significant CO2. The high consumption of these factors, together with the global economic roles and urban development, create a challenging environment for reducing the carbon footprint. In addition, the effect of rulls and pollicy for environment has been played an important role in Co2_emission. These models further elucidate the complex relationship between CO2 emissions and life expectancy, highlighting nonlinear dynamics that have important implications for environmental economics. First of all, increase CO2 _emission seems to be connected with improved living standards and healthcare and then increasing life expectancy. However, this relationship takes a turn beyond a certain economic threshold, where the adverse effects of environmental degradation begin to overshadow the benefits of economic growth. The difference between high-income and upper-middle-income nations best illustrates this contradiction. While high-income countries may use their resources to reduce the negative effects of CO2_emission through advanced healthcare systems and strict environmental regulations, upper-middle-income countries face a more complex scenario. The initial benefits of industrialization and economic development eventually give way to the destructive effects of environmental degradation, emphasizing the lag effect presented by the environmental Kuznets curve hypothesis. Our findings emphasize that countries must carefully pursue the delicate balance between economic growth and environmental sustainability. The diverse responses and impacts among different income groups indicate the need for tailored strategies that address both the immediate benefits of industrialization and its long-term consequences on public health and environmental integrity. The reduction of CO2 _emission' negative environmental effects and the maintenance of global advances in life expectancy can be achieved through investments in cleaner technology, more powerful regulatory frameworks, and more international collaboration. As time goes on, it will become increasingly evident that solving the problems caused by CO2_emission requires for concerted action across national boundaries, industry sectors, and policy areas. The insights gained from this study will contribute to our understanding of these dynamics and hopefully provide valuable insights for policymakers and researchers to create a sustainable path toward economic development and environmental conservation.

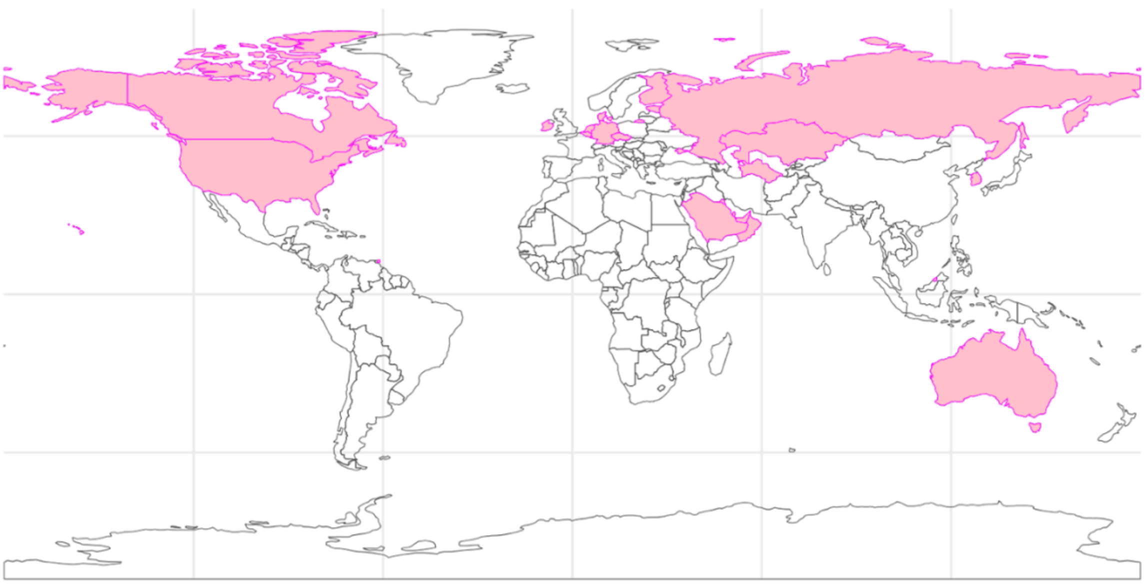

Figure 3- Counties With High Co2

5-3. Population, Mortality, and Health Expenditure

The adverse impact of growing populations on life expectancy may be ascribed to the heightened demand for a nation's resources, such as healthcare systems, which is particularly noticeable in highly populated countries.

5-4. Indirect relationship of Electricity and Expenditure GDP:

The results of all models show that the is no direct significant relation between these control variables and Life Expectancy. This conclusion can be shown that maybe because of the vast use of electricity, can say that it can affect on Life_expectancy of individuals. In addition, although there is no clear relationship between Expenditure GDP on people's view of life, people in the

6- Restrictions and Prospective Research Paths

Despite being thorough in its examination of several variables and how they affect life expectancy, this research has certain shortcomings. Initially, depending too much on secondary data from international databases might lead to differences in the precision and quality of data across countries. Furthermore, all of the socioeconomic and environmental factors such as access to healthcare, lifestyle choices, and levels of local pollution—that affect life expectancy maybe not captured by our models.

Another limitation is the assumption of uniformity due to some factors such as CO2 emissions in different geographical and socio-economic contexts. Countries sometimes differ in their environmental policies, technological advances, and public health infrastructure, which can significantly affect life expectancy.

We believe that future research can address these limitations by incorporating more detailed data, including region-specific environmental and healthcare indicators, to refine the understanding of economic factors and environmental indicators that affect life expectancy. In addition, examining the role of renewable energy adoption and improving environmental protection policy and quality of life around the world can provide practical pathways for sustainable development. By expanding the scope of analysis and incorporating more nuanced data, powerful strategies for balancing economic growth with environmental sustainability and health outcomes can be developed by future studies.

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