Essay 1

Introduction

A common belief is that economic growth – defined as an increase in the amount of goods and services produced per capita — began to accelerate during the Industrial Revolution in the late 1700s. The growth experience since then has been unprecedented and has not been observed in any earlier period of human history. Studies suggest a positive correlation between economic growth and health-related indicators such as longer life expectancy and lower mortality rates (Adelman, 1963).

Improvements in healthcare have contributed to the rapid increase in the global population observed in recent decades. On one side, an increase in the global population might increase environmental emissions. On the other side, people living longer also means an aging population, which has been linked to reducing environmental emissions (Xu, 2024). The dynamic between an aging population and environmental emission are the crux of this essay, which leads us to our research question – **How does an aging population affect CO2 emission per capita?**

There are two main reasons as to why this topic is important. Firstly, according to the World Health Organization (2025) the percentage of people aged 65 and over will double from 12% in 2015 to an estimate of 22% in 2050. An aging population puts a strain on a country's finances as the working population shrinks and more resources is needed to take care of the aging population. Furthermore, a shrinking working population can reduce a country's tax revenue. Secondly, fiscal difficulties due to an aging population might reduce the incentives to reduce CO2 emissions, which is worrying as CO2 concentration and temperature rises (see Appendix A)

- **Literature review**

Existing literature consistently indicates that demographic aging serves as a mitigating factor for carbon emissions across diverse economic contexts. Hassan and Salim (2015) found that while income growth expectedly drives emissions in high-income OECD countries, an aging population is associated with a downward pressure on CO2 per capita. This trend is corroborated by country-specific studies in Asia; for instance, Kim et al. (2020) determined that a 1% increase in South Korea's elderly population reduces emissions by approximately 0.4%, while Xu (2024) observed a similar negative elasticity of 0.3478% in the Chinese context.

Collectively, these findings suggest a global consensus: as populations transition toward older age structures, CO2 emissions tend to decline. However, the literature also highlights that these dynamics are non-linear and can evolve alongside changing consumption patterns and technological shifts. This paper builds upon these localized and regional insights by employing a broader, multi-country panel analysis to investigate if this negative relationship holds universally across 194 nations over a thirty-year period.

Data

To investigate our research question we utilized a balanced panel dataset covering 194 entities from 1990 to 2024, resulting in over 6,600 observations. The dependent variables, CO2 emission are gathered from Global Carbon Budget (2026). To capture the demographic changes, two primary variables are employed; share of the population over 65 (OECD, 2026) and the median age (United Nations, 2026)

To control for economic and structural determinants of emission, the models include GDP per capita and urbanization. Real GDP per capita was constructed by dividing the annual chain-based GDP by total population both retrieved from the OECD database to ensure inflationary adjustment and consistency (OECD, 2026; OECD, 2026). Urbanization – measured as the percentage of the population residing in urban areas – was obtained from the World Bank (2026).

The descriptive statistics provide a comprehensive overview of the global dataset spanning from 1990 to 2024. The dependent variable carbon emissions per capita shows a mean value of 5.01 tons with a substantial standard deviation of 7.76 which indicates significant environmental inequality between nations.

Table 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
CO2 per capita	7,508	5.01	7.76	0	364.79
Aging (65+)	7,127	7.54	5.38	0.86	29.78
Median Age	8,058	27.21	8.94	13.19	62.42
GDP per capita	6,658	21,406	23,872	510.82	174,569
Urbanization (%)	7,127	56.40	23.58	5.27	100

The maximum value of 364.79 tons highlights the presence of extreme outliers in energy intensive economies and justifies the use of a natural logarithm transformation to ensure a normal distribution for regression analysis. Regarding the demographic variables, the population share aged 65 and older averages 7.54 percent while the median age averages 27.21 years. The wide range in aging metrics from a minimum of 0.86 percent to a maximum of 29.78 percent captures countries at every stage of the demographic transition which is essential for identifying the mobility effect on emissions. The economic controls also show high variance with an average GDP per capita of $21406 USD and a mean urbanization rate of 56.40 percent. These figures confirm that the panel is representative of the global economy and that the fixed effects model is appropriate to control for the unobserved heterogeneity inherent in such a diverse group of 194 countries.

Method

To further isolate the effect of an aging population on CO2 emission per capita, control variables need to be included. Furthermore, we would also need to control for time fixed effects and country fixed effects. Several variables for each country are tracked over time. A commonly used method to conduct an analysis like this is ordinary least square regression (OLS) (see Jardon et al., 2017; Hassan & Salim, 2015). We aim to estimate the following model:

$$(1)\quad \ln CO2_{it} = \beta_0 + \beta_1(\%\, over\ 65) + \beta_2 lnGDP\ per\ capita_{it} + \beta_3 Urbanization + u_{it}$$

For robustness we will also run the following regression:

$$(2)\quad \ln CO2_{it} = \beta_0 + \beta_1 median\ age + \beta_2 lnGDP\ per\ capita_{it} + \beta_3 Urbanization + u_{it}$$

A Breusch-Pagan test suggests that both models suffer from heteroskedasticity, meaning that the variance in the error term is not constant. Furthermore, Pesaran's CD test suggests that the sensitivity model suffers from cross-sectional dependencies in the panel data. Given these diagnostics, we opted for Driscoll-Kraay standard error in both models, which are robust to heteroskedasticity, cross-sectional dependency as well as serial correlation.

Figure 1 illustrates the cross-sectional relationship between the share of the population aged 65 and older and the logarithmic scale of per capita carbon emissions. While the red fitted trend line suggests a general upward slope across the entire global sample, it is important to note the significant clustering of data points at higher aging levels. As countries transition beyond a 15-20% elderly population share, we observe a stabilization and a gradual downward shift in emissions. This visualization highlights the complexity of demographic impacts, where the 'green' effect of aging becomes more pronounced in advanced stages of demographic transition.

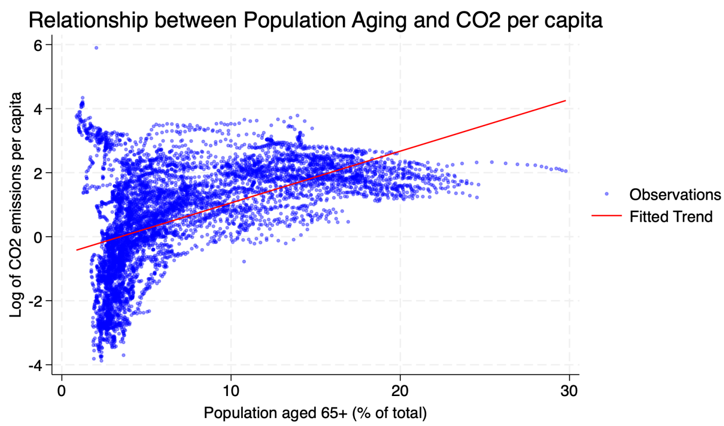

Figure 1- Relationship between Population Aging and Log of CO2 Emissions per Capita.

Figure 2 presents a comparative longitudinal analysis of CO2 emission trends across a diverse group of economies. We observe distinct patterns: while established aging societies like the **UK, Germany, and Japan** show a consistent downward trajectory, emerging or rapidly transitioning economies like **China and South Korea** exhibit different paths. China's sharp increase reflects its intensive industrialization phase, whereas the stabilization in the **USA and UK** further supports our findings that more mature, aging economies tend to decouple growth from emissions. Including countries like **Mexico and Australia** provides a necessary baseline, showing that the 'green aging effect' is most visible in nations that have passed their peak industrial expansion.

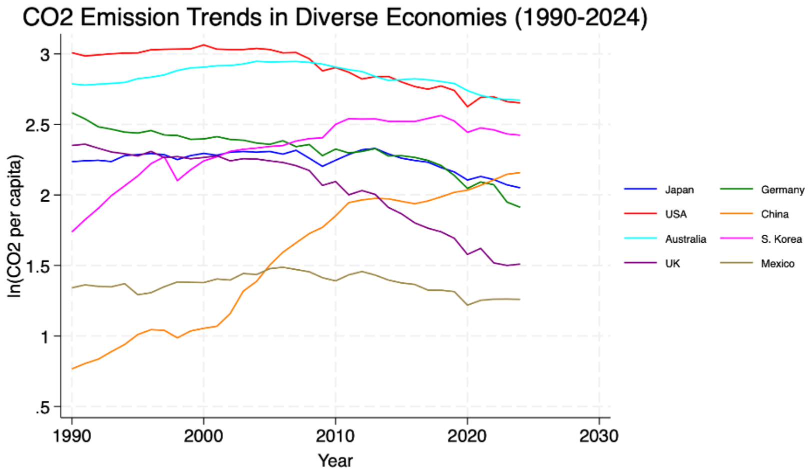

Figure 2 - *Longitudinal Trends of CO2 Emissions in Aging Societies (Japan, Germany, USA, UK, North Korea, China, Mexico and Australia)*

Results

Using the ratio of population over the age of 65, our results suggest that there is a negative correlation between an aging population and CO2 emission per capita, with a p-value of 0,0026 suggesting that this finding is significant. A 1% increase in the share of people over the age of 65, is associated with a reduction in CO2 emission by 6,9%, which is interesting. Although the general direction of our findings is as expected, the magnitude of the effect raised our suspicion. Other empirical results points to a magnitude of less than 1% (Kim et al., 2020; Xu, 2024). The discrepancy in the magnitude of the

Table 2: Baseline Model

	Model 1: % Population 65+	Model 2: Median Age
Aging Variables		
Population 65+ (%)	-0.0690***	
	(0.0026)	
Median Age		-0.0114
		(0.0108)
Control Variables		
Log GDP per capita	0.6904***	0.6437***
	(0.0149)	(0.0689)
Urbanization (%)	0.0159***	0.014***
	(0.0008)	(0.0038)
Model Statistics		
Num.Obs.	6597	6632
R^2	0.4135	0.3890
Std.Errors	Custom	Custom
Country Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes

† p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001
Driscoll-Kraay standard errors in parentheses.

coefficient makes us question the robustness of our results. In an attempt to check the robustness of the result, we constructed a model with median age as a variable for the demographic change. Although the magnitude of the coefficient was more comparable with the literature, the effect ceased to be significant. Further investigation is needed.

Unsurprisingly our results suggest that there is a positive relationship between per capita GDP and CO2 emission. A 1 percent increase in GDP per capita is significantly associated with an increase in CO2 emission per capita of 0.69%. One way to interpret this is that when people have more disposable income they tend to consume more. Higher consumption might imply higher emissions.

Lastly urbanization, which has a coefficient of 0.0159. This result suggest that structural changes such as urbanization is accompanied by higher CO2 emission per capita of 1.59%. This might reflect industry and infrastructure expansion that might lead to higher demand for energy, thus leading to higher consumption and higher emissions.

To further investigate the sensitivity of the results, we ran a sensitivity analysis. We increased the time dimension (1970-2024) but restricted the number of countries to only include Australia, China, Germany, Japan, Mexico, United States and United Kingdom.

The main difference between the baseline model and sensitivity model is that the magnitude of share of population over 65 shruk and became insignificant, which is interesting.

At first glance this might be due to insufficient variance in the age variable. The baseline model includes significantly more countries, allowing for a more precise measure of the relationship between CO2 emissions per capita and age. This is apparent as the baseline model has around 6,600 observations, while the sensitivity model only has around 460 observation – a relatively large difference. Coefficient for GDP per capita and urbanization stays relatively unchanged.

Table 3: Sensitivity model

	Model 1: % Population 65+	**Model 2: Median Age**
Aging Variables		
Population 65+ (%)	-0.010	
	(0.006)	
Median Age		-0.014
		(0.009)
Control Variables		
Log GDP per capita	0.601***	0.623***
	(0.069)	(0.058)
Urbanization (%)	0.014**	0.014**
	(0.004)	(0.005)
Model Statistics		
Num.Obs.	467	462
R^2	0.765	0.766
Std.Errors	Custom	Custom
Country Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Driscoll-Kraay standard errors in parentheses.

The deduction is that both regressions seemingly suggest there is a positive dynamic between GDP per capita and urbanization, as CO2 emission increases as GDP and urbanization increase, respectively. It is, however, more challenging to draw any unambiguous conclusion about population aging, which is the core of our essay. One explanation for the difference in significance between our baseline and sensitivity model might lack of variance in the sensitivity model. From an econometric perspective one would want different countries that experience population aging at different speeds, as this creates variance. Restricting the sensitivity model to only 9 countries significantly reduce to what extent the aging variable can vary, thus making the model more prone to imprecise measures. These results might also suggest that further research should focus on the quantity of countries, as population aging can be classified as a slow-moving variable, which emphasizes the need for sufficient variance. The results also expose our data sets' sensitivity to sample size. Our models yielded interesting results. Nonetheless, our model did not yield results to sufficiently and unambiguously answer our research question.

Conclusion

The empirical results of the study demonstrate a negative correlation between demographic aging and emissions per capita, with the baseline model indicating that a 1% increase in the share of the population aged 65 and older reduces emissions by 6.9%. This finding, while statistically significant, displays a magnitude considerably higher than existing literature, which typically reports effects below 1%. In contrast, the positive coefficients for GDP per capita and urbanization remain robust and consistent across models, confirming that economic wealth and structural expansion are primary drivers of environmental emissions.

The primary strength of this research is its use of a comprehensive global panel of 194 entities and the application of Driscoll-Kraay standard errors to account for heteroskedasticity and cross-sectional dependency. However, the study is limited by the sensitivity of the aging variable, which loses significance when tested against median age or restricted to a smaller sample of countries, suggesting that aging is a "slow-moving" variable sensitive to sample variance.

In conclusion, the findings of this study remain ultimately inconclusive, as the sensitivity of the aging coefficient to sample selection and variable specification prevents a definitive answer to the research question. It is critical to emphasize that these results reflect pure correlations rather than causal links, as the model does not incorporate a sufficiently exhaustive set of control variables, such as energy mix or political institutional quality, to eliminate all potential endogeneity. Despite these econometric limitations, the general alignment with earlier literature suggests a persistent negative relationship between demographic aging and CO_2 emissions. Consequently, future research should move toward tracking the specific consumer behaviors and habits of elderly populations; identifying these low-carbon mechanisms is essential for constructing targeted policies that incentivize the general population to adopt similar sustainable behaviors.

Appendix A

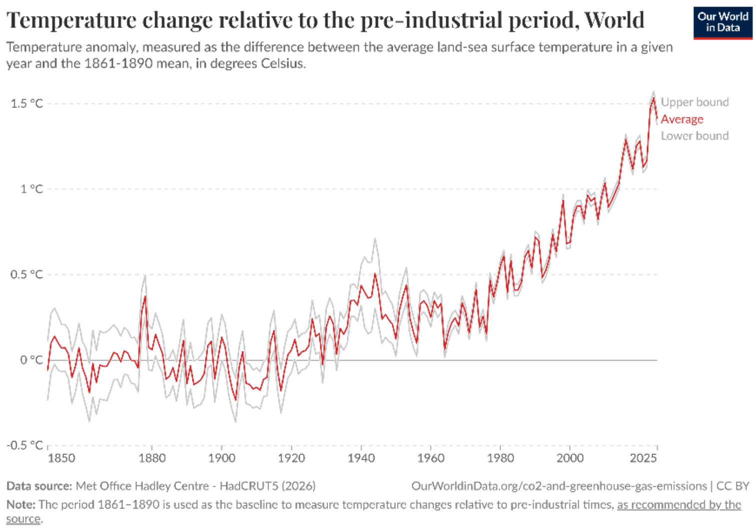

Figure 3 - Increase in global temperatures. Source: Our World in Data, (2026)

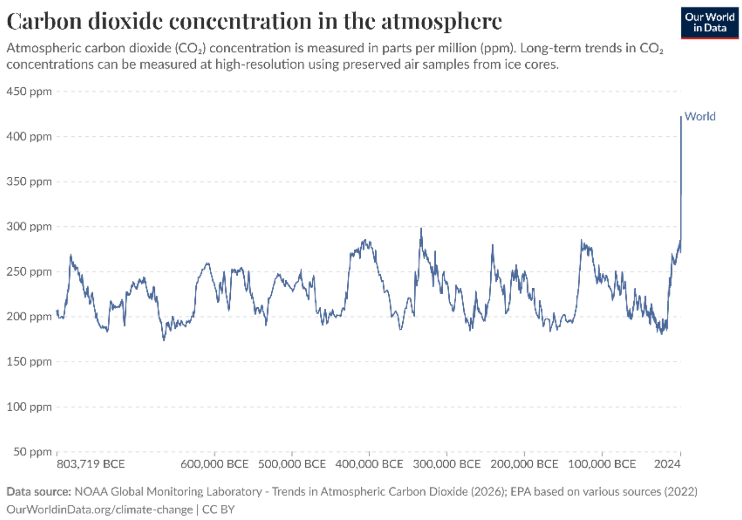

Figure 4 - Increase in carbon dioxide concentration. Source: Our World in Data (2026

References

Adelman, I. (1963). An Econometric Analysis of Population Growth. *The American Economic Review*, *53*(3), 314–339.

Global Carbon Budget. (n.d.). *GCB 2025* (Global Carbon Budget 2025) [Data set]. Retrieved 18 February 2026, from https://globalcarbonbudget.org

Hassan, K., & Salim, R. (2015). Population ageing, income growth and CO_2 emission: Empirical evidence from high income OECD countries. *Journal of Economic Studies*, *42*(1), 54–67. https://doi.org/10.1108/JES-04-2013-0046

Jardon, A., Kuik, O., & S.J. Tol, R. (2017). Economic growth and carbon dioxide emissions: An analysis of Latin America and the Caribbean. *Atmósfera*, *30*(2), 87–100. https://doi.org/10.20937/ATM.2017.30.02.02

Kim, J., Lim, H., & Jo, H.-H. (2020). Do Aging and Low Fertility Reduce Carbon Emissions in Korea? Evidence from IPAT Augmented EKC Analysis. *International Journal of Environmental Research and Public Health*, *17*(8), 2972. https://doi.org/10.3390/ijerph17082972

OECD. (2026a). *Members and partners*. OECD. https://www.oecd.org/en/about/members-partners.html

OECD. (2026b). *OECD Data Explorer • Annual GDP and components—Expenditure approach* [Data set]. https://data-explorer.oecd.org/vis?df[ds]=DisseminateFinalDMZ&df[id]=DSD_NAMAIN10%40DF_TABLE1_EXPENDITURE&df[ag]=OECD.SDD.NAD&dq=A.CHN%2BMEX%2BJPN%2BIND%2BDEU%2BGBR%2BUSA%2BKOR%2BAUS.S1..B1GQ....USD_PPP.LR%2BL..&pd=1950%2C2025&to[TIME_PERIOD]=false&vw=tb

OECD. (2026c). *OECD Data Explorer • Historical population data* [Data set]. https://data-explorer.oecd.org/vis?fs[0]=Topic%2C1%7CSociety%23SOC%23%7CDemography%23SOC_DEM%23&pg=0&fc=Topic&bp=true&snb=2&vw=tl&df[ds]=dsDisseminateFinalDMZ&df[id]=DSD_POPULATION%40DF_POP_HIST&df[ag]=OECD.ELS.SAE&df[vs]=1.0&dq=DEU%2BUSA%2BRUS%2BJPN%2BCHN.POP.PS._T._T.&pd=1950%2C2025&to[TIME_PERIOD]=false

Our World in Data. (2026a). *Carbon dioxide concentration in the atmosphere*. Our World in Data. https://ourworldindata.org/grapher/co2-long-term-concentration

Our World in Data. (2026b). *Temperature change relative to the pre-industrial period*. Our World in Data. https://ourworldindata.org/grapher/temperature-anomaly

Preston, S. H. (1975). The Changing Relation between Mortality and level of Economic Development. *Population Studies*, *29*(2), 231–248. https://doi.org/10.1080/00324728.1975.10410201

United Nation. (2026). *World Population Prospects* (Median Age) [Data set]. https://population.un.org/wpp/downloads?folder=Standard%20Projections&group=Most%20used

WHO. (2025). *Ageing and health*. World Health Organization. https://www.who.int/news-room/fact-sheets/detail/ageing-and-health

World Bank. (2026). *World Development Indicators | DataBank* [Dataset]. https://databank.worldbank.org/reports.aspx?source=2&series=SP.URB.TOTL.IN.ZS&country=#

Xu, N. (2024). How population aging promotes carbon emission reduction in Chinese cities: The chain mediating role of industrial upgrading and energy conservation. *Journal of Environmental Management*, *354*, 120434. https://doi.org/10.1016/j.jenvman.2024.120434