Examining the Correlation Between a Country's Carbon Emissions and Its Citizens' Average Life Expectancy

INTRODUCTION

As humanity approaches the modern era, we face a modern problem: climate change. One catalyst of climate change is humanity's reliance on carbon emissions for nonrenewable energy sources. Explored in IB Biology through topic 4.4, Carbon gets released into the atmosphere as Carbon Dioxide. Carbon Dioxide is what is known as a greenhouse gas: a pollutant gas that absorbs long-wave radiation in Earth's atmosphere, preventing the heat energy to be released into space (Greenhouse Gases). As a result, these gases raise Earth's temperatures above what is considered normal (Overview of Greenhouse Gases). Carbon is especially harmful since it cycles in the atmosphere for an extended period of time (Overview of Greenhouse Gases). In spite of this information, countries continue to burn fossil fuels for their energy, releasing increasing amounts of carbon into the atmosphere in the form of Carbon Dioxide. In 2019 alone, over 36.81 Billion Tonnes of Carbon Dioxide are estimated to have been emitted (Hausfather).

As a result, over the past 100 years there has been an 0.7˚ C average increase in Earth's surface temperature (Schellnhuber and Cramer 4). While 0.7's meager value falsely suggests climate change poses an insignificant threat to Earth, this "meager" 0.7˚C average rise in temperature has effectively thrown the fragile balance of Gaia's ecosystems into chaos, causing harmful positive feedback loops resulting in heavy precipitation, more droughts, intense heat waves, harsher hurricanes, rising sea levels, and a melting Arctic (Shaftel et al).

It is clear that climate change poses a significant threat to Earth's biological organisms through the destruction of their environment. However, at this point in my research, it was unclear to me if climate change posed a significant threat to humans. Humans live in manufactured, self-built ecosystems, partially removed from Earth's ecosystems, I thought. Would carbon emissions still negatively affect human health? Since life expectancy is a measure of human health, the research question can be asked, *Is there a correlation between a country's carbon emissions and its citizens' average life expectancy?*

As examined in IB Biology's Topic 6.4 and D.6, gas exchange occurs in human lungs, behaving as the first step in allowing oxygen, essential for cellular respiration, to be transported into cells. Oxygen enters the body as a person breathes in, travelling down the trachea, through the bronchi, and entering the lung's alveoli (Paxton, et al). Alveoli are shown below in Figure 1.

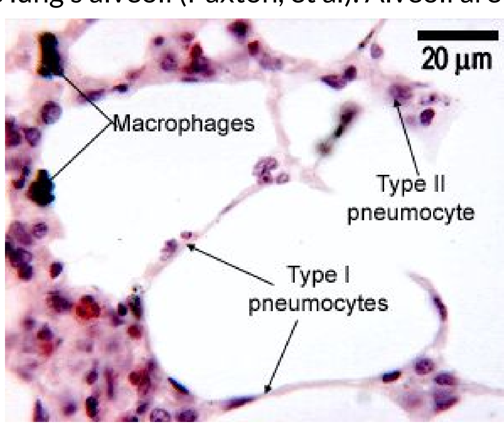


Figure 1. Micrograph of Alveoli of the human lung (Paxton, et al).

It is here that the oxygen diffuses from the highly-concentrated alveolus through the Type I Pneumocyte cells—the flattened, thin cells which line the alveoli—into the capillaries which surround the Type I Pneumocytes. As this diffusion occurs, the rounded Type II Pneumocyte cells located on the alveoli wall secretes fluid—alveolar surfactant—onto the Type I Pneumocyte cells, ensuring, among other things, that oxygen can properly diffuse through the Type I Pneumocyte into the bloodstream (Paxton, et al). These Type II Pneumocytes and the alveolar surfactant they secrete are essential for proper gas exchange in the human lung.

In a 1997 study conducted on pigeon lungs, Corina Lornz and José López found that city pigeons which faced extremely high rates of air pollution had on average 33% less alveolar surfactant secreted by Type II Pneumocytes in their alveoli than countryside pigeons which faced extremely low rates of air pollution did (Lornz and López). Indeed, the study concluded that "Solid particles and high rates of nitrogen oxides [a type of greenhouse gas] in the polluted air... would represent the main factors for the marked decrease in the amount of LB [alveolar surfactant secreted] from type II pneumocytes" (Lornz and López). Pigeon lungs and human lungs are homologous structures (West et al). In a study conducted by Bernhard et al, parallels were drawn between bird alveolar surfactant and human alveolar surfactant (West et al). Thus, the pigeon lungs that Lornz and López studied can serve as models for human lung function. Since their study suggests that air pollution harmfully affects bird Type II Pneumocytes, it suggests that human Type II Pneumocytes, and overall lung function, are harmfully affected by air pollution. Indeed, another study conducted by Marino et al. found that "there is now increasing evidence suggesting that significant exposure to outdoor air pollutants may be also associated with development of lung cancer and with incident cases of chronic obstructive pulmonary disease (COPD) and respiratory allergies" (Marino et al.). It is clear that due to the structure of the human lung, air pollution negatively affects human health. I applied this same logic to carbon emissions, a form of atmospheric pollution, to how it harmfully affects our lungs.

Thus, two hypotheses were formed for the investigation.

- The Null Hypothesis: there is not a statistically significant correlation between a country's carbon emissions and it's citizens' average life expectancy—the correlation could be due to chance.
- The Alternative Hypothesis: there is a statistically significant correlation between a country's carbon emissions and its citizens' average life expectancy—the correlation is likely not due to change.

I believed that because air pollution is detrimental to human lung health, there would be a statistically significant relationship between a country's carbon emissions and its citizens' average life expectancy—the higher the carbon emissions, the lower the life expectancy will be.

If the alternative hypothesis is accepted, it could provide further evidence to legislative bodies to limit reliance on and use of Carbon Dioxide emitting fossil fuels. As someone who has long fought for my state to introduce a Carbon Tax to deter its citizens' use of carbon, I was compelled to determine whether or not the alternative hypothesis could be accepted.

METHODOLOGY

Materials:

- Access to databases pertaining to countries' carbon emissions, life expectancy, and Gross Domestic Product
- Access to LoggerPro

Procedure:

Because this investigation is a database analysis of different countries' carbon emissions and life expectancy, I chose to analyze data from 50 countries. This ensured that I had a large enough sample size to form a valid conclusion—a smaller sample size would have increased the likelihood of a false correlation between life expectancy and carbon emissions and invalidated the results of this investigation. Life expectancy is controlled by a myriad of factors. However, the largest controller of life expectancy was a country's economic status (Wilkinson 165). Income was found to greatly impact a person's disease and disability, psychological health, and illness, thus ultimately impacting a country's overall life expectancy (Wilkinson 165). In order to eliminate this confounding variable, data was collected from the 25 countries with the highest GDPs and the 25 countries with the lowest GDPs, as ranked by the World Bank (GDP (Current US$)). Screenshots of each database used was included in the Appendix for reference under Appendix A-C.

Once the 50 countries were chosen, it was time for me to collect data points on the countries' average life expectancies and carbon emissions from my databases. Because the investigation is inherently reliant on this data, it was essential the databases from which the data was collected were extremely reputable sources to reduce the likelihood of invalid results. The databases were controlled for each measured variable and kept the same for each country. A database from the United States' CIA Agency was used to collect the average life expectancy due to the United States' CIA's reliability and impartial nature. As life expectancy is measured in years, the investigation used years as the unit of measurement for these data points. For the measurement of carbon emissions, data was taken from a study released by Boden et al. which was sponsored by the US Department of Energy, also an impartial source. This was measured in Thousand Metric Tons of Carbon.

As this was a database investigation, there were no apparent safety or ethical concerns. Rather, it is important to take periodic breaks from working to avoid eye strain and ensure proper blood circulation in the body. It is also important to view the data objectively—no judgement should be passed on any country for its life expectancy or carbon emissions.

DATA:

Data Table 1: Countries and their GDPs, Life Expectancy, and Carbon Emissions

Country	**Life Expectancy (Years)** (Boden et al.)	**Carbon Emissions (Thousand Metric Tons)** (COUNTRY COMPARISON :: LIFE EXPECTANCY AT BIRTH)
United States	80.00	1432855
China	75.70	2806634

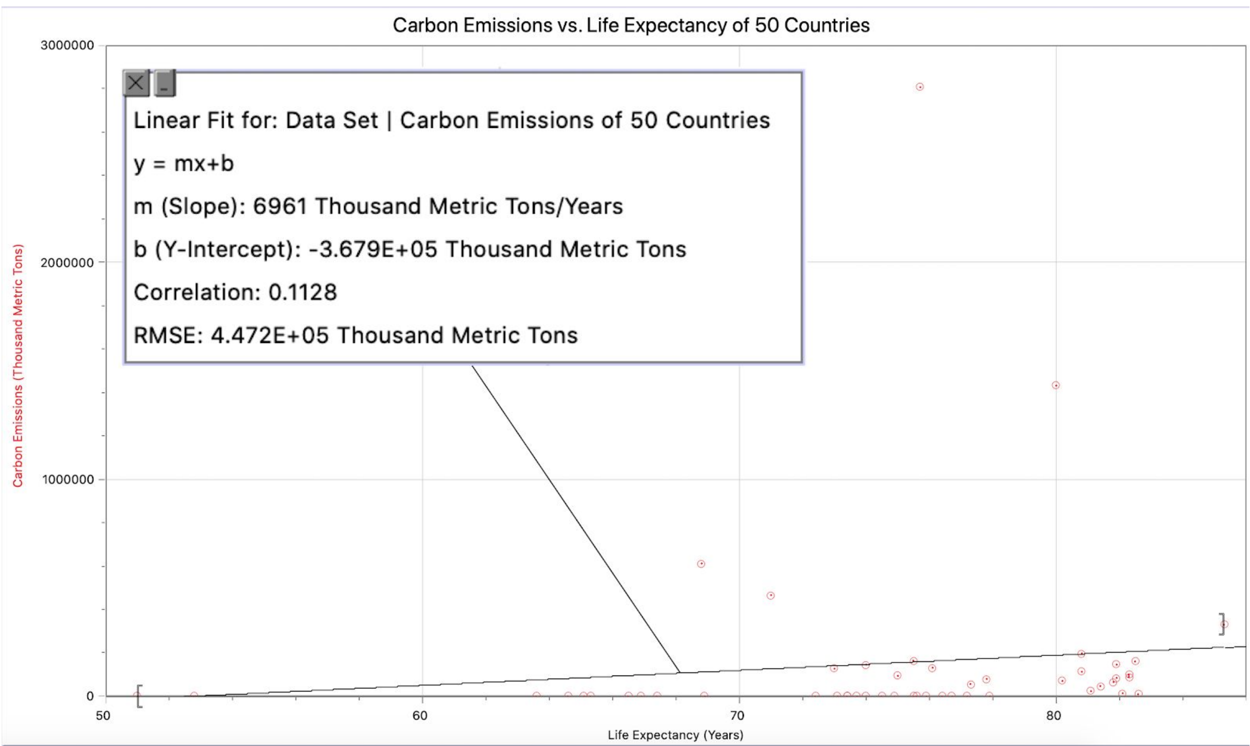
Country	**Life Expectancy (Years)** (Boden et al.)	**Carbon Emissions (Thousand Metric Tons)** (COUNTRY COMPARISON :: LIFE EXPECTANCY AT BIRTH)
Japan	85.30	331074
Germany	80.80	196314
United Kingdom	80.80	114486
India	68.80	610411
France	81.90	82704
Italy	82.30	87377
Brazil	74.00	144480
Canada	81.90	146494
Russia (Russian Federation)	71.00	465052
South Korea (Republic of Korea)	82.50	160119
Spain	81.80	63806
Australia	82.30	98517
Mexico	76.10	130971
Indonesia	73.00	126582
Netherlands	81.40	45624
Saudi Arabia	75.50	163907
Turkey	75.00	94350
Switzerland	82.60	9628
Poland	77.80	77922
Taiwan	80.20	72013
Sweden	82.10	11841
Belgium	81.10	25457

Country	**Life Expectancy (Years)** (Boden et al.)	**Carbon Emissions (Thousand Metric Tons)** (COUNTRY COMPARISON :: LIFE EXPECTANCY AT BIRTH)
Argentina	77.30	55638
Central African Republic	52.80	82
Cabo Verde	72.40	134
Djibouti	63.60	197
Belize	68.90	135
Saint Lucia	77.90	111
The Gambia	65.10	140
Antigua and Barbuda	76.70	145
Seychelles	74.90	135
Guinea-Bissau	51.00	74
Solomon Islands	75.60	55
Grenada	74.50	66
Comoros	64.60	42
Saint Kitts and Nevis	75.90	63
Vanuatu	73.70	42
Samoa	74.00	54
St. Vincent and the Grenadines	75.50	57
Dominica	77.20	37
Tonga	76.40	33
Sao Tome and Principe	65.30	31
Federated States of Micronesia	73.10	41

Country	**Life Expectancy (Years)** (Boden et al.)	**Carbon Emissions (Thousand Metric Tons)** (COUNTRY COMPARISON :: LIFE EXPECTANCY AT BIRTH)
Palau	73.40	71
Marshall Islands	73.40	28
Kiribati	66.50	17
Nauru	67.40	13
Tuvalu	66.90	3

DATA PROCESSING:

Figure 2. Graph depicting Carbon Emissions in Comparison to the Life Expectancy of 50 Countries



The graph, shown above in Figure 2, shows that there is a direct linear relationship between carbon emissions and life expectancy. Pearson's Correlation Coefficient statistical test determines if there is a statistically significant relationship between two distinct variables. That is, it tests whether or not the correlation found between the two variables is likely due to chance. Since this investigation compared life expectancy and carbon emissions, two discrete data sets, in order to determine correlation, Pearson's Correlation Coefficient was used to determine if the relationship seen in Figure 2. is indeed significant or not. My sample size was 50, which meant that my value for the degrees of freedom, (n-2), was 48. The R value, or the "level of correlation" of my two variables was calculated by LoggerPro and is seen in Figure 2. to be 0.1128. Following Pearson's Correlation Coefficient Statistical test, I used a table of "Critical Values," as seen below in Figure 3, following along with my value for the degrees of freedom to obtain a critical value of R with 0.05 levels of significance. This "critical value" is the value that the calculated R value must be above in order to ensure that, in accordance with the 0.05 levels of significance, there was only a 5% risk of wrongly concluding significance. Because the critical value of R obtained from Figure 2. is 0.1128 and less than the critical value of R of 0.279, I can conclude that the correlation seen in Figure 2. between a country's carbon emissions and the life expectancy of its citizens is not a statistically significant relationship. I reject the alternative hypothesis and accept the null hypothesis: there is not a statistically significant correlation between a country's carbon emissions and it's citizens' average life expectancy.

Values of *r* for the .05 and .01 Levels of Significance

df(*N* − 2)	.05	.01	*df*(*N* − 2)	.05	.01
1	.997	1.000	31	.344	.442
2	.950	.990	32	.339	.436
3	.878	.959	33	.334	.430
4	.812	.917	34	.329	.424
5	.755	.875	35	.325	.418
6	.707	.834	36	.320	.413
7	.666	.798	37	.316	.408
8	.632	.765	38	.312	.403
9	.602	.735	39	.308	.398
10	.576	.708	40	.304	.393
11	.553	.684	41	.301	.389
12	.533	.661	42	.297	.384
13	.514	.641	43	.294	.380
14	.497	.623	44	.291	.376
15	.482	.606	45	.288	.372
16	.468	.590	46	.285	.368
17	.456	.575	47	.282	.365
18	.444	.562	48	.279	.361
19	.433	.549	49	.276	.358
20	.423	.537	50	.273	.354
21	.413	.526	60	.250	.325
22	.404	.515	70	.232	.302
23	.396	.505	80	.217	.283
24	.388	.496	90	.205	.267
25	.381	.487	100	.195	.254
26	.374	.479	200	.138	.181
27	.367	.471	300	.113	.148
28	.361	.463	400	.098	.128
29	.355	.456	500	.088	.115
30	.349	.449	1000	.062	.081

Figure 3. Table of "Critical Values" used for Pearson's Correlation Coefficient (VonBargen).

CONCLUSION:

This investigation compared the average life expectancy and carbon emissions of 50 countries to determine if a statistically significant correlation existed between the two. Based on the investigation conducted, conclusions are as follows

1. I accept the null hypothesis and reject the alternative hypothesis

2. There is no significant correlation between a country's carbon emissions and its citizens' average life expectancy.

This can be seen through the Pearson's Correlation Coefficient Statistical Test concluded. While Figure 2. suggested that there was a positive, fairly linear direct relationship between the two with the slope of the graph following a linear upward path, Pearson's test determined that this relationship was not significant— the critical value of R, given at 0.279, was larger than the calculated value of R, 0.1128. There is no significant correlation between a country's carbon emissions and their citizen's average life expectancy.

I was very surprised by these results. Based on my earlier research, I had hypothesized that because carbon emissions were a form of air pollution and air pollution restricted the full function of Type II Pneumocytes, increased carbon emissions would correlate in a decreased average life expectancy in each country. However, the results from my investigation did not support this hypothesis whatsoever. What confused me even more was that most scientific articles I found stated that pollution negatively affected human health—logically, this would mean that my hypothesis was correct. Initially, I could not understand how I obtained these results.

What could explain these results, I found later, was the fact that I looked for a relationship between carbon emissions and life expectancy within countries. The Earth's atmosphere is not defined by the clear borders which define human populations. Instead, it is controlled largely by convection currents which keep the atmosphere circulating around the globe (Emanuel 3). A country's carbon emissions would cycle in these convection currents around the globe, dispersing and affecting many around the world rather than only affecting citizens in one country. Thus, it would affect the life expectancies of all citizens fairly uniformly. As a result, there would be no significant relationship between one country's carbon emissions and life expectancy. Rather, if there were to be further investigation, I believe a correlation could be uncovered between global lung health and increased carbon emissions.

This conclusion is supported by the United States' Environmental Protection Agency. When referring to greenhouse gases like Carbon Dioxide, the EPA claimed "All of these gases remain in the atmosphere long enough to become well mixed, meaning that the amount that is measured in the atmosphere is roughly the same all over the world, regardless of the source of the emissions" (Overview of Greenhouse Gases). This even layer of greenhouse gases across the Earth's atmosphere would thus affect each its citizens equally.

EVALUATION AND LIMITATIONS:

One limitation of this investigation is the fact that I did not collect the data. While I made sure that my data came from reliable sources, because I did not collect it myself and see all the factors that influenced its outcome, I cannot be completely sure of my data's error and uncertainty. I was still not able to add uncertainty bars to Figure 1., the Graph of Carbon Emissions vs. Life Expectancy of 50 Countries. I made sure to reduce this as much as possible within the investigation by choosing as reliable sources as possible. Because I used data published by unbiased, reputable sources, I am able to ensure that there is little error in the data collected. Indeed, I was able to obtain a large sample size of 50 different countries, making sure to account for differences in Gross Domestic Product and its influence on human life expectancy. These are strengths of my investigation, increasing the validity of my conclusions.

Another limitation of this investigation was when the data was collected. My data for life expectancy was collected for the year 2017 and my data for carbon emission data was collected for the year 2014. Because the data was not collected for the same year, it introduced error into the investigation—there could be small changes in the data between 2017 and 2014. However, because 2017 and 2014 are only three years apart and carbon emissions and human life expectancy are data values which do not vary wildly from year to year within a country, this error does not invalidate my conclusions. Because of the large difference between my critical value of R of 0.279 and my calculated R value from the Pearson's Correlation Coefficient statistical test of 0.1128, it is unlikely that the small changes in data points from 2014 to 2017 would have changed the conclusion of the investigation.

Since the limitations of the investigation largely are a result of not conducting data trials myself, possible extensions of the investigation could be to determine the relationship between carbon emissions and life expectancy through experiment and conduct my own data trials. Since it is unethical to test on live animals, it could be possible to test the relationship between incidence of aerobic bacteria and carbon levels inside a petri dish.

APPLICATION:

The applications for this investigation are endless. For one, it suggests that while legislation about carbon emissions and the use of fossil fuels may vary from country to country, all humans may feel the effects equally. There is no evidence to suggest that carbon emissions specifically targets the life expectancy of one country over another. This discovery has the potential to influence future laws and bills as the world progresses toward a more global society.

In addition, this investigation looked at one aspect of climate change: carbon emissions. Future studies could examine other factors of climate change—deforestation, fertilizer runoff, oil spills, etc.—and how they affect other aspects of human health. This can further aid governmental organizations to be fully informed when they write legislation surrounding the legality of these environmentally harmful chemicals.

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APPENDIX A: Screenshot of World Bank Database of Countries GDP

All Countries and Economies

Country	Most Recent Year	Most Recent Value (Millions)
Afghanistan	2018	19,362.97
Albania	2018	15,102.50
Algeria	2018	173,757.95
American Samoa	2018	636.00
Andorra	2018	3,236.54
Angola	2018	105,750.99
Antigua and Barbuda	2018	1,610.57
Argentina	2018	519,871.52
Armenia	2018	12,433.09

APPENDIX B: Screenshot of CIA Database of Human Life Expectancy By Country

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COUNTRY COMPARISON :: **LIFE EXPECTANCY AT BIRTH**

Life expectancy at birth compares the average number of years to be lived by a group of people born in the same year, if mortality at each age remains constant in the future. Life expectancy at birth is also a measure of overall quality of life in a country and summarizes the mortality at all ages.

DOWNLOAD DATA

RANK	COUNTRY	(YEARS)	DATE OF INFORMATION
1	MONACO	89.40	2017 EST.
2	JAPAN	85.30	2017 EST.
3	SINGAPORE	85.20	2017 EST.
4	MACAU	84.60	2017 EST.
5	SAN MARINO	83.30	2017 EST.
6	ICELAND	83.10	2017 EST.
7	HONG KONG	83.00	2017 EST.
8	ANDORRA	82.90	2017 EST.
9	GUERNSEY	82.60	2017 EST.
10	SWITZERLAND	82.60	2017 EST.
11	KOREA, SOUTH	82.50	2017 EST.
12	ISRAEL	82.50	2017 EST.
13	LUXEMBOURG	82.30	2017 EST.

<u>APPENDIX C:</u> Screenshot of EPA Database of Carbon Emissions by Country

Ranking of the world's countries by 2014 total CO2 emissions from fossil-fuel burning, cement production, and gas flaring. Emissions (CO2_TOT) are expressed in thousand metric tons of carbon (not CO2).

Source: Tom Boden and Bob Andres
Carbon Dioxide Information Analysis Center
Oak Ridge National Laboratory

Gregg Marland
Research Institute for Environment, Energy and Economics
Appalachian State University

doi 10.3334/CDIAC/00001_V2017

RANK	NATION	CO2_TOT
1	CHINA (MAINLAND)	2806634
2	UNITED STATES OF AMERICA	1432855
3	INDIA	610411
4	RUSSIAN FEDERATION	465052
5	JAPAN	331074
6	GERMANY	196314
7	ISLAMIC REPUBLIC OF IRAN	177115
8	SAUDI ARABIA	163907
9	REPUBLIC OF KOREA	160119
10	CANADA	146494
11	BRAZIL	144480
12	SOUTH AFRICA	133562
13	MEXICO	130971
14	INDONESIA	126582
15	UNITED KINGDOM	114486
16	AUSTRALIA	98517
17	TURKEY	94350
18	ITALY (INCLUDING SAN MARINO)	87377
19	THAILAND	86232
20	FRANCE (INCLUDING MONACO)	82704
21	POLAND	77922
22	TAIWAN	72013
23	KAZAKHSTAN	67716
24	MALAYSIA	66218
25	SPAIN	63806
26	UKRAINE	61985
27	UNITED ARAB EMIRATES	57641
28	ARGENTINA	55638
29	EGYPT	55057
30	VENEZUELA	50510