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Air Pollution and Life Expectancy

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Abstract: This article explores the effect of air pollution on life expectancy. While prior studies heavily supported the link between long-term exposure to air pollution and harmful effects on health, most are based on single-country data. The objective of this article is to fill the gap in the literature by conducting a cross-country analysis. It evaluates the effect of average air pollution on life expectancy across 111 countries between 2010 and 2015. The additional country-specific control variables that are used include GDP (Gross Domestic Product) per capita, percentage of people with access to water, population density, health care expenditure (in terms of GDP), and the GINI index (a measure of inequality). This study finds a negative association between average exposure to air pollution and life expectancy. Specifically, it is estimated that for every additional mean microgram per cubic meter of PM (Particulate Matter) 2.5 air pollution exposure, life expectancy declines by 0.04 years on average.

Introduction

In recent years, environmental consciousness and sustainability have become a greater focus, as global warming threatens the stability of the planet. In September of 2016, the United States joined the Paris Agreement, one of the most comprehensive climate change agreements in history. More than 190 countries pledged to this agreement, with the intention of reducing global emissions and maintaining temperature increases with targets through 2030 (Peters, et al. 2016).[2] During a historic period in the climate change movement, it is imperative now more than ever to understand the consequences of environmental neglect. Existing studies have presented a heavily supported link between long-term exposure to air pollution and harmful effects on health (Correia 2013). The majority of these studies, however, are based on single country data.

It is estimated that up to 40 percent of premature mortality is related to the adverse effects of pollution (Goenka 2012). Additionally, a recent World Health Organization (WHO) study suggests that approximately 656,000 premature deaths occur due to air pollution and 96,000 as a result of water pollution in China. By comparison, the number of premature deaths in India due to air pollution is estimated to be 537,000 while the corresponding estimate is 46,000 in the United States (Goenka 2012). Since the 1970s, Congress has passed several laws to protect the environment in the United States. In order to reduce air pollution across the country, the first Clean Air Act was introduced in 1970 under the supervision of the Environmental Protection

[1] I would like to thank Professors Khawaja Mamun and Jennifer Trudeau for their helpful comments and insight.

[2] Following the 2016 U.S. presidential election, however, President Donald Trump maintained his campaign vow by announcing the US withdrawal from the Paris Agreement on June 1, 2017 (Böhringer and Rutherford 2017).

Agency (EPA). This act set limits on the amount of pollution released into the air by large industries such as steel mills and chemical plants. The increasingly strict air quality controls required by the EPA over the years have led to improvements in ambient air quality in the United States at costs that have been estimated as high as $25 billion per year (Correia 2013). Unfortunately, many developing countries are not able to afford this standard of environmental care. As a result, air pollution levels may be higher in those countries. While the results from this study are not causal, they confirm the single-nation study results--that air pollution has a negative association with life expectancy.

Literature Review

The available research on this topic is somewhat limited in that past population-based studies were based on the associations between air pollution and mortality. The analysis of mortality data, however, requires a time-series model in order to account for daily variations in pollution and mortality counts. The downfall of using a time-series model for this kind of data is that the results can be biased from factors such as temperature and influenza epidemics, which are prone to variation within a short time frame (Goenka 2012). Consequently, more recent studies have analyzed the relationship between air pollution and life expectancy as a measure of overall public health, as life expectancy is gathered at a yearly rate of comparison.

The most recent study published in 2013 gathered data from the years 2000-2007 and found that ambient levels of fine particulate matter (PM2.5) in the United States have been declining as a result of EPA interventions. Yet this decline occurred at a slower rate than previous years of data collection and analysis (1980-2000). Researchers included several variables that measure socioeconomic status, smoking prevalence, and demographic characteristics for the purpose of control variables. This study also concluded that a decrease of $10_{mg}/m^3$ in the concentration of PM2.5 was associated with an increase in average life expectancy of 0.35 years. It indicated that this association was stronger with more urban and densely populated areas. These results have important implications for public health because reductions in particulate matter air pollution are associated with reductions in both cardiopulmonary mortality and overall mortality (Correia 2013).

Another study by Pautrel (2007) investigated the effect of environmental policy on economic growth, emphasizing the relationship between pollution and life expectancy as the foremost channel of transmission. The researcher concludes that, “when pollution affects health and health influences life expectancy, environmental policy is ambiguous for growth” (Pautrel 2007). Overall, he found that environmental policy is a positive tool for stimulating growth. Based on this study, the evidence suggests that active environmental policies may be implemented to improve health and therefore promote growth.

Mariani, Pérez-Barahona, and Raffin (2009) conducted a cross-section analysis of 132 countries and found strong evidence in support of the relationship between longevity and environmental quality. The authors argued that, in order to increase longevity, people should be willing to invest in all aspects of the environment. This study focused on the environment as a whole, including air and water pollution, depletion of natural resources, biodiversity, and sustainable energy as critical factors affecting environmental health. One interesting aspect of this study was that as a result of the findings, some countries end up caught in a "low-life-expectancy/low-environmental-quality trap." More specifically, "out of 66 countries with an EPI index lower than the median value (56.04), 54 also belong to the group characterized by a life expectancy below the median (69.5)," and that, "out of the 66 countries with lower-than median life expectancy, 55 also exhibit a below-the-median value of the EPI."

These researchers suggest that the way people value their future is critically affected by their life expectancy. When longevity increases, people become more sympathetic to future generations as well as their future selves. Therefore, if someone expects to live longer, he or she should be more invested in the quality of their environment and surroundings. There is a consensus among scientists and economists alike that pollution has a negative impact on life expectancy. With both the global environment and longevity of everyone in consideration, this topic of research is abundantly relevant and critical.

Empirical Model and Data Description

Due to the structure and availability of data, the model used in this research is cross sectional. Of the 195 countries in the world, 111 samples were gathered. The model takes the following form:

Lifeexp = f(Pollu, GDPPC, Accesstowater, Popdens, Healthcareexp, Gini)

where *Lifeexp* is the life expectancy at birth in years, *Pollu* is mean exposure to PM2.5 air pollution (micrograms per cubic meter), *GDPPC* is GDP per capita, *Accesstowater* is percentage of population with access to an improved water source, *Popdens* is population density (people per square km. of land area), *Healthcareexp* is health expenditure as a percentage of total GDP, and *Gini* is the GINI index (a measure of inequality). A priori, it was expected that *GDPPC*, *Accesstowater*, and *Healthcareexp* would have positive coefficients and that *Pollu*, *Popdens*, and *Gini* would have negative coefficients. The countries that were examined in the study are depicted in Figures 1 and 2, where average pollution level and average life expectancy are shown.[3]

[3] These figures were produced by the author using Stata.

Figure 1

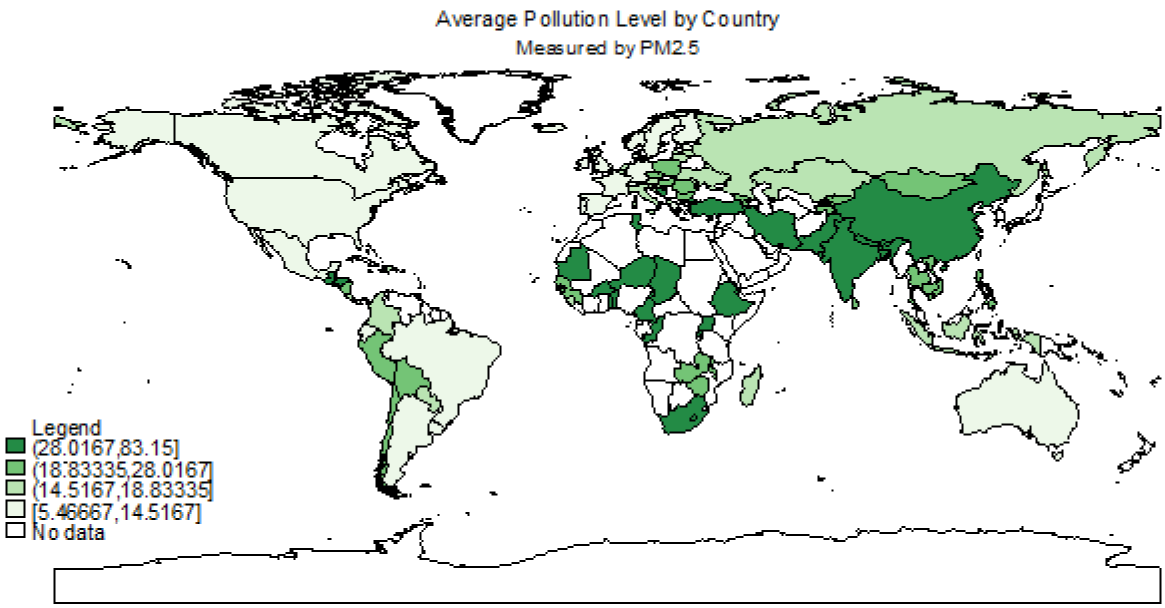
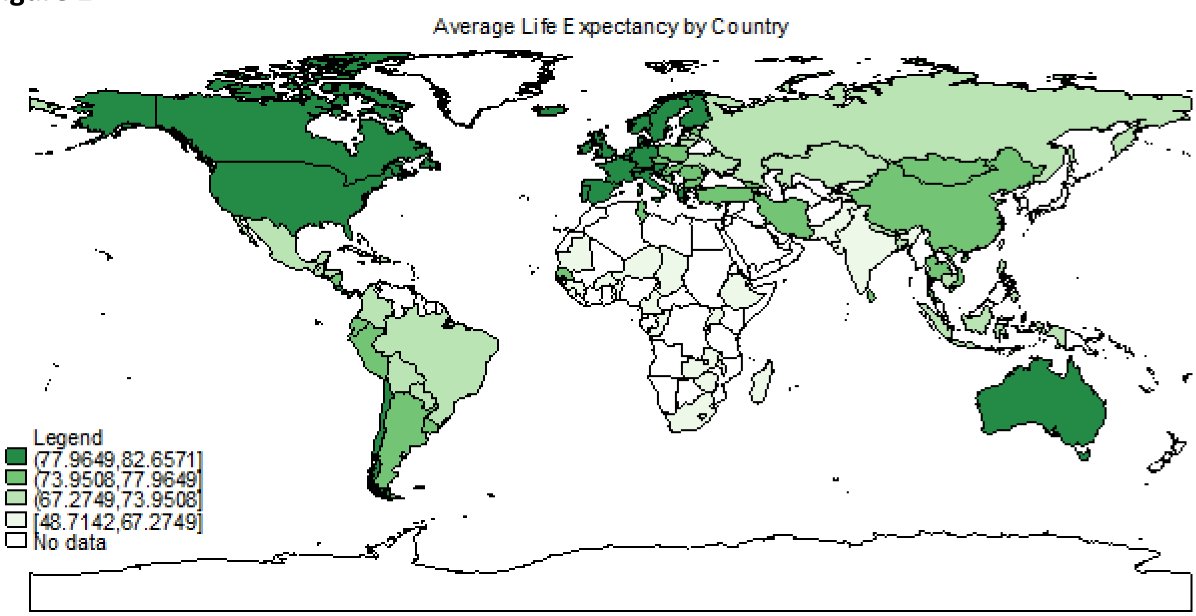


Figure 2



This study uses 111 observations total from 111 countries with data averaged between the years 2010 and 2015, using data from the World Bank's DataBank. The summary statistics are provided at the end of the section in Table 1.

The dependent variable in this study is life expectancy at birth, measured in years. It is the number of years a newborn would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life (World Bank). The mean life expectancy from the data is approximately 71 years, with a maximum measure of 83 years (in Switzerland) and a minimum of 49 years (in Lesotho). The key independent variable is population-weighted exposure to ambient PM2.5 pollution, which is defined as the average level of exposure of a nation's population to concentrations of suspended particles measuring less than 2.5 microns in aerodynamic diameter. These particles are capable of penetrating deep into the respiratory tract and severely affecting health. This exposure is calculated by weighting mean annual concentrations of PM2.5 by population in both rural and urban areas (World Bank). The mean level of PM2.5 exposure is 25.5 mg/m^3, with a maximum measure of 120 mg/m^3 (in Saudi Arabia) and a minimum of 3 mg/m^3 (in Kiribati). It was hypothesized that a higher level of pollution would decrease life expectancy.

The other control variables included in the model are also drawn from WorldBank. GDP per capita is measured as gross domestic product divided by mid-year population, in constant U.S. dollars. I predicted that an increase in GDP per capita is associated with an increase in life expectancy. The GINI index measures the extent to which the distribution of incomes among individuals and households within an economy deviates from a perfectly equal distribution. This is generally a good measure of economic inequality within a nation (World Bank). It was predicted that a higher score on the GINI index decreases life expectancy.

Population density is defined as the mid-year population divided by land area in square kilometers. Population includes all residents regardless of legal status or citizenship and land area is a country's total area, excluding area under inland water bodies (World Bank). It was predicted that an increase in population density decreases life expectancy, based on the idea that places with higher population density are generally exposed to more environmental factors, including air pollution.

Additionally, the model controls for two key determinants of life expectancy, access to water sources and health care expenditures. Access to an improved water source refers to the percentage of population using an improved drinking water source. This includes piped water on premises such as well water and other improved drinking water sources such as public supply, protected springs, and rainwater collection (World Bank). It was hypothesized that an increase in access to water increases life expectancy. The total for public and private health care costs is counted as health care expenditure. This includes health services, family planning, diet and nutrition, and emergency funds. It does not include provisions for water and sanitation (World Bank). It was predicted that a higher health care expenditure increases life expectancy.

Table 1. Summary Statistics

Variable Name	Observations	Mean	Std. Dev.	Max.	Min.
Lifeexpec	202	70.95	8.66	83.54	48.71
Pollu	194	25.5	19.33	120.15	3.27
GDP per capita	197	$15,243.14	$23,110.25	$145,221	$216.40
Accesstowater	197	88.14	15.35	100	31.5
Popdens	216	420.13	1920.96	18693.3	0.137
Healthcareexp	190	6.72	2.74	17.11	1.09
GINI	113	38.11	8.42	63.38	24.55

Results

Table 2 reports the effect of each variable, including pollution, on life expectancy. The White Test revealed there was significant heteroskedasticity in the model that needed to be corrected for (reported in Table 2, Panel B). The issue of heteroskedasticity may be present due to the multicollinearity between GDP per capita and health care expenditure as a percentage of total GDP. Across the adjusted and unadjusted models, the estimate of the effect of the GINI coefficient remained insignificant.

The results confirmed the hypothesis regarding the effect of air pollution on life expectancy--that increased air pollution has a negative association with life expectancy. From Table 2, we can conclude that for every mean microgram per cubic meter of PM2.5 exposure, life expectancy decreases by 0.04 years, or 15 days, on average. This variable is also significant at 5% with an adjusted t-score of -2.14. The average life expectancy for the entire sample was equal to 70.95 years. Comparing this with the 70 countries with the highest measures of air pollution (above the mean of 25.5 mg/m^3) encountered an average of 44.7 mg/m^3 of exposure and a life expectancy of 66.54 years demonstrates that it is important to consider the effects of pollution on these vulnerable populations. These findings are consistent with earlier findings, which presented a “low-life-expectancy/low-environmental-quality trap” (Mariani, Pérez-Barahona, and Raffin, 2009). They are also very similar results to the Correia (2013) study which observed that in the United States, for a decrease of in the concentration of PM2.5 by 10 mg/m^3 there was an increase in average life expectancy of 0.35 years.

According to the model, both GDP per capita and access to water are significant determinants of life expectancy. The results indicate that an increase in GDP per capita increases life expectancy by approximately 1.5 years while an increase in the percentage of people with access to water also increases life expectancy by 0.34 years. Both variables are significant at 1 percent. Population density, health care expenditure and the GINI index, once controlling for heteroskedasticity, are not significant determinants of life expectancy according to the model.

Conclusion

The purpose of this study was to understand the associations between air pollution and life expectancy on a global scale. This study confirms the hypothesis that an increase in average air pollution exposure decreases life expectancy, on average, when utilizing cross-country data. The model including observations from 111 countries yields results that each additional microgram per cubic meter of PM2.5 decreases life expectancy by 0.04 years. This is in line with the expectation that air pollution would have a negative effect on average life expectancy with the inclusion of GDP per capita, access to water, population density, health care expenditure, and the GINI index as variables within the model.

There are, however, several limitations to consider. First, there may be other control variables that are important in explaining the variation in life expectancy across these countries, but data was limited. A second consideration is multicollinearity in the included measures. Although the adjusted models account for heteroskedasticity in the data by running the regression a second time to get accurate t-scores, there may be some remaining. For example, it may have been better to obtain a measure of healthcare expenditure data independent of the country's GDP per capita since it is another control in the model.

One shortcoming of this study is that we only observe the association, and not the causality, between air pollution and life expectancy. Future research should consider the causal link between the two variables in order to make accurate policy decisions. Based on this study, as well as prior research, it would prove beneficial for a nation to increase environmental protection laws in order to increase life expectancy. While many countries prosper with high environmental quality and high life expectancy, those that fall within the lower ends of those categories, the low-life-expectancy/low-environmental-quality trap, will need to consider serious changes in order to improve the conditions of their nation. Global agreements enforcing positive environmental policy, such as the Paris Agreement, are a step in the right direction. A reduction in air pollution benefits not only the planet, but the life of its inhabitants as well.

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Table 2. Main Results (Panel A: Life Expectancy)

Life Expec	Model I	Model II	Model III	Model IV	Model V	Model VI
Pollu	-0.12*** (-3.68)	-0.07*** (-2.71)	-0.04** (-2.03)	-0.04** (-2.08)	-0.04** (-2.2)	-0.08 (-2.47)**
GDPPC		2.69x10^{-4} *** (9.85)	1.54x10^{-4} *** (6.54)	1.52x10^{-4} *** (6.37)	1.61x10^{-4} *** (6.53)	1.26x10^{-4} *** (4.29)
Accestowater			0.34*** (12.1)	0.34*** (11.79)	0.35*** (12.17)	0.34*** (9.03)
Popdens				6.72x10^{-4} (1.05)	4.55x10^{-4} (0.71)	3.37x10^{-3} (1.11)
Healthcare exp					-0.13 (-0.72)	-0.28 (-1.37)
GINI						-0.11** (-2.01)
Obs.	189	183	178	177	175	111
Adj. R^2	0.06	0.39	0.67	0.66	0.68	0.72
F-Stat	13.57 (0.00)	58.48 (0.00)	118.27 (0.00)	86.54 (0.00)	73.11 (0.00)	46.21 (0.00)
Heteroskedasticity	4.13 (0.04)	1.18 (0.31)	5.01 (0.002)	3.81 (0.005)	3.97 (0.002)	4.31 (0.001)
DW Stat	1.64	1.83	1.78	1.73	1.76	1.31

Table 2. Main Results (Panel B: Consideration for Heteroskedasticity)

Life Expec	Model I	Model II	Model III	Model IV	Model V	Model VI
Pollu	- 0.12*** (-2.90)	-0.07*** (-2.85)	-0.04** (-2.44)	-0.04** (-2.53)	-0.04** (-2.5)	-0.08** (-2.14)
GDPPC		2.69x10^{-4} *** (8.99)	1.54x10^{-4} *** (7.82)	1.52x10^{-4} *** (7.82)	1.61x10^{-4} *** (6.79)	1.26x10^{-4} *** (4.00)
Accestowater			0.34*** (11.68)	0.34*** (11.21)	0.35*** (11.74)	0.34*** (7.73)
Popdens				6.72x10^{-4} (1.43)	4.55x10^{-4} (1.11)	3.37x10^{-3} (1.26)
Healthcare exp					-0.13 (-0.63)	-0.28 (-1.18)
GINI						-0.11 (-1.46)
Obs.	189	183	178	177	175	111
Adj. R^2	0.06	0.39	0.67	0.66	0.68	0.72
F-Stat	13.57 (0.00)	58.48 (0.00)	118.27 (0.00)	86.54 (0.00)	73.11 (0.00)	46.21 (0.00)
Heteroskedasticity	4.13 (0.04)	1.18 (0.31)	5.01 (0.002)	3.81 (0.005)	3.97 (0.002)	4.31 (0.001)
DW Stat	1.64	1.83	1.78	1.73	1.76	1.31