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The Health Tradeoffs between Development and Pollution

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Abstract

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On a country level, development generally benefits human health by increasing the quality of medical care, sanitation and other resources. However, there is also a negative externality as development appears to be correlated with pollution, which is harmful to human health. As a result, there is a tradeoff between developing and polluting. In this paper, I evaluate the proposed health tradeoff using country-level panel data on CO_2 emissions to measure pollution, and infant mortality and life expectancy to measure health. The results show that development increases pollution and positively affects both measures of health. On the other hand, pollution increases infant mortality but has no significant effect on life expectancy. Taking into account all partial effects, though, the health benefits from development seem to outweigh the costs from pollution.

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Figures and Tables

Introduction

High pollution levels are currently of great local and international concern, because of the risks they pose to humans and the environment. As a result, there is significant pressure is on individuals, firms, and countries to reduce their emissions to create a healthier, more sustainable ecological system. In the past couple of decades there has been a move toward international negotiations and agreements regarding pollution regulations. In 1997, the Kyoto Protocol set legally binding emissions targets for 37 industrialized countries, with the goal of collectively decreasing greenhouse gases by five percent of 1990 levels over a four year period. Nations are now negotiating a new emissions plan for when the commitment period on the Kyoto Protocol runs out in 2012. Already it appears that subsequent global regulations will target both developed and developing nations. In December 2009, countries at the United Nations Climate Change Conference in Copenhagen, Denmark, made progress toward a global emissions agreement. The Copenhagen Accord details the terms of this agreement, but currently the emissions targets are not legally binding.

The effects of such pollution restrictions are arguably different for developing and developed countries. The cost of reducing emissions is based largely on a country’s wealth and level of industrialization. Developed nations have the technology and resources to lower pollution without hindering production. However, in low and middle income countries, pollution is generally correlated with economic growth, so increases in emissions might reflect important advancements in development. Therefore, limiting emissions in all countries could amplify the already present economic disparities between developed and developing nations.

In this paper, I explore the link between development and pollution and the resulting effects on health. Pollution is undesirable for many reasons; one of them being the negative effect it has on health. However, it is possible that the returns to health from development outweigh the health costs associated with pollution. Improved access to medical care, better sanitation systems, and increased education are byproducts of development that could have positive impacts on health. If the health benefits from developing are large enough, global emissions restrictions could prevent low income countries from achieving the same level of social progress enjoyed by the United States and Europe.

First, I investigate the proposed positive relationship between development and pollution using CO_2 emissions as an indicator of air pollution levels. I measure development mainly through GDP but I also include fertility and percent manufacturing as additional indicators. As I suspect this relationship is not universal, I also evaluate different regions and developing/ developed countries separately.

After establishing the previous relationship, I quantify the tradeoffs between pollution and development when considering health. I run regression analyses using both life expectancy and infant mortality to indicate a country's overall level of health. As an additional measure, I also investigate the differences in factors affecting life expectancy for developed and developing countries.

The results show a strong, positive relationship between pollution and development and also between development and health. In contrast, evidence suggests that pollution raises infant mortality rates but has no effect on life expectancy. When taking into consideration the partial effects of GDP, fertility, manufacturing, and education on health, the benefits from development appear to outweigh the costs from polluting.

Background

Much environmental economic research revolves around a popular theory that the relationship between environmental deterioration and economic development is not linear. This is known as the Environmental Kuznets Curve (EKC), which is named after Kuznets (1955). Kuznets theorizes that income disparity increases over time with economic growth up until a certain point at which in begins to decrease. The EKC has a similar inverse-U-shaped pattern and over the past 15 years it has become an important part of environmental policy.

Grossman and Krueger (1991) are the first to suggest a link between income and environmental quality. In research using time series data on various air and water pollutants, they find that environmental quality deteriorates initially with an increase in per capita income but then improves as development continues (Grossman and Krueger 1995). Grossman and Krueger hypothesize that the later phase of improvement can be attributed to an increase in demand for environmental quality at higher levels of income.

Other studies find similar patterns in environmental degradation. Using panel data for 149 countries from 1960 to 1990, Shafik (1994) concludes that particulates and sulfur oxides increase and then decrease with income. As air pollution is relatively costly to eliminate, this problem tends to be addressed by middle income countries, who can afford the technologies needed to reduce emissions. However, Arrow et al. (1995) warn policy makers to use caution when interpreting the inverse-U-shaped curves as economic growth is not necessarily sufficient to bring about environmental improvement. They stress the need for accompanying policy reforms to ensure a resilient ecological system. Such reforms must take into account international consequences and the composition of growth (i.e. inputs and outputs).

Policy makers should also consider how the EKC changes with different types of pollution. For example, the inverse-U-shaped curve holds for many air pollutants but the relationship is unclear when considering carbon dioxide emissions. Schmalensee et al. (1998) find an EKC type relationship between CO_2 emissions per capita and income per capita using a flexible parametric approach. On the other hand, Azomahou and Van Phu (2001) use nonparametric methods and find that both early and advanced stages of development negatively affect emissions. There is even evidence that this relationship might differ for OECD and non-OECD countries (Galeotti et al., 2006). Therefore, at this point, it is clear that pollution does not always increase with development, but the literature disagrees about the exact relationship between the two variables.

I do not attempt to reevaluate the EKC but instead I take this research further by investigating the relationship between development and pollution as it relates to health. There is uncertainty as to the exact health costs of pollution on a country level but there is no evidence to suggest that pollution alone is beneficial.

On the other hand, health intuitively benefits from development through an increase in income and resources. Preston (1975) in fact argues that national income is the best indictor of health because it reflects changes in a number of factors related to the standard of living in a country. He explores the relationship between health and national income and finds that life expectancy is strongly associated with average income for poor countries but less so for wealthy countries. This suggests that development is more important for low income countries when considering returns to health.

For this reason, I not only investigate the global relationships between pollution, income and health but also the differences in these relationships for developing and developed countries. Quantifying the tradeoffs will yield new insight on the implications and potential consequences of international emissions regulations.

Data

Using the World Bank classifications,[1] I code all countries as "developing" or "developed." I also group the countries into nine world regions, including Western Europe, Eastern Europe, Asia, North America, South America, Africa, Oceania, Central America and the Caribbean, and the Middle East. I base these designations on the ones used by the CIA World Factbook.[2]

I extrapolate and interpolate all variables to fill in gaps in the data and provide a more complete picture of the trends in these variables. Where necessary, I drop extrapolated and interpolated values less than zero.

Table 1 presents the summary statistics for the extended dataset. Sample sizes for each variable differ as data does not exist for every country. The standard deviations are particularly important for interpreting the empirical results.

A. Pollution

I use carbon dioxide (CO_2) emissions to indicate pollution levels due to the quality of data available. While other pollutants such as ozone, carbon monoxide, and

[1] Full information regarding these classifications can be found online: http://www.worldbank.org/
[2] See https://www.cia.gov/library/publications/the-world-factbook/

sulfur dioxide are more detrimental to human health, data on them is only available for select countries (generally highly industrialized areas) and years. This is partly because these pollutants are hard to measure whereas the combustion of fossil fuels yields a predictable amount of CO_2, making it easy to quantify.[3] Yet, like the pollutants mentioned above, substantially elevated atmospheric concentrations of CO_2 are the result of human activity. Therefore, I choose this variable to indicate the general trends in air pollution across countries.

I collect CO_2 data from the EarthTrends division of the World Resources Institute (WRI). The data consists of annual measurements from 1950 to 2005 for 185 countries. The WRI gathers information from the Carbon Dioxide Information Analysis Center (CDIAC), the International Energy Agency (IEA) and the Energy Information Administration (EIA). The dataset presents the annual CO_2 levels by country in metric tons of carbon dioxide. The values include the amount of CO_2 produced from the combustion of solid, liquid and gaseous fuels, as well as from cement manufacturing and gas flaring. However, the data only includes emissions from gas flaring from 1980 to the present. This is not a significant concern as this source represents a very small percentage of the total emissions.

B. Development

I use several variables from the World Bank's World Development Indicators (WDI) to measure country development. The gross domestic product (GDP) and gross national income (GNI) per capita serve as measurements of country wealth. While GDP

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[3] CO_2 emissions are measured through inputs rather than outputs and depend mainly on the composition of the fuel, leading to an easy mathematical model for determining national levels. The input-output ratios for other gases, such as carbon monoxide, are more complicated, making them difficult to measure.

is the most common measure of relative income, the WDI uses GNI per capita to designate countries as low, middle or high income, which suggests its usefulness as an indicator of development. The WDI calculates GDP and GNI in current U.S. dollars and reports the annual values for most countries from 1960 to 2008. Data is only missing for some smaller island countries, which is not a problem for this analysis.

I collect fertility rate data as another indicator of development. The total fertility rate refers to the number of births per woman in a given country. This number tends to be lower for more industrialized countries due to better resources, education, and higher income. Data is available from 1960 to 2007 but contains gaps of, on average, two to three years. Yearly fertility rates only exist for select countries.

Additional variables I use in my analysis are manufacturing, aid per capita and population. The WDI measures manufacturing as a percent of GDP and aid per capita in current U.S. dollars. Annual manufacturing data exists for many countries from around 1965 to 2008 and annual aid per capita data exists from 1960 to 2007. Again, some smaller countries and islands are missing values but overall, the data is sufficiently extensive. Population data extends from 1960 to 2008 for almost every country.

C. Health and Education

Life expectancy and infant mortality are traditionally good indicators of the overall health of a country’s citizens. The infant mortality rate is the number of deaths of infants under one year old per 1,000 live births, while the life expectancy at birth is the average number of years a newborn baby is expected to live regardless of sex. The WDI data for these variables extends from 1960 to 2007 with values every two to five years.

Educational information is not well documented for developing countries but data on the primary school completion rate is relatively good. The primary school completion rate is the number of students successfully completing the last year of primary education in a given year as a percentage of the total number of children of graduating age. Increases in the completion rate indicate increases in the level of education for a given country. The WDI provides measurements of this rate approximately every five years from 1970 to 2008 for a sufficient number of countries.

Empirical Methodology

I use two models in this project, one to determine factors affecting pollution and the second to determine factors affecting health. I estimate these relationships using the ordinary least squares (OLS) regression method. I will begin by discussing the first model, as it is important for understanding the second.

A. Pollution Model

My main objective in using the pollution model is to determine the effects of changes in country level development on pollution, while holding other potentially significant variables constant. As development increases, one can expect production and building to increase as well, leading to higher levels of pollution. My base specification measures changes in pollution levels (CO_2 emissions) as a function of GDP, population, and fertility:

$$pollution_{it} = \beta_0 + \beta_1 (GDP)_{it} + \beta_2 (population)_{it} + \beta_3 (fertility)_{it} + \theta_t + \gamma_i + \mu_{it} \,, \tag{1}$$

I run this regression using year effects (θ_t) and with and without fixed effects (γ_i). Year effects control for factors which vary by year (t) but not by country (i), while fixed effects control for factors which differ between countries but are constant over time. I scale pollution by 1,000 metric tons of CO_2. GDP, population, and fertility are in units of standard deviations in order to make the coefficients easier to interpret and compare. GDP and fertility are included in the model as indicators of development. Therefore, if there is a positive relationship between development and pollution, I expect β_1 to be positive and β_3 to be negative. The population variable controls for the changes in a country's population over time that are correlated with both pollution and development.

To further explore the relationship between country wealth and pollution, I use the variable GNI per capita instead of GDP to measure income:

$$pollution_{it} = \beta_0 + \beta_1(GNI)_{it} + \beta_2(population)_{it} + \beta_3(fertility)_{it} + \theta_t + \gamma_i + \mu_{it}\ , \tag{2}$$

As with the other variables, GNI per capita is in units of standard deviations. GNI per capita and GDP should have similar relationships with pollution as they are both measures of national wealth. However, slight variations in the definitions of these variables might lead one to capture certain factors that the other does not.

In a final specification of this model, I include manufacturing and aid as two additional variables of interest. Manufacturing as a percent of GDP will help to single out the specific effects of domestic industrialization on country levels of pollution. Aid per capita is a potential omitted variable as it could be negatively correlated with GDP and also increase pollution through expansion and building projects. It also might be an indicator of development as more aid is given to low income countries. Therefore, manufacturing and aid per capita are added to the first equation as new variables of interest:

$$\begin{aligned} pollution_{it} = \beta_0 + \beta_1(GDP)_{it} + \beta_2(population)_{it} + \beta_3(fertility)_{it} \\ + \beta_4(manufacturing)_{it} + \beta_5(aid)_{it} + \theta_t + \gamma_i + \mu_{it}, \end{aligned} \quad \textbf{(3)}$$

I run regressions for the above equations using all countries and then for developing and developed countries separately. By doing so, I can explore whether or not the relationship between pollution and development is dependent a country's economic status. As mentioned previously, the Environmental Kuznets's Curve suggests that there should be a significant difference in pollution trends between high income and low income countries. In addition, I also examine European, Asian, North American, South American, African, and Middle Eastern countries separately to determine if there are any differences in the estimates for these regions.

B. Health Model

I use a second model to quantify and compare the respective effects of pollution and development on health. I use GDP again as the main indicator of development and both life expectancy and infant mortality as indicators of health. Increases in life expectancy and decreases in infant mortality signal improvements in a country's overall level of health. My base specification measures these changes as a function of pollution, GDP, population, fertility, and aid per capita:

$$\begin{aligned} health_{it} = \beta_0 + \beta_1(pollution)_{it} + \beta_2(GDP)_{it} + \beta_3(population)_{it} \\ + \beta_4(fertility)_{it} + \beta_5(aid)_{it} + \theta_t + \gamma_i + \mu_{it}, \end{aligned} \quad \textbf{(4)}$$

As with the first model, I estimate this equation with year effects and with and without fixed effects. All independent variables are in units of standard deviations. While I expect

GDP to have a positive effect on health, the relationship between pollution and health is less intuitive. Also, life expectancy and infant mortality might respond differently to changes in these variables.

I include an additional model specification to address the effects of education and manufacturing on health. The primary school completion rate measures a country's investment in education, and might be an omitted variable as it is correlated with GDP and affects health. On the other hand, percent manufacturing isolates the specific relationship between industrial growth and health. Therefore, I add these variables to the previous equation:

$$\begin{aligned} health_{it} &= \beta_0 + \beta_1(pollution)_{it} + \beta_2(GDP)_{it} + \beta_3(population)_{it} + \beta_4(fertility)_{it} \\ &+ \beta_5(aid)_{it} + \beta_6(education)_{it} + \beta_7(manufacturing)_{it} + \theta_t + \gamma_i + \mu_{it}, \end{aligned} \quad \textbf{(5)}$$

As with the first model, I also run regressions for developing and developed countries separately. It is plausible that the estimates are different for these two groups. The signs and magnitudes of the coefficients should offer interesting information about the health tradeoffs in developing and developed countries.

Results

A. Data Trends

Figures 1-13 depict the general trends in select variables. Figure 1 shows the positive global trends in both GDP[4] and pollution. Despite increased regulations, the total amount of CO_2 emissions is still increasing.

[4] The average GDP in these figures is weighted by population.

Figure 2 shows that there has been a steep increase in both GDP and emissions in the past decade for developing countries. However, for developed countries (Figure 3), emissions appear to be leveling off, while GDP continues to rise. This suggests that the relationship between income and pollution is different for these two groups. Figure 4 graphs total amount of emissions for developing and developed countries. Together developing countries pollute more than developed countries. This might be due to the number of countries in each group, but could also be due to differences in preferences for environmental quality.

Figure 5 illustrates how much each world region contributed to the combined amount of CO_2 emissions in 2008. Asia polluted the most (48%), followed by North America (27%) and Europe (10%). Figures 6-11 show the separate pollution trends for Europe, Asia, North America, South America, Africa, and the Middle East. Europe is the only region where there has been a significant downward trend in emissions. Air pollution in North America appears to be stabilizing but has not yet started to decrease. Conversely, emissions in South America and Africa are increasing steadily, while those in Asia and the Middle East are increasing at a faster rate. Finally, Figures 12 and 13 show that GDP is increasing at a much faster rate than life expectancy but that pollution and life expectancy are, for the most part, moving together.

B. Factors Affecting Pollution

Tables 2-6 display the results from the pollution and health regressions. All estimates are from the ordinary least squares model with standard errors in parentheses. I will evaluate first the results and implications of the pollution model before discussing the effects on health.

Table 2 shows the effects of development on pollution, taking into account all countries from 1960 to 2005. All estimates are significant at either the 1% or 5% level. Column 1 presents the results from estimating equation (1) with year effects and without fixed effects. The results suggest that a one standard deviation increase in GDP is associated with a 305,383 metric ton increase in CO_2 emissions. In other words, as development (measured by GDP) increases, the amount of country level pollution increases as well. This is intuitively reasonable as greater development generally means more production and urbanization.

The effects of population and fertility on pollution are also significant. Pollution increases with population and decreases with fertility. It makes sense that an increase in the number of people would increase the amount of pollution but it is unclear as to whether this is due to more transportation, greater industrialization or another factor. Developing countries tend to have higher fertility rates than developed countries so the negative sign on fertility supports the positive relationship between development and pollution.

In column 2, I add fixed effects and weight the countries by population. The signs of the estimates do not change but the magnitudes do, as now I am controlling for the average differences across countries. For example, the effect of GDP is now less, with a one standard deviation increase leading to a 125,665 metric ton increase in CO_2 emissions.

Column 3 estimates equation (2), which replaces GDP with GNI per capita. The relationship between country wealth and pollution still holds as GNI per capita is both positive and significant. In fact there is little difference between regressions 2 and 3 as the effect of a one standard deviation increase in GNI per capita is only 47,000 metric tons greater than that for GDP. The effect of fertility on pollution is smaller and its significance has dropped from the 1% level to the 5% level.

I present the results from equation (3) in column 4. Here I examine the effects of adding variables for manufacturing and aid per capita to the model. Controlling for these variables seems to strengthen the positive relationship between GDP and pollution. A one standard deviation increase in GDP now results in an 848,226 metric ton increase in CO_2 emissions. The consistent significance of this variable demonstrates a robust relationship between GDP and pollution.

As expected, pollution increases with manufacturing. This demonstrates a positive relationship between industrial growth and emissions. On the other hand, the relationship between aid per capita and pollution is difficult to understand. In this case, the coefficient on aid per capita is positive which suggests that low income countries are using their aid to pollute through some channel, such as increased transportation or production. However, there are other factors besides income which determine how much aid a country receives, making this relationship more complicated. The effect of fertility is positive and significant in the fourth regression, which suggests that other variables are now absorbing the changes in development previously reflected in the fertility rate.

In Table 3 I examine how the previously mentioned relationships change when I look at developing and developed countries separately. The results suggest that an increase in GDP is more likely to increase pollution in developing countries. Comparing columns 1 and 5, a one standard deviation increase in GDP increases CO_2 emissions by 188,081 metric tons for developing countries and by only 46,476 metric tons for developed countries. However, when I include fixed effects and weight by population in column 6, the coefficient on GDP becomes negative. This negative sign suggests that pollution decreases in developed countries as GDP increases. Yet, GNI per capita is insignificant in column 7 and GDP is positive again when additional variables are added in column 8. Therefore, I am hesitant to make assumptions regarding the effect of GDP on pollution in developed countries as this relationship is not consistent.

On the other hand, GDP appears to have a strong positive association with pollution in developing countries as all estimates are large and significant (columns 1, 2, and 4). GNI per capita is also positive, providing further evidence that increases in national wealth increase pollution in developing countries.

The estimates for population are positive and significant at the 1% level for all specifications in Table 3. However, these estimates are much larger for developed countries than developing countries. Comparing columns 2 and 6; a one standard deviation increase in population results in an increase in CO_2 emissions of 416,675 metric tons for developing countries and 4,541,429 metric tons for developed countries. This suggests that in developed countries, increases in pollution are largely the result of personal sources, such as automobiles, rather than industrial sources. Therefore, it seems that the marginal person is a bigger polluter in developed countries than developing countries. The estimates for manufacturing in columns 4 and 8 further support this hypothesis. Increases in manufacturing increase pollution in developing countries and decrease pollution in developed countries. Again, this suggests that in developing countries, pollution increases are primarily due to factors outside of production, such as transportation.

Table 4 displays the results of equation (1) for selected regions of the world. I include year and fixed effects and weight by population in all cases. The positive relationship between GDP and pollution is strongest for those regions with a higher concentration of low and lower-middle income countries (Asia, Africa, and the Middle East). For these regions, a one standard deviation increase in GDP results in a 350,000-400,000 metric ton increase in CO_2 emissions. Conversely, in Europe a one standard deviation increase in GDP results in a decrease in emissions by 16,148 metric tons. This relationship is unclear for North and South America.

As with GDP, the effects of fertility differ by region. The estimate on fertility is negative in less developed regions (Asia, Africa, and the Middle East), and positive in others. This suggests that in lower income regions, decreases in fertility indicate increases in development, which lead to more pollution, while in higher income regions, decreases in fertility primarily lead to a smaller number of people polluting. The results for North America are not significant, but this is likely due to a much smaller sample size, as there are only three countries in this region.

C. *Health Tradeoffs*

Tables 5 and 6 summarize the results from the second set of regressions, which explore the relative effects of pollution and development on health. In Table 5, I include data from all countries for the years 1960 to 2005 and use both life expectancy and infant mortality to indicate health. The left and right sides of the table are the same except for the dependent variable.

Column 1 shows that life expectancy increases with GDP and decreases with both population and fertility when using only year effects. These results are significant at the 1% level. Without controlling for fixed effects, the coefficient on GDP is surprisingly large. A one standard deviation increase in GDP increases life expectancy by 5.6 years. The estimate on fertility is also high, as a one standard deviation decrease (about 2 years) will increase life expectancy by 9.3 years. Fertility tends to be higher in less developed countries, so the negative value is reasonable.

In column 2 I add year effects to the model and weight by population. GDP, population, and fertility remain significant but the coefficients are smaller. For example, a standard deviation increase in GDP now results in an increase in life expectancy of 0.38 years.

Column 3 presents the results from adding variables for education and manufacturing. Both of these variables are significant at the 1 % level. I use the primary school completion rate to indicate education. As expected, better education increases a country's life expectancy. The amount of manufacturing as a percent of GDP also increases life expectancy. These partial effects offer further support for the positive relationship between development and health.

The estimate on population changes from negative in column 1 to positive in columns 2 and 3. Yet, it is difficult to determine what this means as there is not an intuitive relationship between population and life expectancy. On one hand, an increase in the population might decrease the life expectancy because of fewer available resources. On the other hand, there might be a reverse causality if an increase in life expectancy increases the population simply because more people are living longer. Due to this ambiguity, I do not focus on the relationship between population and health.

The estimate for pollution also changes signs but is not statistically significant, which suggests that there is no significant relationship between pollution and life expectancy. GDP, however, has a strong, positive association with life expectancy. The partial effect alone is not large but the estimates on fertility and education also indicate that life expectancy increases with development.

The right half of Table 5 presents the results from using infant mortality to measure health keeping all other factors the same. The estimates from column 4 are significant but appear overestimated when compared to those in columns 5 and 6. Nonetheless, infant mortality decreases as GDP rises and increases with higher rates of fertility, which is consistent with the previous life expectancy results. On the other hand, the relationship between health and aid per capita is now reversed (compared to column 3). Aid per capita decreases infant mortality, which represents a positive impact on health. In this case, it is possible that more aid is spent on mothers and children than on other members of the population, which would explain why it decreases infant mortality but does not increase life expectancy. However, there might be simultaneous causality as more aid is generally given to poorer countries. Aid loses significance in regressions 5 and 6, making it even harder to determine its actual relationship with health.

GDP and fertility retain their relationships with infant mortality but decrease in magnitude after adding fixed effects and weighting by population in column 5. Now a one standard deviation decrease in fertility decreases infant mortality by 18.6 deaths (compared to 41.1 deaths in the fourth regression).

Column 6 shows that education and manufacturing are again positively associated with health. As the primary completion rate and level of manufacturing in a country increase, infant mortality decreases. Together with GDP and fertility, the significance of these variables suggests a strong relationship between development and health.

Conversely, there is some evidence that pollution negatively affects health. When controlling for fixed effects and weighting by population (columns 5 and 6), an increase in pollution results in an increase in infant mortality. Compared to the results for life expectancy, this relationship suggests that infant mortality is more closely related to pollution than adult mortality. As people get older they are more likely to die from other health related problems such as heart disease or cancer.

Looking at columns 5 and 6, the positive effects of GDP on infant mortality are less than the negative effects from pollution. However, when taking into account the partial effects of other indicators of development (fertility, education, and manufacturing), the health benefits from development appear to outweigh the costs from pollution.

Table 6 further explores the determinants of health by separating countries into developing and developed, with life expectancy as the dependent variable. GDP, population, and fertility are significant for developing countries in all three specifications (columns 1-3). The results are similar to those in Table 5, as life expectancy increases with GDP and decreases with fertility. The inclusion of education and manufacturing does not change this relationship. Instead, the estimates for the primary completion rate and percent manufacturing provide further evidence of a positive connection between development and health.

On the other hand, pollution is not a significant determinant of life expectancy in developing countries. An increase in pollution, holding all else constant, does not necessarily lead to a change in overall health. So in this case, the health benefits from development outweigh the detrimental effects of pollution for developing countries.

Columns 4-6 of the same table, present the results for developed countries. The relationship between development and health is not as clear in this instance. GDP is positive in the fourth regression, negative in the fifth and insignificant in the sixth. This suggests that in high income countries, increases in GDP do not result in predictable changes in life expectancy. As highly developed countries tend to import more, other countries might be polluting for them.

Similarly, fertility has a weak relationship with health in developed countries, as it changes signs when including education and manufacturing in the model. However, the primary completion rate and percent manufacturing are still positively associated with life expectancy, suggesting that some aspects of development are beneficial to health.

The results in columns 4 and 5 suggest a positive relationship between pollution and health. Controlling for fixed effects and weighting by population, a one standard deviation increase in pollution increases life expectancy by 10.5 years. However, this variable is likely capturing other aspects of development as it loses significance in the sixth regression when adding manufacturing and education.

Conclusion

In this paper I use data from 1960 to 2005 to analyze the relationships between pollution, development, and health. I find substantial evidence that pollution increases with national income, as measured by GDP. Moreover, other indicators of development, such as fertility and percent manufacturing, appear to have a similar effect on pollution. The positive relationship between development and pollution is strongest for developing countries and low income regions of the world. However, for Europe, increases in GDP decrease pollution, which suggests that the economic costs of emissions regulations are not uniform.

There are several omitted variables in the pollution model for which sufficient data does not exist. Transportation, green technology and preferences for environmental quality are factors which are both correlated with GDP and affect pollution. Green technology and preferences for environmental quality are positively correlated with GDP but decrease pollution. Therefore, the absence of these variables leads to an underestimation of the effect of GDP. This is not problematic as the relationship between development and pollution would remain positive. Additionally, these variables have more of an effect on pollution levels in developed rather than developing countries. Transportation is a more concerning omitted variable because it is still positively correlated with GDP but increases pollution. This leads to an overestimation of the effect of GDP. However, I predict that even with transportation in the model, the positive relationship between GDP and pollution would hold.

I also provide evidence of a strong link between development and health. The results show that increases in GDP both increase life expectancy and decrease infant mortality. The significant partial effects of fertility, education, and manufacturing further validate this positive relationship between development and health. Again, this relationship is more pronounced for developing countries.

At the same time, pollution does appear to have some negative effects on health. There is no significant relationship between pollution and life expectancy but the results suggest that pollution does increase infant mortality rates. This is not unreasonable as Chay and Greenstone (2003) find a similar relationship when analyzing the effect of recession induced pollution shocks on infant mortality across the United States. However, researchers do not yet understand the pathophysiological mechanism underlying this connection.

The model for health is not flawless, as it does contain some simultaneous causality. For example, there are studies which show that infant mortality has a positive effect on fertility (Yamada, 1985; Palloni and Rafalimanana, 1999). In addition, health might also affect GDP as healthier populations are more productive (Bloom and Canning, 2000). Both of these causality problems could bias the estimates report in Table 5. However, the casual relationships I propose in the model are well documented, which leads me to believe that the results are indeed strong.

Given the empirical evidence I present in this paper, the best environmental policy would curb emissions while encouraging economic growth in developing countries. Results suggest that highly industrialized countries can afford to lower emissions with little effect on GDP. Therefore, these countries should continue to engage in legally binding national and international emissions agreements. Of greater concern, though, is what should be done regarding regulations in developing countries. Results from this study show that economic growth in these countries is good for national health. Yet, at the same time, growth increases pollution, which is positively associated with infant mortality. With this in mind, I would advise international organizations to supply developing countries with green technology instead of monetary aid. Green technology will allow these countries to benefit from development while keeping emissions levels low. Such a policy should also help decrease the large economic disparity between developing and developed nations.

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Figure 1. Global Trends in Pollution and GDP (1960-2008)

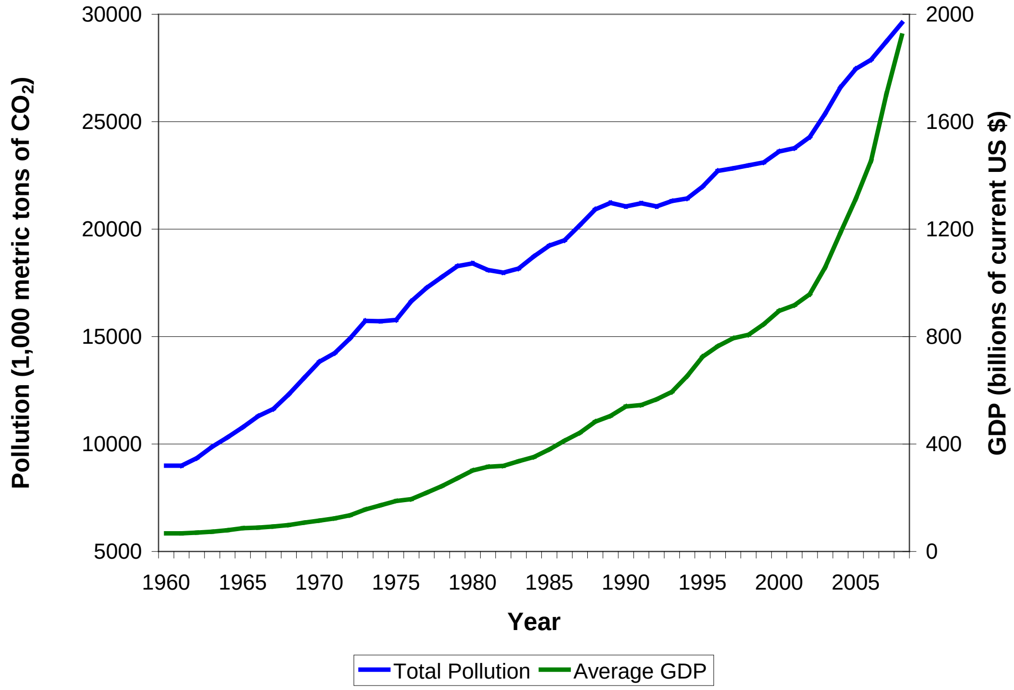

Figure 2. Pollution and GDP Trends for Developing Countries (1960-2008)

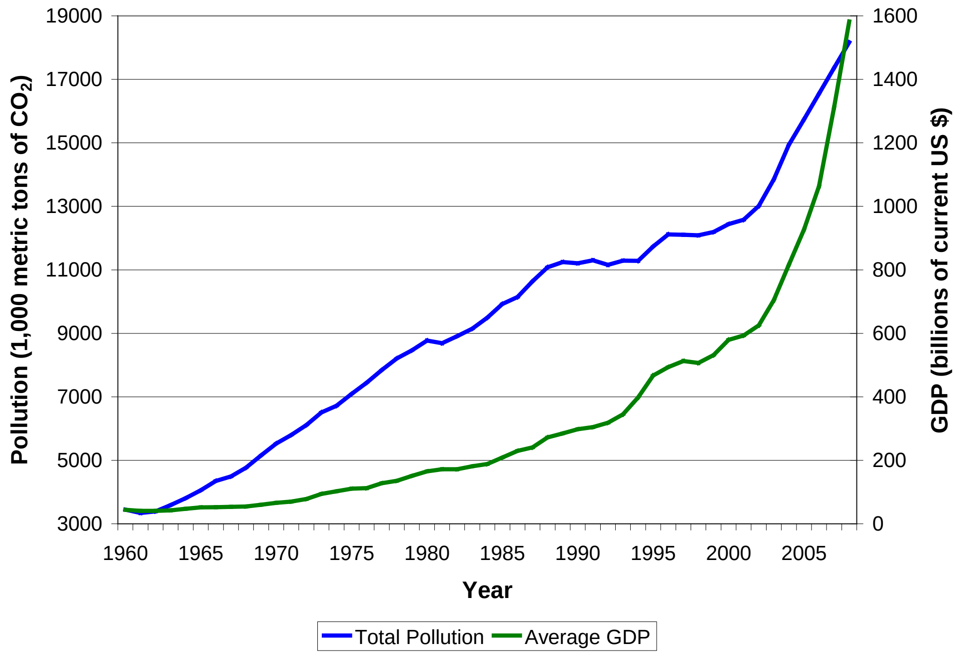

Figure 3. Pollution and GDP Trends for Developed Countries (1960-2008)

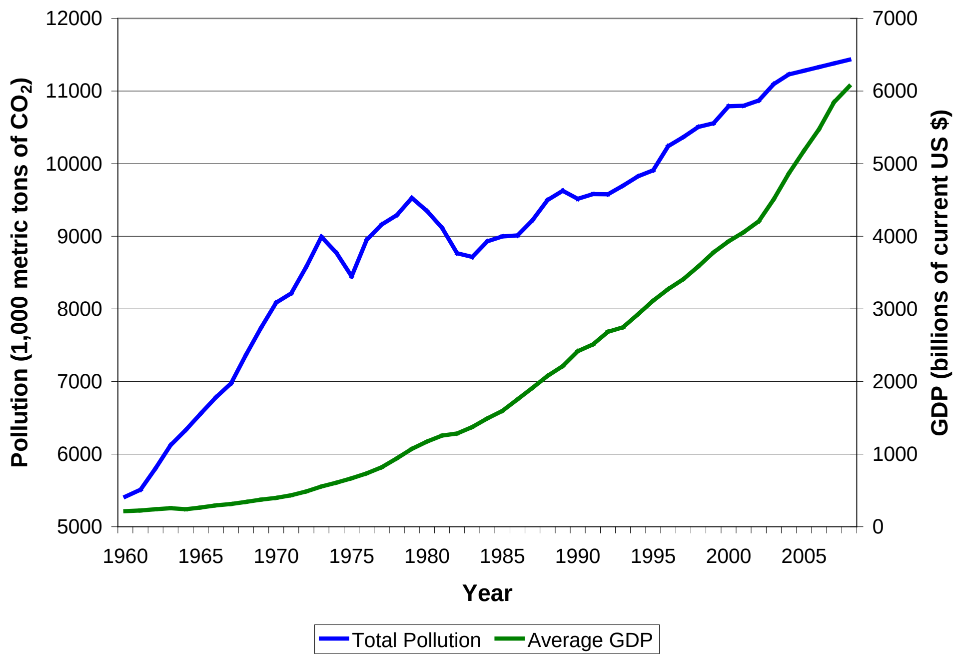

Figure 4. Comparison of Total Emissions for Developing and Developed Countries

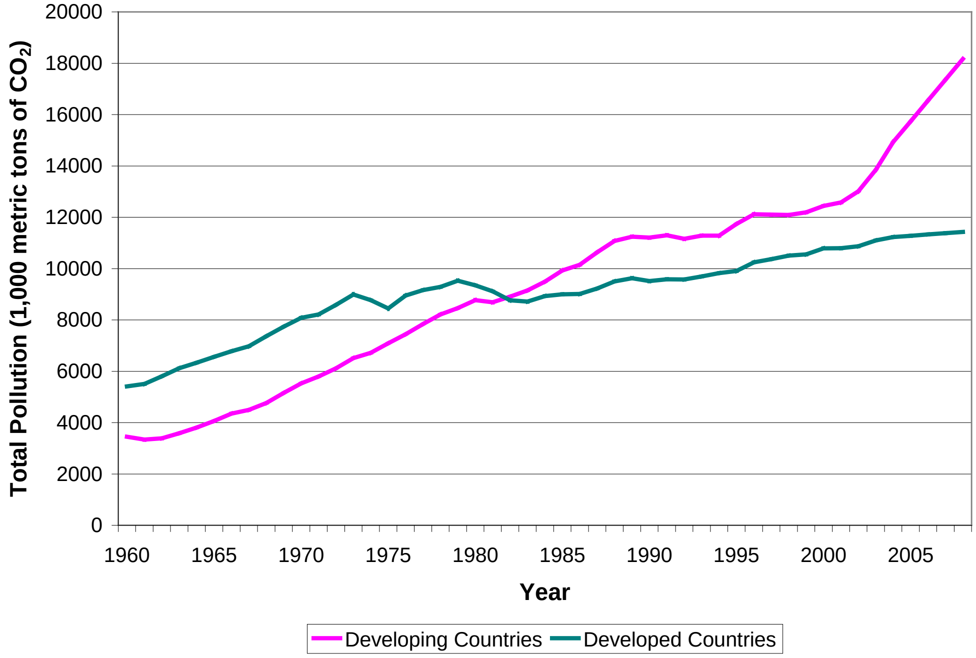

Figure 5. Regional Pollution as a Percentage of Combined CO_2 Emissions in 2008

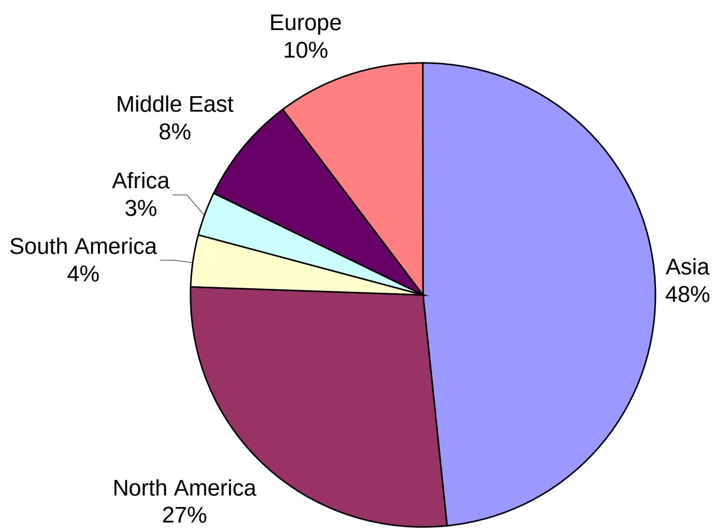

Figure 6. Total Pollution in Europe (1955-2008)

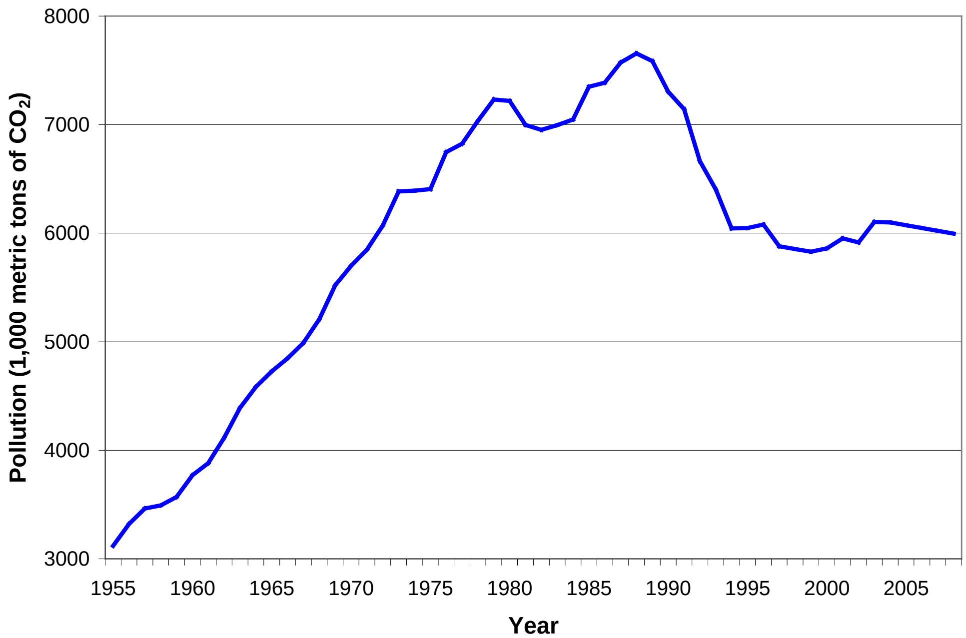

Figure 7. Total Pollution in Asia (1955-2008)

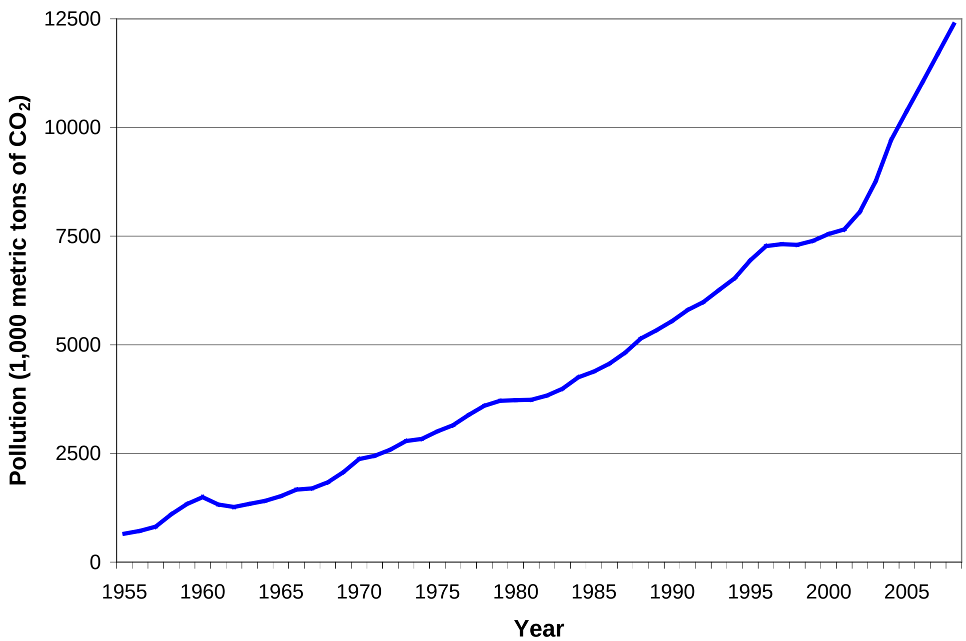

Figure 8. Total Pollution in North America (1955-2008)

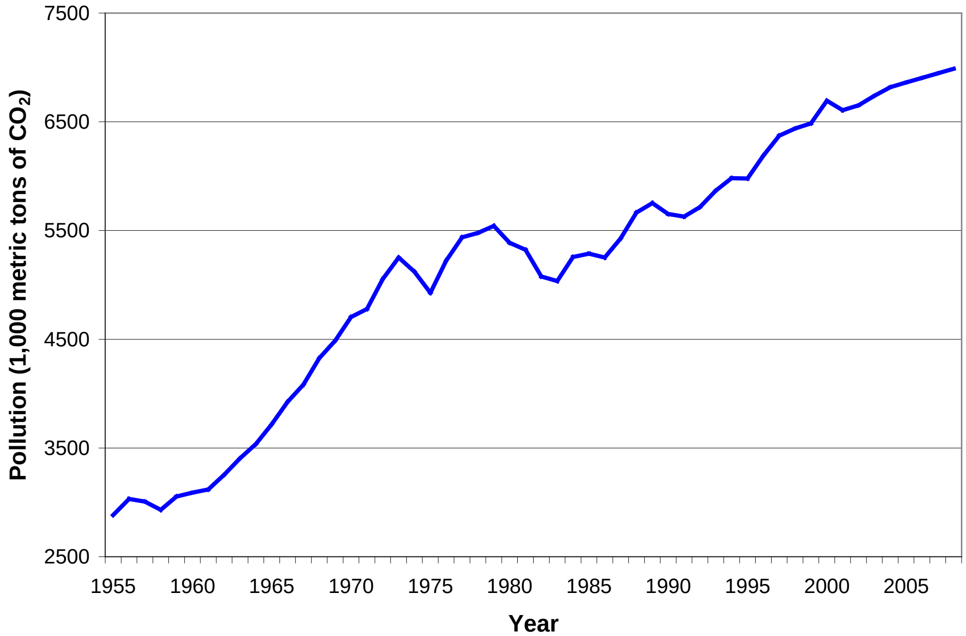

Figure 9. Total Pollution in South America (1955-2008)

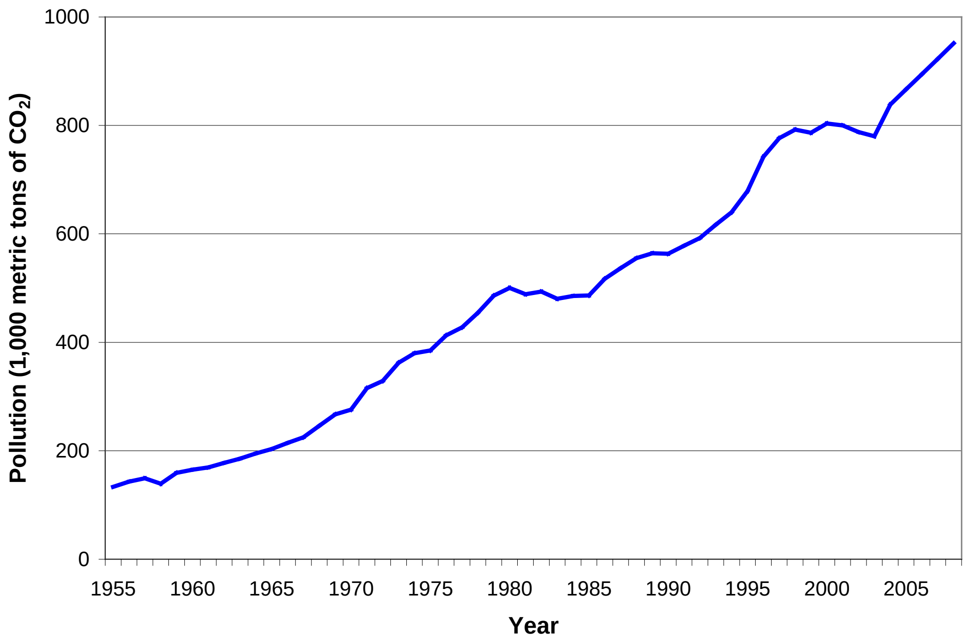

Figure 10. Total Pollution in Africa (1955-2008)

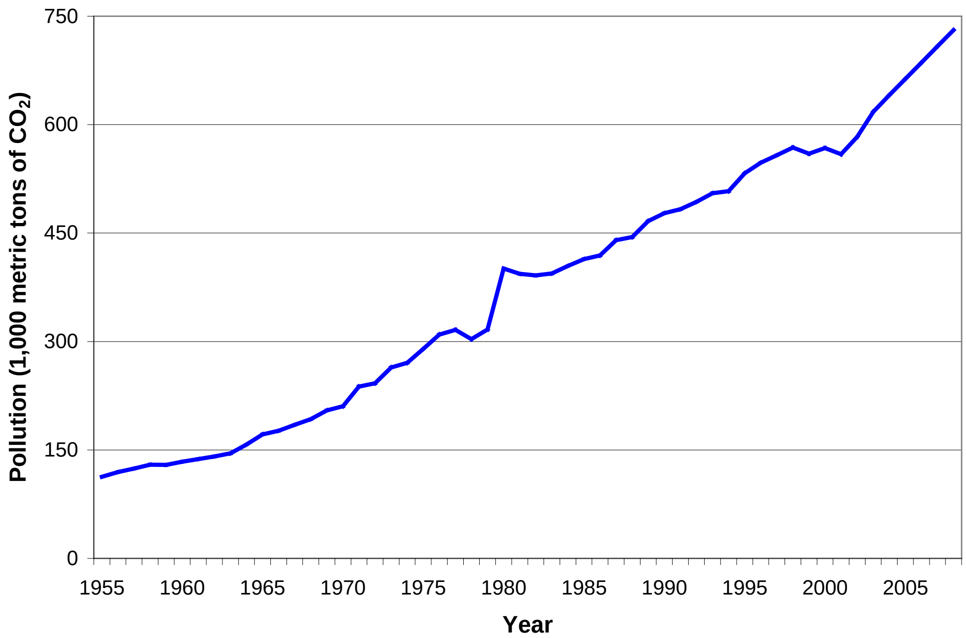

Figure 11. Total Pollution in the Middle East (1955-2008)

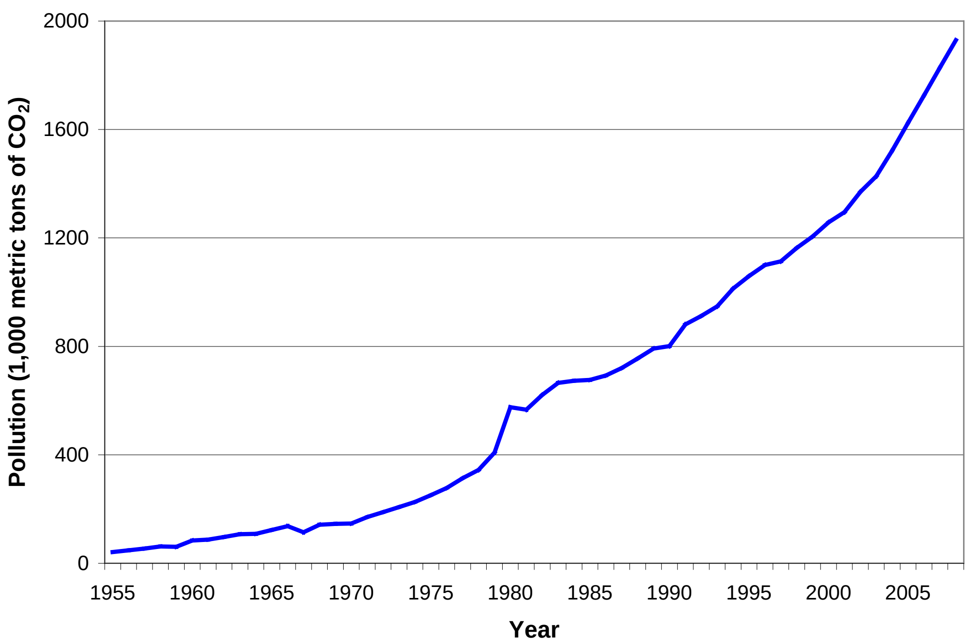

Figure 12. Global Trends in GDP and Life Expectancy (1960-2008)

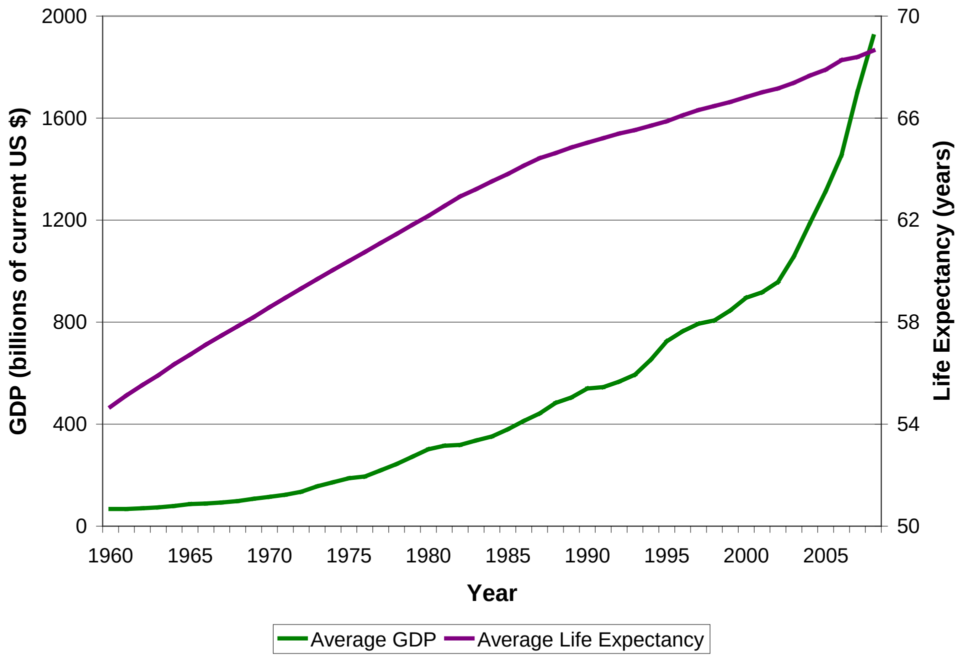

Figure 13. Global Trends in Pollution and Life Expectancy (1960-2008)

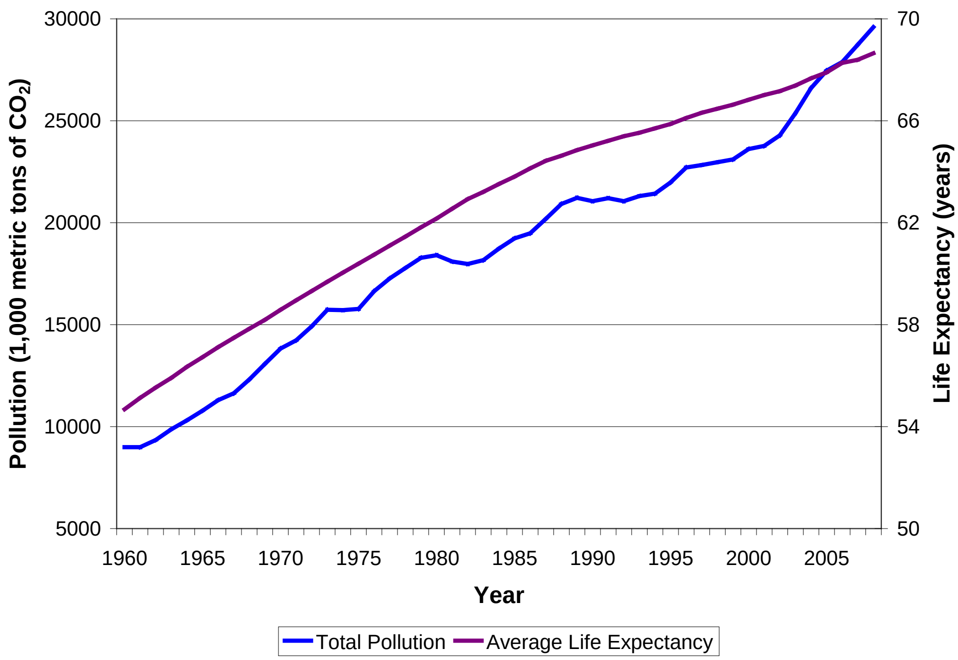

Table 1. Summary Statistics

Variable	Number of Observations	Mean	Standard Deviation
Pollution (thousands of metric tons)	9825	97.24626	430.2522
GDP (billions of US $)	9764	94.54989	536.804
GNI per capita	9489	4365.541	8883.63
Population (millions)	11171	28.78596	118.8001
Fertility	10782	4.304527	2.040666
Aid per capita (US $)	7535	70.77765	271.7588
Manufacturing (% GDP)	8734	19.04042	21.39671
Infant mortality	10347	68.2098	54.48318
Life expectancy	10790	61.84219	11.59701
Primary school completion rate	9050	79.8298	49.11035

All statistics are calculated using the extrapolated and interpolated dataset. The numbers of observations differ due to missing values for some smaller countries.

Table 2. Country Factors Associated with Pollution from 1960 to 2005

	Pollution (1,000 metric tons of CO_2)			
	(1)	**(2)**	**(3)**	**(4)**
GDP	305.383** (3.07)	125.665** (2.83)		848.226** (5.91)
GNI per capita			172.837** (10.66)	
Population	182.468** (3.35)	466.107** (5.95)	507.781** (6.79)	87.260** (3.83)
Fertility	-45.040** (3.17)	-178.773** (15.73)	-33.670* (17.22)	138.482** (11.03)
Manufacturing (%GDP)				67.996** (11.06)
Aid per capita				127.143* (53.65)
Year effects	Yes	Yes	Yes	Yes
Fixed effects	No	Yes	Yes	Yes
Weighted by population	No	Yes	Yes	Yes
Constant	140.498 (20.85)	-434.874 (40.21)	-570.463 (44.02)	278.674 (29.92)
Sample Size	7505	7460	7275	5234
Adjusted R^2	0.702	0.935	0.920	0.984

All regressors are measured in standard deviations. Standard errors are reported in parentheses below the estimated coefficients. Individual coefficients are statistically significant at the *5% or **1% significance level.

Table 3. Comparison of Pollution Factors for Developing and Developed Countries (1960-2005)

	Pollution (1,000 metric tons of CO_2)							
	Developing Countries				Developed Countries			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GDP	188.081** (5.05)	325.867** (7.16)		848.319** (6.28)	46.476** (4.65)	-78.354** (4.25)		259.648** (11.67)
GNI per capita			112.697** (18.22)				16.839 (10.69)	
Population	171.927** (2.44)	416.675** (6.62)	507.713** (7.50)	87.878** (4.08)	1967.707** (23.84)	4541.429** (94.84)	2760.621** (27.27)	1439.650** (34.95)
Fertility	-55.051** (2.97)	-187.804** (17.08)	-25.242 (19.39)	140.949** (11.80)	50.129** (5.96)	-190.721** (20.56)	-375.360** (22.16)	-4.539* (2.18)
Manufacturing				67.581** (11.77)				-6.830* (3.29)
Aid per capita				140.083* (61.49)				-1.465 (2.85)
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Weighted by population	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Constant	118.506 (17.13)	-496.434 (47.61)	-775.143 (52.56)	279.999 (32.33)	394.650 (30.93)	-1092.605 (45.36)	-414.129 (29.77)	365.012 (8.92)
Sample Size	5584	5542	5451	4632	1921	1918	1824	602
Adjusted R^2	0.634	0.909	0.875	0.984	0.938	0.997	0.997	0.991

All regressors are measured in standard deviations. Standard errors are reported in parentheses below the estimated coefficients. Individual coefficients are statistically significant at the *5% or **1% significance level.

Table 4. Factors Contributing to Regional Pollution Trends (1960-2005)

	Pollution (1,000 metric tons of CO_2)					
	Europe	**Asia**	**North America**	**South America**	**Africa**	**Middle East**
GDP	-16.148** (5.28)	366.058** (15.96)	50.917 (32.88)	8.460 (4.74)	397.130** (8.84)	367.909** (26.65)
Population	3544.971** (130.50)	454.970** (16.97)	1569.352 (837.73)	304.794** (9.26)	65.599** (3.24)	436.868** (27.26)
Fertility	304.576** (29.06)	-498.262** (47.53)	47.753 (180.21)	24.659** (2.89)	-12.689** (1.14)	-85.584** (5.19)
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Weighted by population	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-16.569 (75.51)	-1998.501 (144.17)	523.426 (764.92)	-19.603 (5.43)	95.938 (2.93)	66.886 (7.56)
Sample Size	1695	1183	138	598	1937	748
Adjusted R^2	0.959	0.904	0.993	0.987	0.973	0.912

All regressors are measured in standard deviations. Standard errors are reported in parentheses below the estimated coefficients. Individual coefficients are statistically significant at the *5% or **1% significance level.

Table 5. Factors Affecting Health as Measured by Life Expectancy and Infant Mortality (1960-2005)

	Life Expectancy (Years)			Infant Mortality (per 1,000 live births)		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Pollution	-0.474 (0.34)	0.015 (0.07)	-0.096 (0.07)	-3.000* (1.56)	2.778** (0.30)	2.940** (0.32)
GDP	5.607** (0.91)	0.383** (0.15)	0.746** (0.15)	-8.534* (4.18)	-2.179** (0.67)	-2.813** (0.71)
Population	-1.150** (0.16)	0.742** (0.04)	0.566** (0.05)	6.513** (0.72)	-2.613** (0.20)	-2.269** (0.22)
Fertility	-9.325** (0.12)	-4.449** (0.12)	-3.686** (0.13)	41.107** (0.53)	18.596** (0.54)	18.006** (0.62)
Aid per capita	0.264 (0.10)	0.285 (0.50)	-1.820** (0.60)	-1.554** (0.48)	-2.544 (2.28)	2.455 (2.85)
Primary completion			1.197** (0.14)			-4.410** (0.67)
Manufacturing (% GDP)			2.149** (0.13)			-1.157* (0.59)
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	No	Yes	Yes	No	Yes	Yes
Weighted by population	No	Yes	Yes	No	Yes	Yes
Constant	59.053 (0.71)	49.452 (0.32)	49.392 (0.37)	88.387 (3.25)	124.322 (1.47)	122.101 (1.74)
Sample Size	5724	5683	4932	5724	5683	4932
Adjusted R^2	0.641	0.961	0.963	0.654	0.962	0.961

All regressors are measured in standard deviations. Standard errors are reported in parentheses below the estimated coefficients. Individual coefficients are statistically significant at the *5% or **1% significance level.

Table 6. Comparison of Factors Affecting Health in Developing and Developed Countries (1960-2005)

	Life Expectancy (Years)					
	Developing Countries			Developed Countries		
	(1)	(2)	(3)	(4)	(5)	(6)
Pollution	-0.556 (0.33)	0.011 (0.07)	-0.096 (0.07)	21.369** (5.87)	10.505** (2.57)	-0.734 (2.56)
GDP	4.486** (0.90)	0.393** (0.16)	0.744** (0.16)	30.408** (7.32)	-12.513** (2.17)	-3.091 (2.19)
Population	-0.824** (0.15)	0.759** (0.05)	0.576** (0.05)	-92.964** (15.32)	31.652** (10.11)	52.713** (9.43)
Fertility	-9.274** (0.13)	-4.482** (0.13)	-3.716** (0.14)	-6.022** (0.25)	-0.721** (0.27)	0.987** (0.30)
Aid per capita	0.235* (0.10)	0.804 (0.61)	-2.132** (0.69)	2.413** (0.67)	-1.692** (0.29)	-0.542 (0.38)
Primary completion			1.168** (0.15)			1.541** (0.33)
Manufacturing (% GDP)			2.150** (0.13)			1.701** (0.45)
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	No	Yes	Yes	No	Yes	Yes
Weighted by population	No	Yes	Yes	No	Yes	Yes
Constant	58.086 (0.72)	50.134 (0.34)	49.911 (0.39)	55.087 (3.28)	66.443 (2.06)	66.018 (1.94)
Sample Size	4986	4948	4406	738	735	526
Adjusted R^2	0.632	0.961	0.963	0.588	0.947	0.966

All regressors are measured in standard deviations. Standard errors are reported in parentheses below the estimated coefficients. Individual coefficients are statistically significant at the *5% or **1% significance level.