Impact of Increasing Air Emission Fee on the Number of Deaths from Respiratory Diseases

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I hereby recognize and pledge to fulfill my responsibilities as defined in the Honor Code and to maintain the integrity of both myself and the College community as a whole.

This work is mine unless otherwise cited.

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Abstract

In 1970, President Richard Nixon passed the Clean Air Act, aiming to improve air quality levels throughout the United States through permits and fees. The State Implementation Plan allows each individual state to control the amount of emissions by executing a dollar per ton fee on all pollutants. Although the act decreased the amount of pollutants being released into the air by 70 percent, concentrations of greenhouse gases were still causing various respiratory diseases throughout the nation. This paper aims to analyze the impact of increasing the air emission fee on the number of respiratory deaths. It is predicted that air quality will improve as the fee increases, decreasing the number of people who suffer from respiratory illnesses. Through multiple regressions, however, estimates were inconclusive due to potential bias from omitted variables. Thus, further research is needed to accurately analyze this research idea.

Introduction

Air pollution can be defined as the contamination of our air at levels that pose a health risk to society. It is said that air pollution is one of the most dangerous environmental problems today, being the fourth largest threat to human health (Hutt, 2016). According to the World Health Organization (WHO), about 92% of the world's population lives in places where air pollution exceeds safe limits. WHO also states that in 2012 about 6.5 million deaths were from air pollution-related diseases. Human activities such as transportation, agriculture, and industrial work are the main contributors to this contamination every day, having enormous impacts on our health and ability to perform day-to-day activities. Thus, control over air pollution is needed to limit the amount of hazardous toxins released into the atmosphere and to improve our world's overall health.

In order to improve environmental conditions and control air pollution, the United States government passed the Clean Air Act (CAA) in 1970. The goal of the CAA is to obtain clean and healthy air quality levels throughout the nation. Throughout the next 20 years, several amendments were added to set stricter standards, including the establishment of a national permit program and allowing states to impose emission fees on certain toxins through the State Implementation Plan (SIP). These plans allow states to decide how they aim to control the amount of emissions released and how they will maintain national standards. Due to pollution's complexity and the abundance of information, this paper will not focus on the operating permits required by Title V of the Clean Air Act but only the effects of the air emission fee in each state.

Since companies now have to pay a fine for every ton of toxins they release into the air, the goal is that companies will produce less toxins, which will increase the state's air quality and

save the company in costs. Therefore, this paper examines the impact of increasing air emission fees on the number of deaths from respiratory diseases. This idea suggests as air emission fees increase, the air quality of each state will improve. Thus, the number of those who suffer from respiratory diseases such as asthma, pneumonia, and chronic obstructive pulmonary disease should decrease due to less hazardous toxins in the air.

Admiringly, the amount of pollutants released has decreased since President Richard Nixon signed the CAA. According to the United States Environmental Protection Agency (EPA), the amount of the national emissions of the six common pollutants – particulate matter, ozone, lead, carbon monoxide, nitrogen dioxide, and sulfur dioxide – has dropped about 70 percent. By 1990, sulfur dioxide emissions were reduced by 40 percent, nitrogen oxide emissions by 30 percent, and carbon monoxide emissions by 50 percent (1997).

Environmental regulations, like the Clean Air Act, are extremely important for preserving the environment and our health. Although the CAA has dropped the amount of emissions released, there has been an increase in the concentrations of greenhouse gases in the atmosphere, causing issues such as prolonged heat waves, droughts, and air pollution. The Industrial Revolution, for example, has contributed to an increase in fossil fuel consumption and deforestation, which ultimately will lead to an increase in emissions and the atmospheric carbon dioxide level that reached 400 parts per million (ppm) on May 9, 2013. For clarification, one part per million is equivalent to 7.5 billion tons of carbon dioxide. This event marks the first time in a few million years since the atmosphere has reached this level and shows the amount of impact humans have had on the environment through fossil fuel use (Bala, 2013).

Emissions from this era have caused many people to suffer from harmful respiratory and cardiovascular related diseases. Pollutants, especially fine particles, enter the respiratory system and cause direct cellular injury (D'Amato et. al, 2016). Additionally, fine particulate matter ($PM_{2.5}$ and PM_{10}) is known for having the greatest effects on the public health and alone caused 3.22 million deaths in 2010 (Chen et. al, 2017). Particulate matter and carbon monoxide cause well-known diseases such as asthma, pneumonia, and chronic obstructive pulmonary disease (COPD). Unfortunately, about one in twelve adults and one in ten children in the United States have asthma (American Academy of Allergy, Asthma & Immunology, 2017) and COPD is the third leading cause of death in many states (World Health Organization, 2017). Untreated illness can lead to more serious diseases including lung cancer, which is the leading U.S. cancer killer in both men and women (Mangiapane et. al, 2005).

These pollutants, as well as ozone, also contribute to the large number of premature deaths. This number is projected to increase anywhere between six and nine million people globally by 2060 (Organisation for Economic Co-operation and Development, 2016). Furthermore, it is projected that six million people will die per year due to air pollution by 2050 (Rinkesh, 2017). Reducing the amount of toxins, such as carbon monoxide and particulate matter, being released into the air is crucial to improving our overall health and the condition of our planet.

Not only does air pollution impact our health, but also has major effects on citizens and our government financially. Common diseases cost the government and the average citizen a substantial amount of money in health expenses. For example, according to American Academy of Allergy, Asthma, and Immunology, asthma prevention alone costs our government $56 billion

in 2007 and costs about $3,300 per person, and is only expected to rise. Due to the projected increase in pollutants, air pollution-related health care costs are expected to rise from $21 billion in 2015 to $176 billion in 2060 (Organization for Economic Co-operation and Development, 2016). This will have a major impact on the market since more people will be suffering from related diseases, thus spending more money towards treatment and prevention. The proper regulations set in place by the federal and state governments ideally will decrease the amount of air pollution, decreasing the overall healthcare costs per individual overtime.

To understand the relationships between pollution regulation, air quality, and health, this paper is divided into three major chapters: Literature Review, Theories, and Empirical Analysis. Chapter 1 first reviews the studies of many authors while focusing on their research ideas and important findings. The following section uses theories such as market-based instruments, the environmental Kuznets curve, and integrated exposure-response to help shape a hypothesis for this paper's research idea. Lastly, Chapter 3 analyzes panel data compiled from numerous databases and interprets the results of multiple regressions. Variables including the emission fee, number of deaths, health expenditures, median household income, and number of people who have health insurance are only a few of the variables that will be used to explain these relations.

Chapter 1: Literature Review

Studying past works of various researchers is crucial to learning about the relationships between environmental regulation, air quality, and health outcomes. This section contains two subsections highlighting the author's key points. First, we observe the effect environmental regulation has on improving air quality, and then the impacts of air quality on numerous health outcomes.

Environmental Regulation and Air Quality

Environmental regulations have numerous impacts on businesses regarding cost, location, and competitiveness due to the air quality of the area. Henderson (1995), for example, studies the impact of local regulatory effort on industrial location and ground level ozone air quality as a county switches from attainment to nonattainment status. For a county or state to be classified as an attainment area, the criteria pollutants need to be below the levels set by the National Ambient Air Quality Standards (NAAQS). If the concentrations of the pollutants surpass the regulated level, the area is considered a nonattainment area. Henderson suggests that counties increase their efforts towards regulations when they switch from attainment to nonattainment status. This switch and increased regulations has lead to improved air quality for ground level ozone by 3 to 8 percent.

The author also finds that pro-environmental states tend to have cleaner air and spend more on pollution expenses. This attainment status has attracted heavily polluted industries to move into these clean counties for less hassle, creating a trend that allows for these industries to spread out geographically and into less populated areas. In a later paper Henderson and Becker

(2000) analyzed this reasoning and the unintended effects of air quality regulation. The researchers state that nonattainment status forces regulators to have specific requirements regarding equipment as a plant increases in size, encouraging companies you use greener equipment to limit emissions. Even though companies will encounter high costs and less productivity, the majority choose to relocate instead of dealing with the harsh regulations.

Kahn (1995) explores the relationship between county economic activity and air quality through particulate regulation. The author observes whether or not more regulated counties experience a decrease in particulate pollutant in a given county. After estimating three equations, Kahn concludes that current regulation slightly reduces manufacturing and economic activity. When comparing regulated counties with counties that did not have a non-attainment statues, this paper does not find evidence suggesting that particulates per manufacturing job fell faster for regulated counties. Thus, Kahn's findings suggest that regulation has little effect on the quality of air regarding particulate pollutants.

In the United Kingdom, Cole, Elliott, and Shimamoto (2004) analyze the correlation between industrial activity, environmental regulations, and air pollution. The authors observe specific UK industry emissions and determinants of emission intensity. Results from this paper conclude that environmental regulations in the UK have decreased the amount and intensity of emissions. Additionally, the results suggest regulations on energy use to decrease pollution. If a differential tax was applied to energy use, the authors explain that pollutants such as sulfur dioxide would benefit because industries would be incentivized to reduce their energy usage and switch to forms of energy that release less toxins.

Air Quality and Health Outcomes

Many researchers have discussed the relationship between certain types of air pollution and the health effects they can cause. Most of the authors focus on the impacts of one type of pollutant and its association with hospital admissions. The most popular toxin among researchers is fine particulate matter since it has a strong effect on those who suffer from respiratory illnesses. Thus, this chapter examines the research of similar topics conducted by other authors.

Dominici et al. (2006) studied the connection between fine particulate matter ($PM_{2.5}$) and the number of hospital admissions for cardiovascular and respiratory diseases among Medicare participants. Due to its relatively small size, $PM_{2.5}$ is extremely dangerous and has a higher chance of reaching small airways causing immediate cellular damage. During their study, the authors looked at eight outcomes: five cardiovascular, two respiratory outcomes, and hospitalizations caused by injuries and other external causes. After considering variables such as temperature and ozone concentration in 204 counties, the authors concluded that a 10-$\mu g/m^3$ (microgram per cubic meter) reduction in $PM_{2.5}$ would contribute to 3,156 fewer hospitalizations for heart failure. Decreasing the amount of particulate matter released into the air would inevitably have a decreasing impact on the number of hospitalizations.

Furthermore, researchers investigate similar concerns in Hong Kong. Wong et al. (1999) perform a Poisson regression to study the concentrations of daily air pollution on the daily counts of emergency hospital admissions for 12 major hospitals. Instead of only observing the effects from particulate matter ($PM_{2.5}$), the authors collect the daily concentrations of nitrogen dioxide, sulfur dioxide, ozone, and particulate matter (PM_{10}). They concluded that hospital admissions for asthma, pneumonia, and influenza were significantly associated with ozone, nitrogen dioxide,

and PM_{10}. Additionally, the type of season has a large impact on the number of admissions, thus observing a positive interaction with ozone during the cold season for both respiratory and cardiovascular admissions.

Schwartz (1996) uses the same ideas as previously mentioned authors, studying the relationship between short-term changes in air pollution and hospital admissions for respiratory related illnesses. Similar to the Dominici et. al. study, the author uses a Poisson regression and collects daily data of hospital admissions in Spokane, Washington on respiratory disease for those aged 65 and older. Schwartz chooses this location since Spokane has high concentrations of PM_{10} and little to no concentrations of sulfur dioxide. Thus, the author concluded that both PM_{10} and ozone were associated with increased risk of respiratory hospital admissions. Surprisingly, there was not a strong correlation between temperature and PM_{10} or any seasonal pattern.

Another age group heavily affected by pollution is children. Dockery et al. (1982) explains that children under 12 years of age are susceptible to a decrease lung function and an increase in common respiratory disease symptoms due to particulate air pollution. Since children tend to be outdoors more, they are exposed to different types of air pollution that damage their respiratory system. Brunekreef et al. (1997) observes the association between traffic-related air pollution and the lung function of children who lived near busy roads. Pollutants released from vehicle traffic, such as nitrogen dioxide and particulate matter, is a major source of air pollution and mainly affects those who live in busy areas. The authors found from their study that those who live closest to the motorways experienced a decrease in lung function.

Morgenstern et al. (2008) conducted a similar study examining the correlations between traffic-related air pollution (nitrogen dioxide and particulate matter) and allergic disease outcomes during the first six years of life. They studied atopic diseases (eczema, asthma, and rhinoconjunctivitis) and allergic sensitization in 2,860 children at 4 years of age and 3,061 children at 6 years of age. Major findings of the authors' research included a strong positive correlation between the distance to the nearest busy road and respiratory illnesses including hay fever, eczema, sensitization, and asthmatic bronchitis. Thus, children are exposed to many different types of pollution throughout their childhood and can have a negative effect on their lung function and likelihood of acquiring various respiratory diseases.

Other studies have linked long-term particulate matter exposure with mortality. Pope III et al. (2004) aims to find a general understanding towards this link through collecting air pollution data for metropolitan areas throughout the US and examines patterns with specific causes of death. The authors' conclusions highlighted that long-term PM exposures contributed to the mortality in ischemic heart disease, dysrhythmia, heart failure, and cardiac arrest. Additionally, an increase of 10-$\mu g/m^3$ in particulate matter is associated with eight to eighteen percent increases in mortality risk. This risk includes issues consisting of pulmonary and systemic inflammation and altered cardiac autonomic function.

However, many papers similar to Pope III et al. have been criticized since they do not control for cigarette smoking and other health risks. Dockery et al. (1993) controls for these individual risk factors when estimating the relationship between air pollution and mortality. The results from their regression suggested a strong correlation between mortality rates and cigarette smoking. The authors also found statistically significant associations between air pollution and

mortality when adjusting the regression for smoking and other risk factors. For example, deaths due to lung cancer and cardiopulmonary disease was positively correlated with air pollution. Lastly, their findings suggest that fine particulate air pollution was strongly associated with air pollution and mortality in certain U.S. cities.

Overall, research shows that there is a distinct relationship between air pollution and respiratory and cardiovascular diseases. Research regarding pollution regulation and air quality suggests regulation can cause economic issues for companies based on an area's attainment status. Authors also obtain mixed results regarding whether the current regulations reduce air pollution, depending on the area observed. Since most authors use hospital admissions as their key variable or focus on a specific pollutant, age group or area, this paper will observe the connection between pollution regulation, air quality, and health outcomes through examining the relationship between the number of deaths from respiratory diseases and the yearly air emission fee. There are little to no studies conducted using the air emission fee of each state as their key variable, thus making it a great place to contribute to the discussions across the globe.

After reviewing previous literature, three theories are discussed and applied in the following chapter to understand the correlation between pollution regulation, air quality, and number of deaths from respiratory diseases.

Chapter 2: Theory

To further interpret the interconnections between pollution regulation, air quality, and health outcomes, we must highlight key theories used in this process. Market-based instruments, environmental Kuznets curve (EKC), and integrated exposure-response (IER) are the significant theories observed in this paper to illustrate this correlation.

Market-based Instruments

Many do not consider the total social cost attached to the pollution they are releasing, thus creating a negative externality. A negative externality exists when a third party, who is not directly involved, is impacted by an economic transaction and has to pay a social cost (Goolsbee et. al, 2012). The majority of companies only focus on private production costs, such as physical labor and capital, and ignore the external costs of pollution that society pays for. Theses social costs include human health illnesses, such as asthma and pneumonia, and an increase in medical costs.

Market-based instruments (MBIs) are regulations that encourage firms to reduce or eliminate negative externalities through market signals. MBIs aim to encourage firms to control their pollution through the firm's best interest while still meeting policy goals through market signals such as charges, taxes, fees, subsidies, and tradable permits (Di Falco, 2012). With the implementation of state air emission fees, firms are forced to consider the amount of pollution they are emitting in order to save money and maximize their profits.

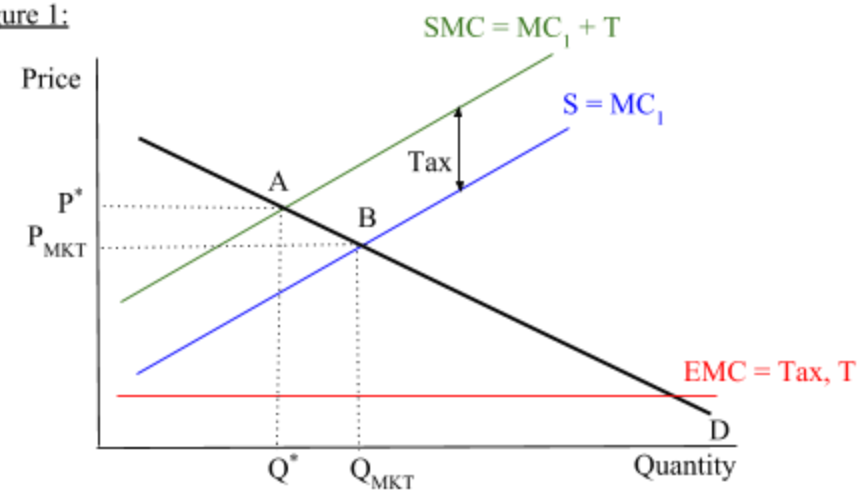
Prior to explaining a regulation that aims to fix pollution-related externalities, understanding how a government chooses an efficient target for the amount of emissions

released is crucial. The efficient level of pollution set by government is considered to be the amount of emissions required to produce a profitable quantity of goods connected to the externality itself (Goolsbee et. al, 2012). In other words, it is where marginal benefit of a firm equals its marginal cost. The goal of setting this level is to have a firm's quantity equal its marginal social costs. Since eliminating emissions completely during production is nearly impossible and would hypothetically wipe out the production of the good, setting a total level of pollution allowable at its efficient level is crucial to limiting the amount of toxic pollutants released into the air, while causing the least amount of harm to the economy.

A common fix for negative externalities is an implementation of a Pigouvian Tax. This tax internalizes the negative externality by increasing a good's price to adjust for social costs (Goolsbee et. al, 2012). Thus, it forces firms to take into consideration how much pollution they are releasing into the air since they now have an added expense and could lead to a decrease in overall emissions. Figure 1 illustrates the effect of a Pigouvian tax before and after it is enforced. Without any regulations, firms overproduce at quantity Q_{MKT} and price P_{MKT} shown at point B. Once a Pigouvian tax that is equal to the external marginal cost (EMC) is introduced, the supply curve (S) shifts the amount of the tax upward to create the social marginal cost curve (SMC). When firms produce quantity Q^* at price P^* (point A), they are taking into consideration the social costs of their product and essentially paying for the consequences of production-related air pollution their firm releases. This causes an overall increase in price and a decrease in quantity demanded of their product, forcing the company to pay attention to their contribution to pollution to maximize sales. This idea is similar to what is known as the Porter hypothesis, which suggests that "pollution is often a waste of resources and that a reduction in pollution may lead to an

improvement in the productivity with which resources are used" (Ambec et. al, 2011). In the end, it will save the firm money while at the same time positively contributing to an increase in air quality which can lead to a decrease in the number of respiratory deaths in the surrounding area.

Figure 1:

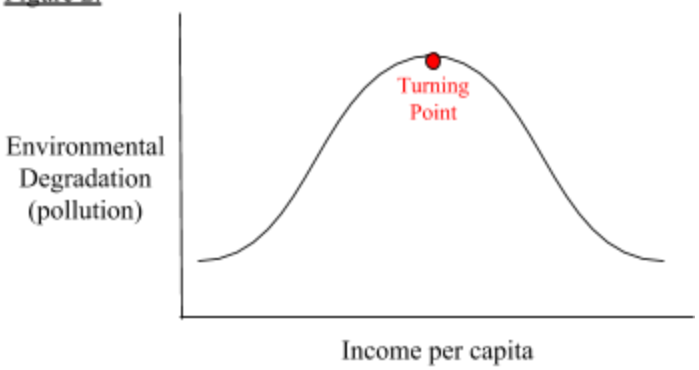


(*Source*: Goolsbee et. al. 2012)

Environmental Kuznets Curve

The environmental Kuznets curve (EKC) can be used to study the relationship between income per capita and various indicators of environmental degradation. The curve forms an inverted U-shaped function, suggesting that with increasing income per capita environmental degradation will increase and then fall (Stern, 2004). In 1955, Kuznet hypothesized this function but it wasn't until the early 1990s when the idea became well known through Grossman and Krueger's study. Figure 2 demonstrates this idea of a positive, sloped relationship between economic growth and environmental degradation of a country until the turning point, causing the function to slope downward as income continues to increase.

Figure 2:



There is evidence from previous research stating that some pollutants follow this inverted U-shaped function when compared to a country's income (Andreoni, 2001). Arrow et. al. (1995) claims that this inverted pattern is due to the natural economic development of a country as they transform from clean to polluting and back to clean economies. Many countries are able to transform this way through exporting their pollution-intensive production overseas to less developed countries to take advantage of cheap labor and avoid pollution regulations in their home country. This movement allows developed countries to change from an industrial manufacturing economy to a service-based economy. These actions allow authors such as Bartlett (1994) to conclude that environmental regulations that reduce economic growth may contribute to a reduction of environmental quality. Even though this is a popular conclusion among research, there is strong additional evidence that shows how neighboring communities in countries, such as Asia and Latin America, strongly influence factories and push them towards environmentally friendly practices through informal regulations due to inefficient formal regulators.

Additionally, many other authors claim that countries with higher incomes show a decrease in emissions through a strong push for environmental regulations and market-based

incentives (Dina, 2004). For example, the United States's real gross domestic product has increased by 246 percent from 1970 to 2015 while at the same time decreasing the national emissions of common pollutants by 70 percent according to the EPA. Researchers suggest that formal environmental regulation, such as the CAA, can flatten the EKC and is the main contribution to the reduction in pollution as countries grow past middle-income status (Dasgupta, 2002). Panayotou (1997) proved this idea for sulfur dioxide when observing 30 developed countries, finding that effective regulations can tremendously decrease environmental degradation at low income levels and speed up improvements at the higher income levels. This led to a flattening of the EKC through the removal of environmentally harmful subsidies, internalizing externalities, and enforcing property rights over natural resources, ultimately shrinking the overall environmental cost of growth.

Determining the status of the United States as a whole regarding the EKC is tricky since emission programs, economic patterns, and the amount of certain pollutants in each state vary. For example, Franklin and Ruth (2012) search for evidence of an EKC in the United States over a 200 year period. Even though they found evidence that an EKC existed, they were unable to reject their hypothesis due to heteroskedastic errors, autocorrelated errors, and scarcity of variables for this time period. Additionally, Yang and Qiu (2016) observe the short and long run relationships between carbon dioxide emissions, energy consumption, and economic development of each state to analyze their EKCs. The authors find that 13 states demonstrate an inverted U shaped curve, 18 states show an N shaped curve, 6 states show a decreasing relationship, 6 states show a positive relationship, and the remaining 8 states do not convey a cointegration relationship. Yang and Qiu suggest that finding both N and inverted U shaped EKC

is important since it creates the question of whether pollution decreases at the economic threshold or if the decrease is only from a local pollutant. The latter would imply that pollution is being exported to less developed countries.

Thus, there are many mixed results about where the United States is located on the EKC. Due to the overall decrease in emissions and increasing GDP, one can surmise that the United States is located on the right side of the EKC. However, this conclusion is not certain and needs to be analyzed further.

Integrated Exposure-Response

When studying low- and middle-income countries, information on the global burden of disease from pollutants such as particulate matter ($PM_{2.5}$) is hard to find due to lack of data. Thus, the integrated exposure-response (IER) function was created to estimate relative risk across the globe through standardized reviews of literature. It combines information on mortality relative risks from all types of $PM_{2.5}$ exposure including ambient air pollution, active smoking, household air pollution, and second-hand tobacco smoke (Narain et. al, 2016). This allows researchers to attain a better understanding of the relationship between air pollution and certain health diseases as the magnitude of $PM_{2.5}$ exposure varies. Some diseases previously analyzed with the IER function are ischemic heart disease, cerebrovascular disease, chronic obstructive pulmonary disease, lung cancer, and acute lower respiratory infection. In 2015, $PM_{2.5}$ was number five when ranking mortality risk factors and caused 4.2 million deaths worldwide (Cohen et. al, 2017). This was an increase from 3.5 million deaths in 1990 and represented 7.6 percent of the total global deaths.

Originally, risk functions illustrated a linear increasing function of relative risk (RR) from 7.5 to 50-$\mu g/m^3$. However, these linear functions were thought to contain unrealistically large estimates of RR and the WHO suggested a switch to a logarithmic model when observing long-term exposure (Burnett et. al, 2014). Through analyzing previous literature, researchers found that at lower levels of ambient exposure a linear function is present while higher levels demonstrate a curved relationship between relative risk. This type of model suggests that as ambient $PM_{2.5}$ exposure increases, relative risk increases but tends to flatten at higher exposure levels. Thus, the IER function shows that an increase in ambient air pollution and relative risk is associated with an increase in mortality, coinciding with the idea of this paper.

Depending on the type of disease being analyzed, the burden of $PM_{2.5}$ tends to vary. Pope III et. al (2011) compares the exposure-response relationships with lung cancer and cardiovascular mortality and found a qualitative difference. At low levels of $PM_{2.5}$, more cardiovascular deaths occur whereas lung cancers carries the most of the burden at high levels of exposure. As a result, an increase in exposure to $PM_{2.5}$ and other pollutants, such as ozone, can be causally linked to an increase deaths due to diseases including chronic obstructive pulmonary disease and causing chronic changes in lung structure and function in human beings (Cohen et. al, 2017).

Consequently, ambient air pollution has a tremendous global burden on disease and is expected to increase in low- and middle-income countries. To lessen this global burden and maintain per-person mortality at 2010 levels, countries such as China and India are expected to decrease air pollution levels by 2030 (Apte et. al, 2015). Thus, these countries need effective

policy instituted to decrease the relative risk of harmful respiratory diseases and possibly increase the life expectancy over a short period of time.

Chapter 3: Empirical Analysis

Data Sources

To achieve the goal of this paper, data will be needed from a number of sources for values of the different variables affecting this research idea. Databases such as Centers for Disease Control and Prevention (CDC), National Center for Health Statistics (NCHS), and National Emission Inventory will be used to collect panel data for this regression. These databases will convey the number of deaths from respiratory diseases, current percentage of smoking adults, and the amount of pollutants being released into the air at the state level. The average amount of precipitation in each state, average annual state populations, and median household income are collected from the United States Census Bureau and National Climate Data Center (NCDC). Average state air quality rating, number of students, and gross domestic product variables are obtained from the Environmental Protection Agency (EPA), National Center for Educational Statistics (NCES), and Bureau of Economic Analysis. Lastly, the Centers for Medicare and Medicaid Services (CMS), American Hospital Association Annual Survey, American Community Survey (ACS), and Current Population Survey (CPS) provided the average health expenditures, number of hospitals, and number of people insured in each state.

To obtain information about the annual air emission fee for each state, contacting multiple staff members in each state's department of environmental protection and quality was a necessity due to the lack of information readily available on their websites. The responding staff members either dug into their archives or ran a specific query to retrieve the desired fee schedules. Unfortunately, five states – California, Indiana, Louisiana, Massachusetts, and North Carolina – did not reply to this request and thus will not be included in this dataset.

Variables

This subsection describes each variable compiled from the numerous data sources included in the following regressions. These variables are observed at the state level for each year, focusing on the time period between 1999 and 2014.

a. Gooddays represents the average number of 'good days' of air quality. A day receiving a good air quality index value of 0 to 50, also known as a 'good day', means that the quality of the air is satisfactory and has little to no health effects. This will be the dependent variable in the first regression.
b. Numberofdeaths represents the number of deaths related to various respiratory diseases including chronic obstructive pulmonary disease and pneumonia. This variable will be the dependent variable in the second regression.
c. Emissionfee represents the dollar per ton Title V fee implemented on manufacturers for all types of emissions. This fee is expected to have a positive correlation with the number of days with good air quality.
d. AmtCO, AmtNH_3, AmtNO_X, Amt$PM_{2.5}$, AmtSO_2 displays the amount of fuel combustion industrial emissions of carbon monoxide (CO), ammonia (NH_3), nitrogen oxides (NO_X), particles that are less than 2.5 microns in diameter ($PM_{2.5}$), and sulfur dioxide (SO_2) released per 1,000 tons. These variables are predicted to have a negative relationship with air quality.
e. Experience variable measures the experience of each state's emission program by subtracting the state's program start year by each year in the dataset. This variable will be used in both regressions. It is predicted to have a positive relationship in the regression

regarding air quality and a negative relationship in the regression analysing the impacts on the number of respiratory deaths.

f. Smokers represents current cigarette smoking prevalence (percentage) among adults. Smoking adults are more likely to have comparable lungs and more susceptible to illnesses.

g. Gooddayhat is a linear prediction from the the first regression. This variable is used to connect the two regressions to accurately analyze the hypothesis. It is expected to have a negative correlation with the number of respiratory deaths.

h. Householdincome shows the median household income in current dollars and demonstrates how much each household has to spend on care. Income and respiratory deaths are predicted to have a negative relationship.

i. Students is the total number of students enrolled in school from kindergarten through 12th grade. This variable is used to analyze the education level of each state.

j. Precipitation is the average annual precipitation rate in inches. Weather can set off allergy symptoms affecting the respiratory system.

k. Healthexpen represents health expenditures calculated in current dollar per capita. This variable is used to measure how much the state spends on health, such as hospital care and physicians. A negative association with respiratory deaths is predicted.

l. Pop18 represents the number of people who are less than 18 years of age. Since humans are still developing at this age, pollutants can cause more damage to the respiratory system. A positive correlation with the number of respiratory diseases is expected.

m. Pop65 displays the number of people who are aged 65 and older. As people age, they can have chronic diseases and may have other illnesses that comprise their overall health. It is predicted to have a positive relationship between respiratory diseases.

n. Totpop represents the total population of each state. It is predicted that a positive relationship will exist between the total population and respiratory deaths.

o. Healthinsurance displays the number of people who have health insurance per thousands. This variable is used towards calculating the availability of care and is expected to show a negative relationship with the number of respiratory deaths.

p. Hospitals is the total number of hospitals in each state. Like health insurance, this variable is helps calculate a person's access to care.

q. GDP is the gross domestic product of all industries calculated in current million dollars. This variable is used to measure each state's total value of goods and the state of their economy. It is predicted to have a negative relationship with respiratory deaths.

r. ManufGDP is the gross domestic product of manufacturing in current million dollars. Like GDP, this variable measures the value of each state's manufacturing economy and is expected to show a positive correlation with respiratory deaths.

s. Yeardummy and Statedummy variables were created to account for aggregate trends and control for year effects throughout the dataset.

Due to multicollinearity, variables such as the number of moderate and unhealthy days recorded, and population of each state from ages 18 to 64 are some of the omitted variables in these regressions. As previously stated, information about the dollar per ton emission fee from five states are not included due to their lack of response.

Regressions

Analyzing the three relationships of pollution regulation, air quality, and health risks requires two separate regressions. The first regression analyzes the relationship between each state's air emission fee and the reported air quality. The subscripts 'i' and 't' refer to the states and years in the dataset, respectively.

$$\text{Gooddays}_{it} = \alpha_0 + \alpha_1\text{Emissionfee}_{it} + \alpha_2\text{AmtCO}_{it} + \alpha_3\text{AmtNH}_{3\,it} + \alpha_4\text{AmtNO}_{X\,it} + \alpha_5\text{AmtPM}_{2.5\,it} + \alpha_6\text{AmtSO}_{2\,it} + \alpha_7\text{Experience}_{it} + \alpha_8\text{Smokers}_{it} + \alpha_9\text{Yeardummy} + \alpha_{10}\text{Statedummy} + u_{it}$$

The second regression uses the results from the previous regression through the linear prediction variable 'Gooddayhat' to connect the effects of implementing an emission fee on the state's air quality to the number of respiratory deaths in a given year.

$$\text{Numberofdeaths}_{it} = \alpha_0 + \alpha_1\text{Gooddayhat}_{it} + \alpha_2\text{Householdincome}_{it} + \alpha_3\text{Students}_{it} + \alpha_4\text{Precipitaion}_{it} + \alpha_5\text{Healthexpen}_{it} + \alpha_6\text{Pop18}_{it} + \alpha_7\text{Pop65}_{it} + \alpha_8\text{Totpop}_{it} + \alpha_9\text{Healthinsurance}_{it} + \alpha_{10}\text{Hospitals}_{it} + \alpha_{11}\text{Experience}_{it} + \alpha_{12}\text{GDP}_{it} + \alpha_{13}\text{ManufGDP}_{it} + \alpha_{14}\text{Yeardummy} + \alpha_{15}\text{Statedummy} + u_{it}$$

With each regression the fixed effects model is used to hold constant each state and year in order to control for omitted variables.

Results

As previously stated in this chapter, two regressions are used to analyze the impacts of air emission fees on the number of respiratory related deaths in the United States. Table 1 shows the results from the first regression regarding the relationship between pollution regulation and air

Summary Table

Variable	Obs	Mean	Std. Dev.	Min	Max
Gooddays	800	202.3716	49.0457	80	346.5
Numberofdeaths	800	4645.411	4575.351	168	24359
AmtCO	799	21.39243	24.46672	0.118224	153.321
AmtNH3	790	0.3733315	0.6373996	0.00000376	5.099478
AmtNOX	799	35.06565	42.61537	0.4205599	358.5606
AmtPM2.5	799	4.112702	5.97252	0.0420444	43.12215
Experience	752	11.41489	6.18991	-9	24
Smokers	800	21.018	7.592958	9.1	208
Gooddayhat	677	203.4042	44.57319	105.682	348.5963
Householdincome	800	47500.62	8492.951	29297	76165
Students	800	976915.6	1129595	84409	6441557
Precipitation	800	41.691967	85.80408	6.24	2410
Healthexpen	800	6161.441	1597.367	2795	11064
Pop18	800	1464198	1658584	121786	9418497
Pop65	800	736081.7	764017.8	34000	4164493
Totpop	800	5978627	6585739	491780	38700000
Healthinsurance	800	5059.165	5401.298	413	33531
Hospitals	800	98.56	79.31229	5	428
GDP	800	267290.6	3330301.3	15771	2358811
ManufGDP	800	34897.51	40971.92	801	268428

quality. Nitrogen oxides show an inverse association with the number of ‘good days’ a state has in a given year with only nitrogen oxides being statistically significant. In other words, the more tons of nitrogen released, the less days receiving a good air quality index for that state.

Table 1 (Air Quality): obs = 677, R^2 = 0.8238

Gooddays	Coefficient	Standard Error	P > |z|
Emissionfee	0.1296233**	0.0457185	0.005
AmtCO	0.0330044	0.1836204	0.857
$AmtNH_3$	0.8217394	3.108282	0.791
$AmtNO_x$	-0.2993878**	0.1015172	0.003
$AmtPM_{2.5}$	0.1969811	0.3352502	0.557
$AmtSO_2$	0.0581693	0.0610577	0.341
Experience	-2.731566*	1.180596	0.021
Smokers	0.1532567	0.1193023	0.199
_cons	283.2566*	22.5466	0.000

** significant at 90 percent confidence interval*
*** significant at 99 percent confidence interval*

Surprisingly, this is not the case for all pollutants. Carbon monoxide, ammonia, particulate matter, and sulfur dioxide demonstrate a positive relationship, stating that an increase in the amount of pollutants emitted increases the number of 'good days'. Additionally, the amount of experience a state has regarding their emission program has a negative correlation, meaning that the each year of experience a program has is associated with a 2.73 decrease in the number of 'good days'. These estimates contradict this paper's hypothesis and show evidence of upward bias since the coefficients of these variables are higher than the true parameter. Furthermore, each state's emission fee, the key variable in this regression, and the percentage of smokers have a positive correlation with the number of 'good days', with emission fee being statistically significant at the 99 percent confidence interval. As the emission fee increases by 1 dollar, the number of reported 'good days' by each state increases by 0.1296 days, ceteris

Table 2 (Deaths): obs = 677, R^2 = 0.9975

Numberofdeaths	Coefficient	Standard Error	P > |z|
Gooddayhat	7.106179**	2.326582	0.002
Householdincome	-0.015357**	0.003758	0.000
Students	0.0005098	0.0005959	0.392
Precipitation	0.0912547	0.096423	0.344
Healthexpen	-0.1205922**	0.0354759	0.001
Pop18	-0.0024294**	0.0004452	0.000
Pop65	-0.0000634	0.0001143	0.579
Totpop	0.0007032**	0.0000997	0.000
Healthinsurance	0.3435981**	0.0843371	0.000
Hospitals	4.35132**	1.418037	0.002
Experience	143.9293**	36.78899	0.000
GDP	-0.0029255**	0.0004465	0.000
ManufGDP	0.0133757**	0.0023168	0.000
_cons	-1698.816*	824.1798	0.039

** significant at 90 percent confidence interval*
*** significant at 99 percent confidence interval*

paribus. Namely, air quality increases as the state's emission price increases.

Table 2 displays the results from the second regression, which observes the relationship between air quality and the number of deaths related to respiratory illnesses by using results from the first regression. Although there are many statistically significant variables, some coefficients are different from expectations. The 'Gooddayhat' variable, for example, suggests a positive relationship with the number of deaths from respiratory diseases. Ideally, a negative correlation

is hypothesized since an increase in the number of days reporting good air quality should lead to a decrease in the number of people dying. However, poor air quality is not the only reason someone may suffer from a respiratory related illness, potentially creating a bias. Since this variable is the linear prediction from the first model, unknown errors or biases that previously occurred may have disrupted the results in the second regression.

Furthermore, variables regarding the number of hospitals and people with health insurance in each state have a statistically significant positive correlation with the number of deaths. It is estimated that an additional hospital is associated with a 4.35 increase in the number of deaths from respiratory diseases. Furthermore, 1,000 more people obtaining health insurance is associated with a 0.344 person increase in the death toll, ceteris paribus. Amongst many reasonings, these estimates can be explained by the constant increase in the United States' total population since there are more people searching for health insurance and hospital care. In this regression, total population suggests a statistically significant positive relationship. As the total population of a state increases by 1 person, the number of people who suffer from respiratory diseases increases by 0.0007 people. Even though this relationship is expected, the small coefficient displays a lack of economic significance for total population in this regression.

Household income, health expenditures, and the number of people who are younger than 18 and older than 64 have inverse relationships with respiratory deaths. As health expenditures and the average household income increase, the number of respiratory deaths decrease. People with higher incomes are assumed to spend more on their health, thus increasing the amount they are willing to spend on health expenses and their overall health. Additionally, the number of students and average precipitation of each state show a positive relation. Similar to total

population, these estimates do not have an economic significance due to small coefficients. For example, a 1 inch increase of rainfall is correlated with a 0.0912 increase in the number of deaths from respiratory diseases while an additional student increases respiratory deaths by 0.00051 people.

The total gross domestic product (GDP) of each state estimated a statistically significant negative relationship, suggesting that a one million dollar increase is associated with a 0.00292 decrease in respiratory deaths. Countries with high GDPs tend to have more regulations towards protecting the environment, indirectly contributing to a lower death toll. When observing the GDP of manufacturing each state, the number of respiratory deaths increases as manufacturing GDP increases since more manufacturing can lead to more emissions contaminating the air and more health risks.

Contrasting the results from the previous regression, there is a statistically significant positive relation between respiratory deaths and the amount of experience a state has in regards to their emission program. The longer the emissions program has been active, more respiratory deaths have been recorded. Ideally this relationship should be negative to demonstrate a decrease in respiratory deaths as states become more knowledgeable about the best way to implement the Title V emission fee. Therefore, there is no apparent evidence why these results suggest a positive relationship other than a presence of an unknown bias.

Ultimately, the results of both regressions do not fully support the hypothesis of this paper. While the first regression states that a higher emissions fee increases the number of ‘good days’ a state has, the second regression shows a positive relationship between the number of respiratory deaths and the linear prediction of ‘good days’ from the first model. The latter

contradicts this paper's hypothesis since it was predicted that the estimates from the first regression should be negatively correlated with respiratory deaths. This would have been consistent with the projects hypothesis that an increase in each state's emission fee improves air quality and decreases the number of deaths from respiratory diseases. Additionally, four of the five pollutant variables demonstrated a positive relationship with the number of 'good days'. These results also go against this paper's prediction since a decrease in the amount of pollutants released should contribute to an increase in the number of days with good air quality.

It is evident that many variables contain upward bias. Endogeneity, which can be defined as when explanatory variables are associated with the error term in a regression, may also be an issue due to omitted variables and measurement error (Roberts et. al, 2013). Omitted variable bias occurs when a variable that impacts the dependent variable is not included in the regression since it is correlated with one or more of the independent variables (Bascle, 2008). Incorrect or rounded data may have been obtained when collecting the emission fees from each state since the majority of the information was collected through contacting representatives at the state environmental departments. The information given may have not been the exact dollar per ton amount and rounded to the nearest dollar or cent. If this were true, the conclusions from these regressions may not be completely accurate.

Conclusion

As addressed in this paper, air pollution is causing many health risks and environmental issues such as droughts and heat waves. Through the Clean Air Act (CAA), the United States has depleted the amount of emissions from the six criteria pollutants by 70 percent. However, concentrations of greenhouse gases such as carbon dioxide, methane, and nitrous oxide are still increasing. This paper aims to analyze the relationship between pollution regulation from the CAA, air quality, and health illnesses by focusing on each state's dollar per ton Title V air emission fee. Ideally, air quality of an area will improve as emission fee increases which will contribute to a decrease in the number of deaths from respiratory diseases in each state. After analyzing previous literature and economic theories, two regressions were run using data from numerous sources to test this paper's research idea. The first regression aimed to estimate the relationship between pollution regulation and air quality in a given state. Using a linear prediction of the dependent variable from the first model, a second regression was constructed to interpret the correlation with respiratory diseases.

Although many variables were statistically significant, some variables were estimated to have the opposite effect of what was originally predicted. For example, all of the pollutant variables were expected to have an inverse relationship with the number of days with good air quality. However, only nitrogen oxides showed this correlation. The linear prediction of the number of 'good days' from the first model that was used in the second model regarding the number of deaths is another example showed a statistically significant positive relationship. Ideally this estimate should have had a negative relationship with the number of people who die from respiratory diseases since better air quality should decrease the death toll. Due to the results

of these variables, it is obvious that an upward bias is present throughout both regressions. Therefore, it is difficult to conclude if each state's emission fee has directly contributed to a decrease in the number of respiratory deaths in the United States.

To attempt to eliminate bias and obtain more economically significant results, other factors can be included in future research that were originally omitted. For starters, gathering fee schedules from the five states that were not included in this data set and may give different results. Since the emission fee is not the only regulation from the Clean Air Act, operating permits can also be included and compared to the impact of the emission fee. Different types of pollutants, such as methane, and emissions from different industries, such as transportation, may be observed in addition to or instead of industrial emissions. This research idea can also be applied to other countries, specifically ones with high air pollution from various industries. Electronic waste, for example, is causing many health effects and environmental pollution in developing countries. Government regulations regarding electronic waste (although most of the dumping is illegal) can be analyzed in comparison to the air pollution affecting the health of these countries. Lastly, more variables may be added to both regressions to help eliminate or reduce bias.

Overall, this paper adds to the many papers regarding pollution regulation and health effects. It examined this relationship from an economic lense by analyzing the impacts of an air emission fee. Even though the research question was not fully answered, this analysis encourages more environmental research regarding economic principles including regulations, taxes, and fees. Finding more information about these relationships is key to making the best decisions necessary for improving our overall health and preserving our planet.

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