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Health Impact of Mountaintop Removal and Federal Air Quality-related Policies: A Study on Respiratory Disease and Lung Cancer Mortality Rates in KY

Hannah Harrison
University of Kentucky, h.harrison.ky@gmail.com

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University of Kentucky

Martin School of Public Policy and Administration

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Executive Summary

Coal mining has been a major industry in Central Appalachia for over a century, and in the 1970s, it went through a major transition. In an effort to access coal seams previously inaccessible to traditional underground mining methods, coal companies began to adopt a new extraction method known as mountaintop removal (MTR). This new approach to surface mining involved deforesting a mountaintop and then removing the remaining rock and vegetation that is sitting atop a coal seam via explosives and heaving machinery. Compared to underground mining, MTR released more air pollution than underground mining in the form of particulate matter from the explosives and diesel fumes from the machinery and transport trucks.

The Clean Air Act (CAA) of 1970 sets air quality guidelines that states must meet to ensure the welfare of the nation, but states can develop their own strategy in order to meet those guidelines. Despite this policy, literature has consistently supported the correlation with MTR and various illness correlated with air pollution such as birth defects, dementia, cardiovascular disease, COPD, and depression in Central Appalachia. This research looks at counties in Kentucky with MTR and counties without in order to compare how MTR has impacted mortality rates from respiratory disease and lung cancer. The goal is to understand the impact MTR has on the respiratory health of communities in Kentucky. The conclusion will help in evaluating Kentucky's implementation of federal air policies and the ability of those air policies to protect MTR communities.

The results of the data analysis showed that between the years 1990 to 2019, mortality rates for respiratory disease and lung cancer are higher in MTR communities than communities without. There was also evidence that the disparity in mortality rates for both diseases has increased since more from 1990 to 2019 than between 1968 and 1989. This indicates that not

only does MTR impact the respiratory health or nearby communities, but that it has gotten worse since 1968. Therefore, my research can be used to inform the theory that federal air policy is not protecting Central Appalachian communities from MTR pollution.

Introduction

In the 1960s and 1970s, the Central Appalachian region was running out of coal seams accessible by traditional underground mining methods. To address this issue, a new form of surface mining was introduced called mountaintop removal (MTR). MTR is the process of literally removing the top of a mountain that covers a coal seam, which is positioned in the rock like the middle layer in a cake (Fox, 1999). The mountain is removed using explosives, heavy machinery, and large diesel trucks. The portion of the mountain that is removed is deposited into the adjacent valley. This process was faster and used less miners that previous forms of surface mining and all forms of underground mining, and by the 1970s, mountaintop removal became the dominant method of coal extraction. Although more efficient, MTR has led to an increase in the destruction of habitats and an increase in many types of pollution, including air pollution (Hendryx et al., 2020).

As MTR increased in popularity, the US entered the decade of environmental policy that was the 1970s. During this time, three policies were passed that had great implication for the operation and regulation of MTR, which were the Clean Air Act of 1972, the Clean Water Act of 1972, and the Surface Mining Control and Reclamation Act of 1977. These policies were developed under the federalism model with meant that the federal government set standards for air or water quality and states developed their own programs and methods to achieve these standards in the time allotted, all regulated by a federal agency. While states would still develop and implement their own programs and methods on air and water quality, they were now for the first time to meet federally-set environmental standards. Despite the passage of these policies, MTR continued to contribute to a public health crisis in regions like Eastern Kentucky. These public health impacts are indicated by an increase in various illnesses and conditions, such as lung cancer and respiratory disease mortality rates, for counties with surface mining in Central Appalachia (Hendryx et al., 2020).

The Clean Air Act called on states and the EPA to address specific air pollution problems that negatively impact the air quality of the US and the welfare of its citizens. It was amended first in 1977 and for the last time in 1990. The first amendments passed increased the time that firms and states had to comply with air quality standards. The amendments in 1990 were more multifaceted than the 1977 amendments, and they encouraged the use of low-sulfur coal, among other things. Low-sulfur coal is found in Central Appalachia, and as a result of these amendments, MTR activity in the region increased. This led to an increase in MTR activity in counties where the practice has already negatively impacted the air, water, and biodiversity for decades. This has been known to contribute to a public health crisis in Eastern Kentucky which is perpetuated by high poverty rates, a lack of access to quality medical care, and low educational attainment (Hendryx et al., 2020). Outside of the CAA, most policy regulating air pollution is passed at a federal level such as the Respirable Dust Rule passed in 2014. This targets coal dust from coal mines but mainly targeted levels at the mines themselves, as the goal was to protect miners from black lung disease. Not many studies empirically examine the public health impact of a series of regulatory policies from a longitudinal perspective.

This research fills the gap by looking at one state, Kentucky, in order to review their success in implementing federal air policy in a way that if fulfills its purpose: to protect the welfare of every person in the US. My research questions are: Are counties in the Appalachian region of Kentucky with MTR seeing an increase in deaths from respiratory illness, despite nationwide improvements in air quality attributed to federal air policy? How does MTR impact community health? By comparing CDC data on respiratory disease and lung cancer mortality rates from 1968-2019, this capstone will review the possible impacts of MTR on public health in relation to the 1977 and 1990 CAA amendments, as well as the 2014 rule that specifically targets coal dust. Research on this issue can be beneficial to community leaders and policy makers in Central Appalachia as this is a regional problem, not just a Kentucky problem. As the most air pollution regulation is federal policy, the results could be useful to legislators and other government actors at the federal level as well. Environmental nonprofits and political action committees would also be interested in this information, as they often lobby for or against policies concerning coal mining and air pollution.

Literature Review

In 1970, one of the most impactful and revolutionary policies of the 20th century was passed and signed into law: The Clean Air Act. The purpose of this legislations was to protect the public health and welfare of everyone in the nation. The federal policy set air quality standards for six criteria pollutants and states were required to develop programs to achieve these standards. The CAA has provisions focused on reducing pollution from cars and stationary sources, such as power plants and factories (https://www.epa.gov/clean-air-act-overview). As of 1996, there were implementation failures at the state level as some states refused to follow certain standards (Driesen, 1996). States did whatever they could to avoid implementing difficult measures that might have been costly or led to relocation of industry to another, more lenient state (Driesen, 1996). This article also pointed out that the reason the CAA is not as strong as it could be is that the EPA not being politically independent from the executive branch as its leadership is largely comprised of presidential appointees (Driesen, 1996). Instead, the EPA's power and purpose fluctuates with every presidential cycle or congressional party shift (Driesen, 1996).

The Surface Mining Control and Reclamation Act (SMCRA) was passed in 1977. The purpose of this act was to guarantee resources and organize the regulation of surface mining and reclamation of abandoned mines. In 1981, Donald Menzel explained the tensions forming between the Office of Surface Mining (OSM) and state regulators, as there were two different approaches to implementation: states wanted loose regulation and bargaining and the OSM wanted a strict rule structure (Menzel, 1981). States disliked the presence of federal authorities and frequently disobeyed the rules from the OSM (Menzel, 1981). This study revealed the weaknesses in the SMCRA and other federal policies like the CAA, which have only increased through the decades as they have been weakened through litigation, and the tension that exists between the federal government that is trying to regulate and the states that are fighting regulation.

According to Fox (1999), the coal industry of West Virginia and greater Appalachia was controlled by a few "absentee owners". The regulation system of the SMCRA failed as local leaders and regulators are under the control of mining companies and the structure of the polices allow this corruption and mismanagement to continue (Fox, 1999). The presidency of George W. Bush only exacerbated the struggles the federal regulatory agencies had in implementing their polices on strip mines (Davis and Duffy, 2009). Surveys of state regulatory authorities found that federal oversight by the OSM decreased greatly from Clinton to Bush (Davis and Duffy, 2009). The regulatory strength of the SMCRA and CAA were tenuous to begin with but now they are subject to the political agenda of the current party in power.

In 1990, major revisions were made to the CAA designed to curb three environmental issues: acid rain, toxic car emissions, and air pollution in cities. In an effort to reduce acid rain, the legislation promoted low sulfur coal that produced less air pollution when burned (https://www.epa.gov/clean-air-act-overview/1990-clean-air-act-amendment-summary). The CAA was undoubtedly successful in reducing emission from coal fired power plants: coal plants that used low sulfur coal or installed air pollution control technologies in compliance with the 1990 amendments saw between an 18 and 64% reduction in harmful chemicals and 49 and 68% reduction in gas emissions (Gingerich, 2019). Despite success with this facet of coal production, the CAA did not regulate emissions from other key steps in the process, such as the extraction of coal and storage of waste (Bell, 2016). Due to the sparse regulation of air pollution from MTR extraction, companies will shift their environmental costs to vulnerable communities like those in Central Appalachia (Bell, 2016).

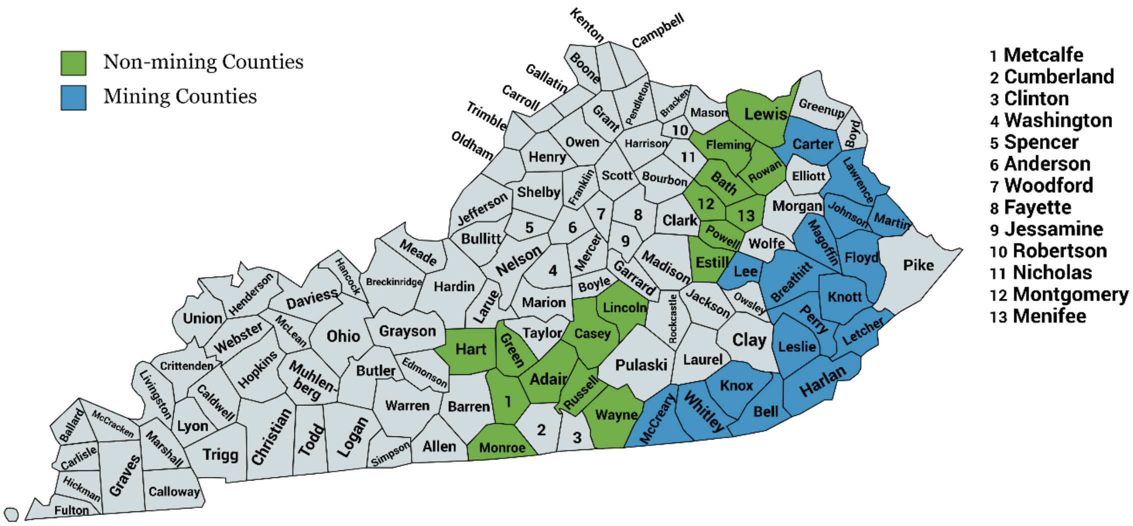
Despite the various air quality policies, air pollution is significant cause for concern as far as the health of communities near MTR activity and coal processing as of 2014, according to a study by Kurth et al. (2014). There are two significant sources of air pollution closely related to MTR activity: particulate matter (PM) released as a result of the extraction process, and fumes from diesel trucks used for the transportation of coal (Hendryx et al., 2020). Counties with coal MTR mining were found to have greatly higher amount of PM than counties with only underground mining or no mining (Kurth et al., 2014). The primary type of PM found was lithogenic aluminosilicate dust which can directly impact the human respiratory system (Kurth et al., 2014). Further proof that the PM was released by the MTR mines was the concentration of PM in the atmosphere, which fluctuated with the production schedule of the mines studied over a period of one year (Kurth et al., 2014). The massive amount of coal extracted from these surface mines is transported in diesel trucks that release fumes that contribute to the local air pollution (Hendryx et al., 2020).

In the last two decades, research has concluded detailing the correlation of coal mining and increasing mortality rates from respiratory diseases and cancers (Hendryx et al., 2020). While controlling for covariates like smoking, poverty, education, age, sex, race, etc., Hendryx et al. (2008) found positive correlations between elevated lung cancer mortality rates and proximity to coal mining. Hendryx and Luo (2015) has also shown how MTR affects respiratory health using nonexperimental data from two rural counties in Virginia. Though a small study, the results concluded that people in MTR areas have elevated prevalence of respiratory symptoms and chronic obstructive pulmonary disease (Hendryx and Luo, 2015). It was also found in West Virginia that the increased concentration of atmospheric particulate matter attributed to MTR can impair the central nervous system (Salm and Benson, 2019). By comparing mining counties to non-mining counties in West Virginia, the results found higher dementia mortality rate in counties with MTR (Salm and Benson, 2019). However, these studies established the impact surface mining has on the respiratory health of Appalachian coal mining communities when compared to non-mining communities. These studies analyzed cross-sectional data so they lack information on how the public health impacts have changed over time.

To form a conclusion on the efficacy of the CAA in a specific state, the research must be focused because each state is responsible for achieving the federal air quality standards set in the CAA. My research fills the gap because it focuses on Kentucky where other research into respiratory disease and cancer were based in another Appalachian states or over all of Central Appalachia. This research uses data from the CDC to answer the question of how impactful federal air policy introduced since the CAA of 1970 has been in Kentucky by studying the mortality rates from respiratory illness in counties with MTR compared to counties without mining.

Data Plan

I limited the counties chosen to those with between 5,000 and 40,000 residents and are considered economically distressed by the Appalachian Regional Commission, meaning they are in the bottom 10% of counties in the US, according to their three-year average unemployment rate, per capita market income, and poverty rate (https://www.arc.gov/distressed-designation-and-county-economic-status-classification-system/). Of the 38 Appalachian counties in Kentucky designated economically distressed, I chose 34 to do a comparative study; seventeen are non-mining and seventeen are mining. I eliminated four counties because they were outside my population parameters. My mining counties are Bell, Breathitt, Carter, Floyd, Harlan, Johnson, Knott, Knox, Lawrence, Lee, Leslie, Letcher, Magoffin, Martin, McCreary, Perry, and Whitley. My non-mining counties are Adair, Bath, Casey, Estill, Fleming, Green Hart, Lewis, Lincoln, Menifee, Metcalf, Monroe, Montgomery, Powell, Rowan, Russell, and Wayne. I used the Kentucky Coal Mine Maps developed by the Kentucky Energy and Environment Cabinet that details both active and previously active mines in the state to select these 34 counties (https://eppcgis.ky.gov/minemapping/).



The public health data was collected from Centers for Disease Control and Prevention's "Wonder" database. The dependent variables are respiratory disease and lung cancer mortality rate per 100,000. These diseases were chosen because their prevalence in Appalachia has been well researched to have a positive correlation with mountaintop removal activity. . I gather data from 1968 to 2019, choosing this starting year following Hendryx and Holland (2016), which addressed a similar question to this research about the CAA. I also believe that date will give me a clear picture as to the public health trends in the area before the CAA and SMCRA. 2019 is the most recent accessible data points by CDC.

Research Design

Research Hypotheses

This research test two hypotheses. The first is that there is an increasing difference in respiratory disease mortality rates between a community with MTR and a community without

MTR. The second hypothesis is there is an increasing difference in lung cancer mortality rates between a community with MTR and a community without MTR from 1968 to 2019. By comparing respiratory disease and lung cancer mortality rates over the last 47 years in two similar types of communities in Kentucky's Appalachian region, one with coal mining and one that has never experienced coal mining, my research will reveal the negative impacts of federal air policy in Central Appalachia since 1968. Specifically, I suggest the following hypotheses:

H1: A community with MTR is more likely to have a higher rate of respiratory health diseases than a community without MTR.

H2: A community with MTR is more likely to have a higher rate of cancer mortality rate than a community without MTR.

Analysis Outline

To test my hypotheses, first, I perform independent sample t-tests with the mining group and non-mining group as the independent variables to see if there is a difference in the rates of public health diseases (dependent variables) between a community with MTR and a community without MTR. My two dependent variables are respiratory disease mortality rate per 100,000 deaths and lung cancer mortality rate per 100,000 deaths. From the CDC data, I found each disease rate per county for each year between 1968 and 2019. I will use the county disease rates to develop a mean for each year for both the mining and non-mining group. Second, I compared the means via independent sample t-tests for each year for both respiratory disease and lung cancer. The end product will be graphs visually depicting how rates for each disease rates changed from year to year in coal mining counties and in counties without coal mining. Third, in addition to the graphs will be data on which diseases have the strongest association with MTR if that has changed over the years. Using the data that shows how each disease rate changed through the years for mining vs non-mining counties, revealed how the two policies in question and their amendments have impacted the well-being of Kentucky's Appalachian region for a little over four decades.

Analyzing the data via a t-test will reveal how the two policies in question have impacted the well-being of Kentucky's Appalachian region for a little over four decades. This is accomplished one of two ways. First the graphs will allow me to compare the two independent variables, the mining and non-mining counties. This will tell me if the effectiveness of federal air policy has improved or gotten worse through the years in regards to protecting public health from MTR air pollution. Second, the results from the t-test will allow me to compare the diseases and see how their rates have changed. This will address my problem statement by revealing information on where and how the polices may be failing to protect the communities in Kentucky's Appalachian region from MTR.

I performed two regression analyses, using the 2019 lung cancer mortality rate per 100,000 deaths as the dependent variable in the first regression, and then the 2019 respiratory disease mortality rate per 100,000 deaths in the second. The independent variables are socioeconomic data from the US Census Bureau that may influence public health: poverty rate, median age, educational attainment, number of people without health insurance, and unemployment rate (Monnat, 2018). The regression analyses will allow me to see if any socioeconomic variables have a greater influence on the mortality rate from respiratory illness than the presence of coal mining.

Results

Respiratory Disease

Regarding the first hypothesis, the longitudinal trend data on respiratory disease in a community with MTR and without MTR shows that the disparity in respiratory disease mortality rate between mining and non-mining counties has existed since the implementation of the CAA and has increased through 2019 (see figure 1).

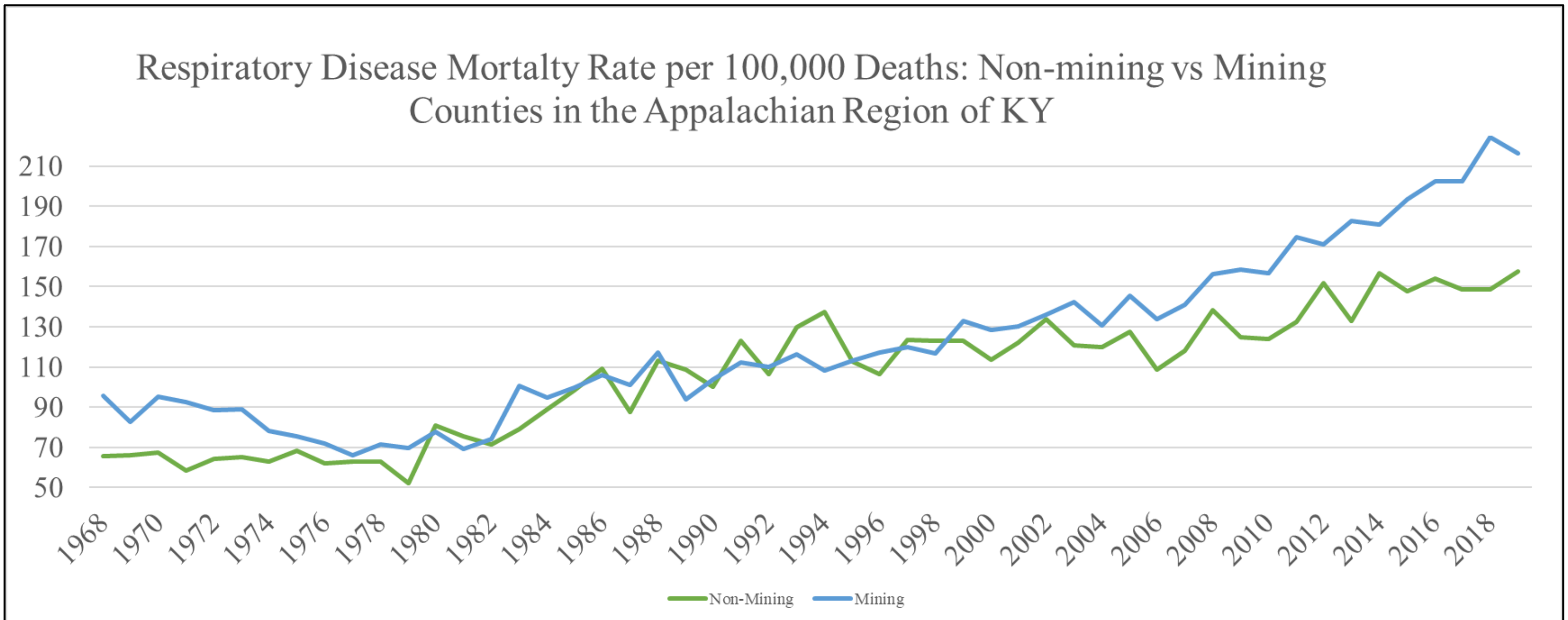


Figure 1. Line graph comparing respiratory disease morality rate per 100,000 deaths from 1968-2019 for mining and non-mining counties in Kentucky's Appalachian region.

Next, the results of the t-test analysis of the respiratory disease mortality rate per 100,000 deaths showed significant difference between non-mining and mining counties in KY. A community with MTR indicates a higher rate of respiratory health diseases than a community without MTR. From 1968 to 2019, seventeen communities with MTR (M= 125.09, SD=41.44 compared to the 17 communities without MTR (M= 110.04, SD=31.14) reported higher levels of respiratory disease mortality, t(85)= -2.02, p =0.023. The t-test that compared the mean morality rate from 1968 to 2019, t(95)=-2.22;p=.029, showed that there was significant difference between the two mining groups. However, the difference was more significant between 1990 and 2019, t(30)=-2.82;p=.007, than between 1968 and 1989, t(22)=-2.27;p=.029. After 1990, the disparity in respiratory disease mortality rate per 100,000 deaths in counties with mining (M=148.6, SD=34.81) distanced even more from the rate in non-mining counties (M=128.9, SD=15.9). These results indicate that counties with coal mining are at a greater risk of seeing elevated mortality rates of respiratory disease than those without. The fact that the t-statistic increased from 1968-1989 to 1990-2019, shows that the magnitude of the relationship between mining and respiratory disease mortality increased.

To further extrapolate this information, a t-test was run for each year between 2015 and 2019. The results also confirms that a community with MTR has a higher rate of respiratory health disease related deaths per 100,000 than a community without MTR. In 2015, communities with MTR (M= 182.3, SD=38.77) compared to the 17 communities without MTR (M=152.2, SD=31.05) reported higher levels of respiratory disease mortality, t(31)= -2.49, p =.018. In 2016, communities with MTR (M=208.7, SD=53.49), when compared to communities without mining (M=157.1, SD=40.80), had more deaths per 100,000 attributed to respiratory disease t(31)= -2.49, p =.018. The mortality rates in 2017 (t(30)= -4.049, p =..0003) were once again higher for mining counties (M=201.7, SD=39.75) than non-mining (M=152.7, SD=30.13) than they had been the previous two years. Following the trend, 2018 saw an increase in the disparity between mortality rates (t(25)= -6.05, p =2.5E-06) for MTR counties (M=228.4, SD=45.35) and counties without MTR (M=152.7, SD=24.57). 2019 was the first year that the gap in mortality rates (t(30)= -4.405, p =.0001) shrunk slightly for mining (M=219.3, SD=42.00) and non-mining

(M=163.5, SD=31.15) counties. Figure 2 shows while that the disparity of respiratory disease mortality rates in counties with and without coal mining have grown since the 1990s, they are still increasing.

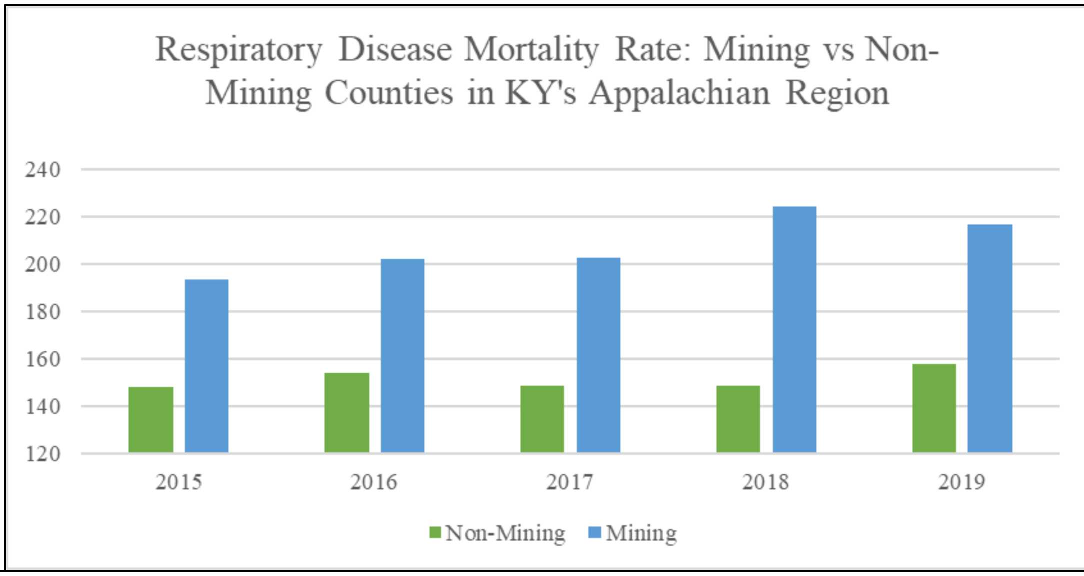


Figure 2. Bar Graph comparing respiratory disease mortality rate per 100,000 deaths in counties with MTR and counties without MTR for the years 2015-2019.

Moreover, Table 1 shows the results of regression analysis on respiratory disease mortality rate, presenting coefficients for independent and control variables to show their relative importance on respiratory disease mortality rate in 2019. The regression analysis that looked for trends in the 2019 respiratory disease mortality rate per 100,000 deaths and socioeconomic data from each county. The independent variables were population below the population, poverty rate, median age, population with high school degree, population without health insurance, and unemployment rate. There was a correlation at 99% confidence level with the presence of coal mining and respiratory disease mortality rate. MTR is found to be positively and significantly associated with Respiratory disease mortality rate (coefficient on MTR= 63.62, p-value < 0.01).

Table 1. Results of Multiple Regression on Respiratory Disease Mortality Rate per 100,000 Deaths				
	Coefficients	*Standard Error*	*t Stat*	*P-value*
MTR (Yes=1;NO=0)	**63.62044**	**14.1684**	**4.49**	**0.000*****
Population in 2019	-0.0017181	0.000966	-1.78	0.087
Population below the poverty line, age 25–54 years, %	0.6175311	1.566966	0.39	0.697
Median Age	3.382532	3.286862	1.03	0.313
% Pop. High School Degree +	1.316708	2.262032	0.58	0.566
Population without health insurance, age 18–64 years, %	2.902938	3.741858	0.78	0.445
Unemployment Rate	1.454446	6.852512	0.21	0.834
Intercept	-89.33776	293.6165	-0.3	0.763
Dependent variable = Respiratory disease mortality rate, p<.10; **p<.05; ***p<.01				

Lung Cancer

Regarding the second hypothesis, the longitudinal trend data on respiratory disease in a community with MTR and without MTR shows that the lung cancer mortality rate per 100,000 deaths of mining counties are similar to that of non-mining counties until the early 1990s. After this point, the two county types begin to separate with mining averaging more deaths per year due to respiratory illness than non-mining (see figure 3).

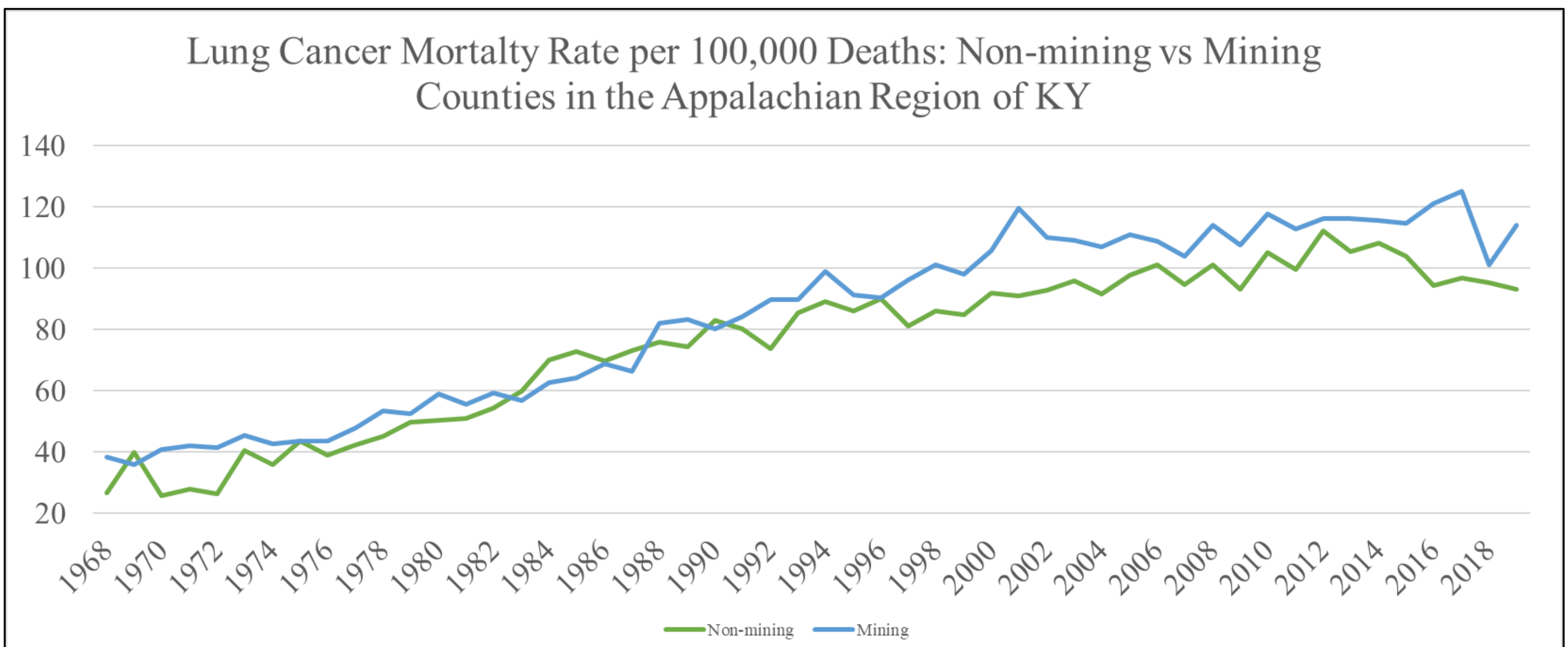


Figure 3. Line graph comparing lung cancer mortality rate per 100,000 deaths from 1968-2019 for mining and non-mining counties in Kentucky's Appalachian region.

The results from the t-test comparing lung cancer mortality rates per 100,000 deaths from 1968 to 2019 between non-mining and mining counties showed no significant difference. From 1968 to 2019, seventeen communities with MTR (M=83.84, SD=28.61) compared to the 17 communities without MTR (M=75.04, SD=25.28) reported higher levels of lung cancer mortality, t(52)= -1.663, p =.0995. comparing mean mortality rates for the 17 mining and 17 non-mining counties across the five decades of data collected, the difference in means was not large or consistent enough to be statistically significant. However, further analysis of the data via t-test shows that the difference in mortality rate per 100,000 deaths for lung cancer between county types was, in fact, significant from 1990 on.

From 1968 to 1989 (t(40)=-.898, p=.375), the difference in the mortality rate from lung cancer per 100,000 deaths was not substantial before 1990 in mining (M=53.95, SD=13.36) vs non-mining (M=49.81, SD=16.97) counties. The results from the analysis of the lung cancer data from 1990-2019 (t(54)=-4.95, p=8E-06) observed a significant disparity between the mortality rates from lung cancer in counties containing active surface mines and counties without surface mines in Kentucky. Mining (M=106.6, SD=10.75) counties began to increase in lung cancer deaths faster than non-mining (M=93.91, SD=8.76). The magnitude of the relationship between lung cancer and county type, also increased based on the size of the t-statistic. This is similar to the results from the respiratory disease data which shows that the disparity in lung cancer mortality rates per 100,000 deaths based on presence of MTR is increasing with the years.

Moreover, Table 2 shows the results of regression analysis on lung cancer mortality rate, presenting coefficients for independent and control variables to show their relative importance on respiratory disease mortality rate per 100,000 deaths in 2019. MTR is found to have a significant impact on lung cancer mortality rate (see coefficient on MTR= 21.87, p-value =0.038). These results prove, with a 5% significance level, a relationship between MTR and lung cancer mortality rate per 100,000 deaths.

Table 2. Results of Multiple Regression on Lung Cancer Mortality Rate per 100,000 Deaths				
	Coefficients	*Standard Error*	*t Stat*	*P-value*
MTR (Yes=1;NO=0)	**21.87056**	**10.00649**	**2.19**	**0.038****
Population in 2019	-0.0010901	0.0006823	-1.6	0.122
Population below the poverty line, age 25–54 years, %	-1.945568	1.106676	-1.76	0.091
Median Age	-1.899554	2.321359	-0.82	0.421
% Pop. High School Degree +	-1.118525	1.597569	-0.7	0.49
Population without health insurance, age 18–64 years, %	-1.105125	2.642702	-0.42	0.679
Unemployment Rate	0.864233	4.839613	0.18	0.86
Intercept	335.9087	207.3678	1.62	0.117
Dependent variable = Lung cancer mortality rate, p<.10; **p<.05; ***p<.01				

Discussion and Limitations

My H1 stated: A community with MTR is more likely to have a higher rate of respiratory health diseases than a community without MTR. The results of the t-tests shows that since 1968, respiratory disease rates are higher in counties with MTR and rates in those counties have been increasing faster than in counties with MTR since 1990. The t-test results were supported by a multiple regression analysis which tested the relationship of the presence of MTR with various socioeconomic variables. Respiratory disease mortality rate had a positive correlation with whether or not the county had MTR with a 99% probability rate. Based on these results, I can reject my null H1 hypothesis.

Lung cancer mortality rate was tested by my H2 hypothesis which stated: A community with MTR is more likely to have a higher rate of cancer mortality rate than a community without MTR. The t-tests revealed that while lung cancer mortality rate per 100,000 deaths was not significantly different between the two county types (mining and non-mining) for the years 1968-1989, it was significantly difference from 1990-2019. The multiple regression analysis I ran with to test lung cancer mortality rate with the socioeconomic variables and MTR, I found a relationship between MTR and lung cancer mortality rate per 100,000 deaths with a probability of 95%. The second, H2, null hypothesis can be rejected based on these results.

There are a few limitations to this research study that should be noted. The first is that this is a case study of the impacts of MTR on respiratory health in Kentucky. Therefore, these results may not be easily applied to other states as they each develop different methods to achieve the quality standards set in federal pollution policies, such as the CAA. The second limitation with this research is the possibility for omitted variable bias in the regression. It is possible I did not include a variable in the regression that would have had a larger impact on respiratory disease or lung cancer mortality rate than MTR. The third limitation applies to the small sample size. With only 34 counties in total, this research model would be improved if it was replicated with more counties. An addition that could be made to enhance this research design with more resources would be to add qualitative data, such as interviews. The final limitation is the possibility of air pollution from an MTR site in a mining county crossing the border to a non-mining county and impacting their public health. A larger sample size would likely address this limitation.

Conclusion

Based on the data, there is a significant and meaningful difference in respiratory disease and lung cancer mortality rates in counties in Kentucky with and without coal mining between

1990 and 2019. Therefore, I can conclude that MTR has an impact on the respiratory health of communities located nearby. This difference is larger in the most recent three decades, 1990-2019, than it is from 1968 to 1989. This shows the possible unintended impact the 1990 amendment to the CAA had on MTR activity and air pollution. Although the goal of the CAA is to protect the welfare of US communities, it has protected some at the expense of others by promoting low sulfur coal which led to an increase in the amount of coal extracted from Central Appalachia via MTR. While emissions from power plants and acid rain have decreased nationally since 1990, communities that extract the "clean" coal, are experiencing the health impacts of its production now more than ever.

This data demonstrates that, regardless of the incredible improvements made in the air quality of the US as a nation, the mining communities in Central Appalachia are still high rates of respiratory disease and lung cancer than their neighbors, even when controlling for socioeconomic factors. Air pollution policy has been the domain of the federal government since the 1970s, but the results of this research shows that are being protected from air pollution. Therefore, future amendments to existing policies should ensure there are not unintended impacts for MTR and that they are protected. State policies that specifically address the issue would be a possible alternative to federal policies that are not currently protecting Appalachia from air pollution. Another step to addressing the results of this study through policy is to reevaluate the air quality standards for MTR sites according to the CAA and the SMCRA in conjunction with Kentucky's regulation strategies to understand if they can be improved or if they are adequate. Finally, a policy response that would address the needs of MTR communities is to provide the public health resources necessary to cope with the extra burden on their healthcare caused by the air pollution from the mines.

Appendix 1. Descriptive Statistics

Variable	Obs.	Mean	St. Dev.	Min	Max
Respiratory Disease	34	191.3882	46.15193	109.4	287.8
Lung Cancer	34	107.0353	28.11374	60.1	150.7
MTR	34	0.5	0.5075192	0	1
Population	34	18282	7747.242	6593	36590
Poverty %	34	26.82353	6.398251	17	38
Household Income	34	44339.09	6707.851	32386	58294
Age	34	41.30882	2.428663	30.6	44.6
HS Diploma %	34	76.29412	4.46216	65	86
Pop w/o Health Ins.	34	6.323529	1.949679	3	12
Unemployment Rate	34	3.588235	1.131308	2	6

Appendix 2. Correlation Coefficients between Variables

	Resp. Dis.	Lung Cancer	MTR	Population	Poverty %	Age	HS Diploma %	Pop w/o Health Ins.	Unemp. Rate
Respiratory Disease	1								
Lung Cancer	0.3664	1							
MTR	0.6144	0.299	1						
Population	-0.0501	-0.1754	0.2153	1					
Poverty Rate	0.15056	-0.2047	0.084	-0.1987	1				
Age	0.1463	-0.0892	0.0848	0.0896	0.0334	1			
Perct. HS Diploma	-0.1393	0.0151	-0.1472	0.1977	-0.5989	-0.4423	1		
Pop w/o Health Ins.	-0.0343	-0.0371	-0.0662	-0.1072	0.2187	0.3596	0.2569	1	
Unemployment Rate	0.1341	0.1056	-0.1461	0.4962	-0.4973	-0.0819	-0.2274	-0.1851	1

References

Bell, Shannon Elizabeth. "Environmental Injustice and the Pursuit of a Post-Carbon World: The Unintended Consequences of the Clean Air Act as a Cautionary Tale for Solar Energy Development." Brook. L. Rev. 82 (2016): 529.

Davis, Charles E., and Robert J. Duffy. "King coal vs. reclamation: Federal regulation of mountaintop removal mining in Appalachia." Administration & Society 41.6 (2009): 674-692.

Driesen, David M. "Five lessons from the Clean Air Act implementation." Pace Envtl. L. Rev. 14 (1996): 51.

Fox, Julia. "Mountaintop removal in West Virginia: an environmental sacrifice zone." Organization & Environment 12.2 (1999): 163-183.

Gingerich, Daniel B., Yifan Zhao, and Meagan S. Mauter. "Environmentally significant shifts in trace element emissions from coal plants complying with the 1990 Clean Air Act Amendments." Energy Policy 132 (2019): 1206-1215.

Hendryx, Michael, and Benjamin Holland. "Unintended consequences of the Clean Air Act: Mortality rates in Appalachian coal mining communities." Environmental Science & Policy 63 (2016): 1-6.

Hendryx, Michael, Kathryn O'Donnell, and Kimberly Horn. "Lung cancer mortality is elevated in coal-mining areas of Appalachia." Lung Cancer 62.1 (2008): 1-7.

Hendryx, Michael, Keith J. Zullig, and Juhua Luo. "Impacts of coal use on health." Annual review of public health 41 (2020): 397-415.

Hendryx, Michael, and Luo, Juhua. "An Examination of the Effects of Mountaintop Removal Coal Mining on Respiratory Symptoms and COPD Using Propensity Scores." *International Journal of Environmental Health Research* 25.3 (2015): 265-76. Web.

Hendryx, Michael, and Melissa M. Ahern. "Mortality in Appalachian coal mining regions: the value of statistical life lost." Public health reports 124.4 (2009): 541-550.

Kurth, Laura, et al. "Atmospheric particulate matter in proximity to mountaintop coal mines: sources and potential environmental and human health impacts." Environmental geochemistry and health 37.3 (2015): 529-544.

Menzel, Donald C. "Implementation of the federal surface mining control and reclamation act of 1977." Public Administration Review (1981): 212-219.

Monnat, Shannon M. "Factors associated with county-level differences in US drug-related mortality rates." American journal of preventive medicine 54.5 (2018): 611-619.

Salm, A K, and Benson, Michael J. "Increased Dementia Mortality in West Virginia Counties with Mountaintop Removal Mining?" *International Journal of Environmental Research and Public Health* 16.21 (2019): 4278. Web.