Intro

Decreasing air quality is a pressing issue for many large cities across the globe. In addition to irritating eyes, lungs, and throats of habitants, poor air quality can cause lasting conditions such as asthma and other respiratory and cardiovascular diseases. In the US alone poor air quality contributes to more than 100,000 premature deaths each year.

Salt Lake City is consistently among the worst cities in the world for air quality. This is in part due to its unique geographical location, as well as high wildfire risk. While topology cannot be changed, strict fire regulation can allow mitigation of airborne particulates into already polluted air. With airborne particulates being a rising concern across the nation, the federal government has made efforts to curb the use of pollution since the 1960s. Additionally, the State of Utah has made increasing efforts to protect its own air in recent years with State laws and ordinances specific to the mountain west.

The purpose of this paper is to analyze how Utah's state regulations in recent years have affected the air quality index (AQI) in the state. To do this, I will use a difference in difference model comparing Utah's AQI to surrounding states' over time. Utah State rule R307 (effective 1998) will serve as the treatment with surrounding states as the control. R307 expands on federal law by further regulating natural gas flaring, prescribed burning, factory emissions, and more. Data is collected from the United States Environmental Protection Agency (EPA) database. The publicly available datasets provide county level annual AQI data for each state. The 7 years prior to the bill's introduction (1990-1997) will compare the states before the regulation is put into action, and the 7 years after (1999-2006) will help determine the effect the bill has had post implementation.

Motivation

The Clean Air Act of 1963 is the first of such regulations and has been amended numerous times to combat the air quality pandemic in the United States. The act allows sweeping federal regulation on polluting practices with the goal of protecting the US from ozone degradation, dirty power production, acid rain, and more. As implied by its name, the Clean Air act focuses largely to combat decreasing air quality across the county. Air quality is measured by the United States Environmental Protection Agency (EPA) using the air quality index (AQI) standard. AQI measurements range from 0-500 and fall into the following categories as per the standard set by the EPA (***below***)

One of the original goals of the Act was to set National Ambient Air Quality

Standards (NAAQS) and achieve them by 1975 to combat the health and welfare risks associated with increases in airborne pollutants. In order to do this, national regulation directed the development of state initiatives called state implementation plans (SIPS). Standards for emissions and air quality are covered in section 112 of the Clean Air Act (last amended 1990). Due to broad requirements in section 112, there is great variation in air quality policy between states.

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

Historically, Utah has had among the worst air quality in the United States. In recent years, Salt Lake City's poor air has rivaled even dirtiest cities in China and India. The city averages over 25 poor air days a year compared to the EPA target of 3.2 or less. R307 was introduced in 1998 to combat increasing amounts of airborne particulates. This paper will analyze its effectiveness in doing so.

Empirical Design

In order to model the effect of the policy change in 1998, this paper will utilize a simple difference in difference regression. Difference In Difference uses data from two groups over multiple time periods to provide some level of causality without randomization on the individual level. The technique removes bias in post-treatment comparisons that is attributed to constant differences between groups over time. Additionally it removes biases over time in the treatment group that can be used with the assumption that both the treatment and control groups trend similarly over time.

The goal of the model is to measure the impact of the R307 policy change in 1998 and its effect on Utah's air quality compared to neighboring states. To do this we will divide the states in two groups with treatment status *Treat = 0,1* where 0 indicates the states other than Utah that did not receive the policy treatment and were unaffected by it. These states will be our control group. Utah will receive treat = 1 indicating it as the only state that did receive the policy treatment. Additionally, each observation is given a value of *Post* where

Post = 0 represents the time before 1998 and *Post* = 1 represents the time after. These will serve as our pre and post treatment periods. The coefficient on δ captures the added effect of an observation being both treated and in the second period giving the causal effect of the treatment on the outcome variable Yi (average AQI of a state). The error term εi captures unobserved bias in the model.

$$Yi = \alpha + \beta Ti + \gamma ti + \delta\,(Ti \cdot ti) + \varepsilon i$$

Given the assumption of common trends, means of median AQI for each group in each period must trend similarly over time if not for the treatment. Then, the difference in these trends can be attributed to the effect of the policy change alone.

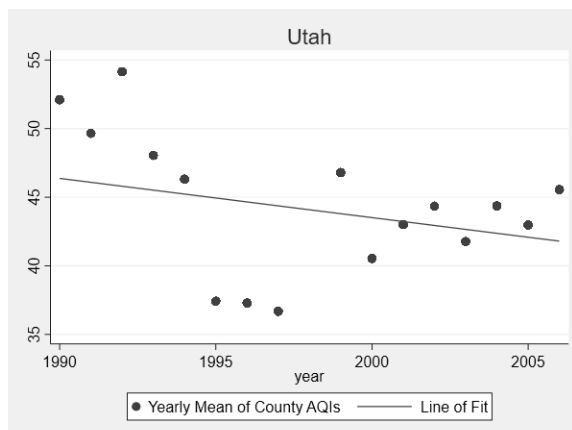
Data

With increasing air pollution being of high concern to both state and federal government, the EPA maintains testing stations across the country for the collection of air quality data. These data are available through API or direct download from the EPA website. The data used in this report are pre-generated annually by the EPA and contain daily observations on the county level. For the purposes of this model, observations are grouped by county and year, then the median is taken for each group. The county medians are then averaged across each state for each year. The resulting values are the means of the median county AQI in an annual panel set. These data will be used for analysis to represent the general AQI of each state in each year.

Results

Due to the common trends assumption taken in the difference in difference model, the data must first defend the claim that Utah and Surrounding states trend similarly over time. This allows viable comparison between the treatment and control groups strengthening the argument for causality.

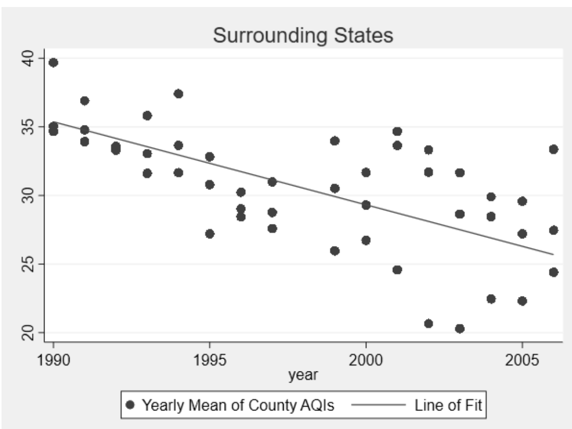
Utah State Means Plotted With Time



To do this, graphics are produced to illustrate similar trends in state AQI over the span of the study. First, for the state of Utah, (above) AQI values are larger than surrounding states generally, but sharply decline in 1995 due to potentially unobserved effects. This could be attributed to policy reform outside the scope of this study or natural effects such as weather patterns, natural wildfire rates, etc. A line of fit has been applied to visualize the trend over time. Utah's average AQI declines over the course of the study by seven over the observations of 15 years.

Similarly, AQI values declined during the observed period for the group of surrounding states (Montana, Idaho, Colorado, Wyoming). The second graphic (below) charts this decline and its line of fit decreases by 9 from 1990 to 2006. These similar trends allow the exchangeability assumption to be satisfied in the model.

Surrounding State Means Plotted With Time



With the assumption satisfied, the credibility of the model is strengthened. To analyze the causal effect of R307 on Utah's air quality, the outcome variable State Mean AQI is regressed on the dummy variables *treat, post,* and *treatXpost.* The table below illustrates the regression output.

The value of *constant* is interpreted as the average AQI of a state in neither the treatment group nor post period. The value of 32.89 is the average of AQIs for non-Utah (Montana, Idaho, Colorado, Wyoming) states in the *pre* period (1990-1997). The coefficient on *treat* is 11.25. This describes the additional effect of being in the treatment group on AQI. In the model, this means Utah has a higher average AQI of 11.25 compared to the other states as a group. The coefficient on *post* describes the additional effect of each group being in the *post* period. This means that the average AQI of groups in the years after 1998 is 5.054 less than the years prior. All of these coefficients are statistically significant at the five percent level. Finally, the coefficient on *Treatment & Post* gives the additional effect of being in both the *treat* and *post* groups. This applies only to Utah post 1998 and yields the causal effect of the R307 policy implementation. The value suggests that Utah's average AQI decreased after 1998 4.582 more than it would have had the policy not been enacted. The coefficient is statistically significant at the five percent level with confidence interval [4.49466, 4.669096]. The R squared value of the regression is 0.6825.

Summary of Difference in Difference Regression Model

VARIABLES	(1) State Mean AQI
Treat	11.25***
	(0.0333)
Post	-5.054***
	(0.0199)
Treatment & Post	-4.582***
	(0.0445)
Constant	32.89***
	(0.0153)
Observations	216,992
R-squared	0.683

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Conclusion

To analyze the effects of R307, we use the coefficient on *Treatment & Post* to claim that average AQI in Utah counties decreased by roughly due to the policy's introduction. The strength of this claim is contingent on the assumption that much of the unobserved bias is captured by the structure of the difference in difference model. Many biases such as population size and demographic are captured but some may remain unobserved. One fault with the model is the use of averages of median county observations. It is possible that bias could arise from the local attributes of different cities in states. There are likely pollution hotspots throughout each that taint the average of the state as a whole (such as Salt Lake City). Due to the limited scope of this analysis, these biases are likely omitted in the regression result.

With possible unobserved variable bias notwithstanding, Utah policy R307 has decreased the amount of airborne contaminants across the state by a significant amount. With this being a central goal to its implementation, the policy is by all accounts successful.