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Air Pollution's Effect on the Labor Force at the State Level

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Abstract

The health effects of air pollution are well established, ranging from increased rates of cancer to cardiovascular disease. Furthermore, a growing body of literature shows that air pollution has a tangible, negative impact on the labor force. However, in their efforts to avoid the endogeneity of air pollution and labor production, the current literature focuses on specific industries at a local level. The objective of this thesis is to expand this research to a state level by using naturally occurring weather events called air stagnations as a proxy for air pollution. These air stagnations correlate with increased levels of air pollution and because they are naturally occurring, they are exogenous to the labor force. This thesis finds that although there is a negative relationship between the air stagnations, which proxy for air pollution, and the growth of labor force productivity and output, the results are statistically insignificant at conventional levels.

Introduction

Since the industrial revolution, economies worldwide have emitted high levels of pollutants into Earth's biosphere. As a byproduct of industry, compounds ranging from carbon dioxide to ozone are released in mass quantities on a daily basis (National Association of Clean Air Agencies, 2017). As particulate pollution concentrations rise globally, organizations like the World Health Organization (WHO) have conducted in depth analyses regarding the impacts of pollution on human health. After decades of research, their conclusions are consistent and alarming. Health effects ranging from asthma to cardiovascular disease have all been correlated with air pollution (Ritchie and Roser, 2017). Furthermore, the World Health Organization concluded that outdoor air pollution is in fact a carcinogen to humans in 2013 (National Institute of Environmental Health Sciences, 2019). Given air pollution's clear negative effect on human health, its effect on the labor force ought to be studied. Impacts on the labor force have significant ramifications for the entire economy. Labor force productivity for instance, is an important factor in the improvement of living standards. According to the Bureau of Labor Statistics (2014), increases in productivity mean "[it] is possible for a greater quantity of goods and services to ultimately be consumed for a given amount of work" (vol. 3). In this thesis, I explore the effect of air pollution on the growth of United States labor productivity and output.

The challenge of identifying the causal impact of air pollution on the labor force is potential endogeneity. That is, because industrial production is a source of air pollution, a change in labor productivity or output may result in changes in air pollution. While it may be possible increased air pollution negatively the labor force, it may also be possible that labor force production increases air pollution as well. This endogeneity problem means that air pollution itself cannot be treated as an exogenous variable.

While the negative health effects of air pollution are well documented, only a handful of studies examine the effect of air pollution on the labor force. Furthermore, the existing literature primarily focuses on air pollution's effect on specific industries in specific locations. For example, Hanna and Oliva (2011) discuss the effect of a refinery closure in Mexico City on the labor supply of the surrounding neighborhoods, while Zivin and Neidell (2011) explore the effects of ozone on the labor force productivity of a select group of agricultural workers in California's Central Valley. Additional research on this subject follows a similar pattern. Chang, Zivin, Gross, and Neidell (2016a) focus on pear packers at a specific location in Northern California, as well as air pollution's effect on a single call center in China (2016b). He, Liu, and Salvo (2019) look at a geographically close group of industrial sites to analyze the effect of particulate pollution on blue collar workers. Archsmith, Heyes, Saberian (2015) study the effects of air pollution in major cities on the niche group of Major League Baseball umpires. Taken together, these studies suggest that higher exposure to air pollution adversely impacts the labor force. While these researchers have repeatedly found a negative relationship between air pollution and the labor force, there still exists a gap in the literature. The existing literature exclusively looks at the effects of air pollution at specific locations or industries and has not attempted to study the changes in the labor force beyond a local level.

In contrast to these studies, I focus on a broader geographic region, the lower 48 U.S. states. Rather than using a direct measure of air pollution, I use a proxy for air pollution that is exogenous, which addresses potential endogeneity concerns. My identification strategy is motivated by Kerr and Waugh (2018), who study a meteorological phenomenon known as an air stagnation and its relationship with air pollution. Based on the findings of their study, I use this atmospheric weather event as a proxy for air pollution exposure. Air stagnations occur in a manner that is independent to any anthropogenic forcing. When an air stagnation occurs, the affected region experiences a greater level of pollution than under normal, non-stagnation circumstances all else equal (General Multilingual Environmental Thesaurus, 2019). The National Oceanic and Atmospheric Administration (NOAA) provides data on such air stagnations for the lower 48 states. By using data on this anomalous weather condition, I can study the relationship between air pollution and labor force productivity in a broader setting than previous studies.

Using the NOAA data combined with data from the Bureau of Labor Statistics and the US Census Bureau, I run a series of model that explore how air pollution affects the nonfarm, private labor force in the United States. I find that although all of the coefficients that correspond to the air stagnation measure show a negative relationship between air stagnations and labor force productivity and output growth, they are not statistically significant. I therefore do not reject the null hypothesis that there is no relationship between air pollution and labor force productivity and output growth. It is possible that I failed to detect any statistically significant relationship because I was working with only 48 states and the sample size may have been too small. In addition, the magnitude of the correlation between air stagnations and air pollution at the national level may be have been too weak to detect a significant relationship.

Literature Review

While the previous literature attempts to address air pollution's effect on the labor force, these studies all run into the same ongoing challenge. Labor force productivity and output are directly related to the level of industrial activity, which is positively related to air pollution. In examining the relationship between the labor force productivity and air pollution, it is difficult to find a completely exogenous effect. In order to effectively study air pollution's independent effect on the labor force, previous literature gets around this issue in a variety of ways.

Some authors choose a certain industry at a specific location that has little contribution to the surrounding air quality. Because of this insignificant contribution to the air quality, these authors can assume the effect of air pollution on these industries is exogenous. Zivin and Neidell (2011) study agricultural workers in California's Central Valley and the effect that air pollution has on their labor supply and labor force productivity. In order to get around the issue of endogeneity, their study revolves around a single farm and its employees. While industry as whole likely has an effect on air pollution, it would be reasonable to conclude that this farm alone had no significant effect on air pollution. Looking at another industry involving physically demanding labor, Chang, Zivin, Gross, and Neidell (2016a) look at the relationship between particulate pollution and pear packers in Northern California. Similar to Nivin and Neidell (2011), this study uses a specific industry at a single location as a means of avoiding the endogeneity problem between industry and air pollution. A single group of pear packers do not reasonably have a serious impact on air pollution; thus, this study can use air pollution as an exogenous effect on their productivity. In their results, Zivin and Neidell

(2011) find that ozone levels—which fall well below the current air quality standard—have a significant negative impact on outdoor agriculture workers' ability to do their jobs. They also find that labor supply is actually very inelastic in the short run for these outdoor laborers. Since these workers arrive and leave their work as crews, it is unlikely that any one worker will take time off due to the effects of air pollution. This study shows how air pollution's effect on the labor force extends beyond output and productivity, affecting labor supply too. However, the results of this study mean that these effects on labor supply may not be as immediate as the changes to output and productivity. Chang, Zivin, Gross, and Neidell (2016a) in their study of indoor pear packers, find that fine particulate matter, which can penetrate indoors, has a significant negative effect on productivity. Since these workers work indoors unlike the agriculture workers, pollutants like ozone have little effect on their overall productivity.

Other literature shifts its focus to white collar workers. Because of air pollution's serious effect on human cardiovascular function (The Impacts of Climate Change on Human Health in the United States, 2016) it may impact physical labor more than non-physical labor. To study the possible differences in air pollution's damage to the labor force Chang, Zivin, Gross, and Neidell (2016b) analyze air pollution's effect on call center workers in Shanghai and Nantong, China. Archsmith, Heyes, Saberian (2017) look at air pollution's effect, specifically the concentration of carbon monoxide, on professional baseball umpires and their ability to correctly determine strikes versus balls. Both of these studies again use the same method of getting around the endogeneity problem between industry and air pollution. They focus on a group of workers small enough that their effect on total air pollution is reasonably negligible. Chang, Zivin, Gross, Neidell (2016b) find that higher levels of pollution decrease the number of phone calls that a worker makes in a single day. As the concentration of particulate pollution increases, each worker spends more time on break and thus less time making phone calls. In this study, white caller workers were shown to have negative responses to air pollution in a similar manner that blue collar workers do. Archsmith, Heyes, Saberian (2017) determine that a single part per million increase in 3-hour CO concentrations causes an 11.5% increase in the propensity of umpires to make incorrect calls. With this finding, these authors show how the effects of air pollution are not specific to industries involving monotonous tasks and can also affect professions that require skilled concentration.

While the study of a select group of workers in specific industries at specific locations is one method of overcoming the endogeneity obstacle, it does limit the extent to which results can be generalized to other settings. To expand the scope of air pollution's effect, other researchers use different techniques. Hanna and Oliva (2011) examine the effect of pollution on labor supply by exploiting the closure of a large refinery in Mexico City. Since the closure of the refinery was not the result of changes in the labor supply of the surrounding neighborhoods, these two authors could analyze an exogenous reduction in air pollution on a slightly larger scale. He, Liu, and Salvo (2019) study the effect of air pollution in China in a unique manner as well. They focus on blue collar, industrial workers at two specific textile industry locations. However, their study uses another method of ensuring the effects of air pollution are not endogenous to industry production. The study uses variability of factory air ventilation, which changed not as a result of the workers' labor, but as the result of an exogenous factor. Any change in the concentrations of air pollutants within the factory was due to an external forcing, so He, Liu, and Salvo could run an unbiased model.

Using their unique method of overcoming the endogeneity problem, Hanna and Oliva (2011) find that neighborhoods in the immediate vicinity saw a significant decrease in the concentration of SO_2. As a result, the workers in that neighborhood increased the amount of labor they were able to provide. Therefore, Hanna and Oliva find that air pollution has a negative impact on labor supply. He, Liu, and Salvo (2019) on the other hand, find no statistically significant response to concurrent air pollution levels. They do, however, find statistically significant adverse effects from more prolonged exposure to pollutants, but the effects are not large.

Rather than using any of the aforementioned methods of controlling for endogeneity, another paper uses a unique type of panel data to account for endogeneity when addressing air pollution's effect on labor supply in Lima, Peru. Instead of choosing a small subset of households on which to focus or using sudden or uncontrollable exogenous changes in air pollution, Aragon, Jose, and Oliva (2016) use panel data that controls for omitted variables and relies on within-household comparisons. The panel data includes week and municipality-by-year fixed effects to account for city-wide and local time-varying omitted variables. The panel data set includes household fixed effects that rule out bias through time-invariant omitted variables. Using this other means of controlling for endogeneity, Aragon, Jose, and Oliva (2016) show that moderate levels of pollutants reduce working hours for adults. Furthermore, they find that this loss in labor supply is partly due to the need for caregiving. As the concentration of particulate pollution goes up, adults reduce their working hours to care for sick dependents.

In the past decade, an increasing number of studies has shown that air pollution has a tangible effect on the labor force. This literature spans a variety of geographic regions and industries. However, current literature does not analyze air pollution on a larger scale. Most of the existing studies focuses on a single industry or a single geographic location. Without a broader understanding of air pollution's effect, environmental policy may not be able to adequately address national economic issues. Workers in the service industry may respond differently to air pollution than workers in the agriculture industry. Similarly, workers in the state of California may differ from workers in other parts of the US. To provide a more complete understanding of air pollution's effect on the American economy, I study the effect that air pollution has on labor force productivity using a state-level panel dataset. Instead of studying laborers in a single industry or at a specific location, my analysis covers workers across all the lower 48 US states who work in private, nonfarm industries. This study therefore provides more general information on the effects of air pollution on labor force productivity and output.

Because my model seeks to explain variation in these two attributes of the labor force, I rely on labor economists that have explored this topic. They find that controlling for educational attainment and income inequality is essential for an unbiased model. Siansi and Reneen (2003) detail the impact of education on economic development while Cingano (2014) studies the effect of income inequality. Sianis and Reneen, in a survey article that incorporates the findings of extensive empirical literature, summarize how increases in average education raise the level of output per capita. While the impact of increased educational attainment depends on the level of the country's development, the study finds that increases in the levels of tertiary education are most important for a country’s growth. As such, I control for educational attainment in my study by including a variable that has the percentage of individuals with college degrees. Cingano, in his study, looks at the 36 countries apart of the Organization for Economic Co-operation and Development (OECD) and finds evidence that income inequality has a negative and statistically significant impact on economic growth. Since the economy and labor force productivity and output are closely related (BLS, 2014), and income inequality has an effect on the economy, a variable that accounts for statewide income inequality is included in my model.

The use of air stagnations as a proxy for air pollution is also not a new concept in academic research. In their study of the boundary-layer air stagnation index (BSI) and its relationship with air pollution, Huang, Cai, Wang, Song, and Zhu (2018) determine that the BSI is positively correlated with the air pollution index during 2000-2012 in China. In essence, these authors have found that a measure for air stagnations can be used as a proxy for exposure to air pollution. These authors use a different type of air stagnation measure (the BSI) that differs from NOAA’s measurement (the air stagnations index or ASI), but they note that this is because of certain Chinese-specific meteorological conditions that make the US air stagnation index inadequate for China. Kerr and Waugh (2018) provide their own insight into the correlation between air stagnations and pollution, finding that there is only a weak positive correlation for much of the US. However, their findings do explain that this relationship is both positive, statistically significant, and strongest in the southern US. While the correlation between air stagnations and air pollution events may be weak, the literature finds that there is a positive correlation between the two. My study relies on this positive correlation in an effort to overcome the air pollution endogeneity problem, but the weakness of the correlation may limit my findings.

Data

I construct a state-by-year panel dataset that covers 48 states over the period 2008 to 2017. Key variables in my analysis, labor productivity and the proxy for air pollution, come from two data sources, the Bureau of Labor Statistics (BLS) and the National Oceanic and Atmospheric Administration (NOAA), respectfully, while control variables come from the US Census Bureau.

The first data set used for the analysis is the Bureau of Labor Statistics Private Nonfarm Productivity and Costs by state and region. This data set is ideal for my purposes because it has detailed information on labor force productivity and output per employee from all 50 US states from 2007 to 2017. However, I will only use the data on the growth of productivity and output which does not begin until 2008.[1] This date then, represents the earliest time in which I can have complete panel data, so I restrict all other data sources to the years 2008-2017.

The first measure, labor productivity growth, is simply the growth of the amount of goods and services that can be produced relative to the number of hours of labor employed. In Map 1, I show the average growth rate of labor force productivity for the lower 48 US states for the years 2008-2017. The second variable, output per employee, measures the amount of goods and services a person engaged in a particular occupation can produce over an interval of time, regardless of the actual number of hours worked (Map 2). As a result, changes in the hours at labor will alter this variable, in addition to any change in productivity. Rather than simply providing information on labor force productivity, this variable provides information regarding labor supply as well. Even

[1] The data regarding labor force productivity and output per employee is represented both in levels and in growth rate. The Bureau of Labor Statistics normalized the data in levels such that 2012=100 for all states. Since this means there is no variability between states, I cannot perform an analysis. However, the growth rates of both these variables do vary by state so I can include them in my panel data.

without a change in hourly productivity, a change in the number of hours worked per week would alter this variable. The first variable on the other hand will only account for changes in productivity.

The second data set comes from the National Oceanic and Atmospheric Administration (NOAA) which measures monthly air stagnation in the lower 48 US states for each 0.25-degree by 0.25-degree longitude and latitude grid point. Air stagnations are a naturally weather occurring phenomenon in which the surface layer of air is trapped over an area for a significant length of time. Typically, this layer of air escapes and any particulates suspended within are dispersed to the upper atmosphere. However, in the event of an air stagnation, the particulates remain at the location for a substantially greater amount of time. As a result, individuals present at that location are exposed to an increased concentration of pollutants. Because of this relationship, the number of air stagnations in a state can be used as an exogenous proxy for air pollution. Air stagnations occur naturally and without human cause, but they affect levels of particulate pollution. NOAA collects its data by counting the number of times per month an air stagnation occurs at each grid point. Because the BLS data set is presented for each state by year, the NOAA data needs to be displayed in a different manner.

I grouped each monthly data table by year, and then I collapsed the data by grid point, so that each new table consists of grid points in one column and the number of times that the grid point experienced an air stagnation per year in another column. Each point was then attributed to its corresponding state using Geographic Information System (GIS) software (Earth Point Inc, 2019). This software inputs a batch of coordinates and returns a spreadsheet with those same coordinates along with the states that each point can be found in. Once the points are properly attributed to their respective states, they were collapsed by state in four different ways. In its final form, the data has measures for the maximum, minimum, average, and the growth of the average number of days of stagnation for each of the lower 48 states for the years 2008-2017.

The first three metrics refer to the number of times that any one point within a state experiences an air stagnation within a given year. The final metric, the growth rate of stagnations is the percent change in growth of the average days of stagnation variable. There are 5 missing states in the NOAA data set for the year 2008: Delaware, Iowa, New York, West Virginia, and Wisconsin. These states do not have information from 2007 regarding stagnation, so their growth rate of stagnations variable cannot be calculated for the year 2008. This means that my panel is unbalanced. The averages of these four variables, found in Table 1, refer to the average of all the four variables between all of the states across the entire time period. Map 3 shows the mean average days of stagnation for the time period for the lower 48 states over the same time period.[2]

The US Census Bureau provides the final two variables, educational attainment and wage inequality. Exclusion of these important controls could lead to omitted variable bias in my estimates. The first panel of data, regarding educational attainment, includes information for all individuals living in the lower 48 US states. In this panel, the US Census Bureau reports the number and the percent of individuals who have reached certain standards of educational attainment (e.g. high school diploma, college degree). Furthermore, the Census Bureau also reported the educational attainment of a series of age-specific categories. For instance, one category included individuals ages 25-34,

[2] The air stagnation index supplied by the National Oceanic and Atmospheric Administration provides air stagnation data from primarily the lower 48 states of the US, but also some additional locations. These locations: Mexico, Canada, and US territorial waters were removed from the data panel. Furthermore, data points collected on the borders of states, were removed to prevent double counting.

another included just individuals age 18-24. I restricted the data set to include only the category of individuals age 25 and older, in order to allow individuals adequate time to progress through their education, but not to otherwise restrict the data. While the data table provided data for men and women separately, I restricted the sample such that sex was not incorporated into the educational attainment variable. There exists only a small difference between men's and women's educational attainment, so I treated all individuals the same. Furthermore, even though the educational attainment variable has data on the number of individuals who reached an educational attainment threshold, I chose instead to use the percent of individuals who reached that threshold, in order to prevent the data from being skewed toward states with higher populations. In Table 1, I show educational attainment of all states grouped together. So, while the variation and averages of the states from the time period 2008-2017 is shown, the individual states are not.

The US Census Bureau also provides Gini Index estimations in the US. This variable estimates the income inequality across the lower 48 US States from the years 2008-2017. The index value represents the level to which the distribution of a state's income deviates from a perfectly equal distribution. A value of 0 would mean perfectly equal distribution, while a value of 100 would indicate perfect inequality (OECD, 2002).

When looking at the summary statistics in Table 1, I can observe several notable parts of the data. The stagnation data varies least when looking at the minimum days of stagnation and most when looking at maximum days of stagnation, meaning that while most states experience a relatively similar minimum number of stagnation days, the maximum number of days varies more substantially by state. The education variable is notable as well. Only around 28% of the US population ever received a bachelor's degree during the time period of my analysis. Not only is the value quite low, it varies considerably between states. The standard deviation of roughly 5 percentage points, combined with the fact that concurrent literature considers college graduation rates to be the most important indicator for a country's growth, reinforces the fact that this data is ideal for my purposes.

The Gini Index which details income inequality does not vary too much over the lower 48 US States. The lowest value is found in 2010 in Utah, one of the most evenly distributed states, while the greatest value was found in 2017 in New York, consistently one of the most unequally income distributed states.

Maps 1, 2, and 3 respectively show labor force productivity growth, output per employee growth, and average days of stagnation by state for the years 2008-2017. Comparison of the maps shows relatively little nationwide correlation between air stagnations and labor force or output per employee growth. However, there does appear to be some correlation between the lack of stagnations in the northern US and higher growth rates there. Furthermore, a high number of air stagnations in the American South correlates with comparatively low or even negative labor force productivity and output per employee growth in that region. These correlations could suggest that air stagnations negatively affect the two labor market outcomes, at least in those regions. Interestingly, the second correlation aligns with Kerr and Waugh (2018) who show that air stagnations most strongly correspond with air pollution in the American South. The two labor outcome maps (1 and 2), as expected, are very correlated as they are both similar measures of the labor force during the same time period (2008-2017).

Graphs 1 and 2 respectively show the average growth rates of labor productivity and output per employee across the entire continental Unites States. Observation of the two graphs also indicates a correlation between the measurements of labor productivity and output per employee growth. The first years of the model have perhaps the least correlation in Graph 1, which compares labor productivity growth and the growth rate of stagnations. This inconsistency roughly corresponds with the years of the Great Recession (2007-2009). Graph 2 and the remaining years of Graph 1 however, show a correlation between both outcome measures and the growth rate of stagnations. The growth rate of stagnations varies more so than either labor outcome, but the trends in all three measurements appear to correspond with one another. Prior to running any of my models, casual empiricism suggests that there is a relationship between these two labor growth outcomes and the growth rate of air stagnations.

Empirical Strategy

In order to examine the effects of air stagnations on labor productivity, I estimate a model of the following form:

$$(1) \qquad Y_{st} = \alpha + \beta AS_{st} + \delta X_{st} + \eta_t + \gamma_s + \varepsilon_{st}$$

where Y_{st} is a measure of productivity growth, in which growth is measured with the computation $Y_{st} = (G_{st} – G_{s(t-1)})/(G_{s(t-1)})$ where (G_{st}) is the measure of productivity at time (t) and the subscript (s) represents each state in my model. AS is my measure of air stagnation, X is the vector of observable characteristics (education and income inequality), η_t represents year fixed effects, γ_s is state fixed effects, and ε is the error term with the usual properties. I run a variety of specifications. The two BLS variables, labor productivity growth and output per employee growth, are used as alternate measures of labor production growth. I run four regressions for both dependent variables in my model. Each of the two dependent variables is regressed on four measures of air stagnation: the average, minimum, and maximum days of stagnation in a state per year, and the annual growth of the average days of stagnation. Finally, the two control variables encompassed by the vector of observable characteristics remain in my model regardless of the specification, and they are represented by the percentage of college graduates in each state and the estimated Gini index in each state.

Results

After running the model, all eight of the air stagnation variables that serve as proxies for air pollution have an inverse relationship with both measures of productivity growth. However, no explanatory variables are statistically significant. The yearly fixed effects found in my regression are the only independent variables that had statistically significant t-statistics and after running this regression. Despite the consistent inverse relationships, I cannot reject the null hypothesis that the four of the measurements of air stagnation, as a proxy measurement for air pollution, do not have an effect on the labor force productivity growth. That being said, it is notable the estimated coefficients are consistently negative across the models.

The first set of four regressions in Table 2, the ones that deal with the labor productivity growth outcome, are the closest to statistical significance. Despite having p-values greater than 0.1, the coefficient for the average stagnation variable does have an inverse relationship with labor productivity growth. The coefficient suggests that for every average additional day of stagnation, that year's productivity growth decreases by roughly 0.02 percentage points, a 2% decrease in growth from the average annual productivity growth rate. The minimum stagnation variable, which deals with the minimum number of days of stagnation per state, is the most significant out of all the specifications of my model, with a p-value of 0.155. Its coefficient shows that for every one unit increase in the minimum number of stagnation days, a state's productivity growth for that year decreases by roughly 0.023 percentage points, which equates to a 2.3% decrease. The maximum stagnation variable on the other hand, shows that for every increase in the maximum stagnation days of annual stagnation, that drop-in productivity growth is around 0.017 percentage points, a 1.7% decrease from the mean growth rate. Finally, the growth rate of stagnations coefficient, that deals with the growth of the average stagnation index from the previous year, also shows an inverse relationship between this independent variable and productivity growth. For every percent increase in the average growth rate of stagnations, there is around a 0.0078 percentage point decrease in the productivity growth, which equals a 0.8% decrease from the mean growth rate. Once again though, these coefficients are statistically insignificant at conventional levels. The two control variables are statistically insignificant as well in this regression; however, they were not as close to significance as the four explanatory variables. Both control variables do have positive coefficients for all specifications of the model, indicating that increases in college graduation rates and income inequality are correlated with increased productivity and output per employee growth. However, these relationships are statistically insignificant. The college graduation rate coefficients are consistent with the literature in regard to its effect on the labor force. As higher percentage of individuals graduate college, the greater the productivity and output of the labor force. The income inequality coefficients are not consistent with the literature on the other hand. I expected a negative relationship between the Gini Estimate and the two labor force outcomes instead of a positive one. This may be due to the fact that the current literature finds a significant negative effect primarily on long run economic growth. My study only looks at the time period 2008-2017 and such a relationship might not be able to be seen on such a short time span.

Moving on to the second set of four regressions that deal with the output per employee growth outcome (Table 3), the variables in my regression continue their inverse relationship with the labor growth outcome, despite their statistical insignificance. The average, minimum, maximum, and stagnation growth coefficients are negative for each specification of the model, however their absolute value is smaller than the first four regression specifications in Table 1. The average stagnation coefficient indicates that for every increase in in average annual stagnation days, the growth of output per employee decreases by roughly 0.0006 percentage points, or a 0.07% decrease from the mean output per employee growth rate. The minimum and maximum coefficients indicate that increases in their respective days of stagnation decrease that state's output per employee growth by 0.0024 percentage points (0.29% decrease) and 0.0046 percentage points (0.55% decrease) respectively. The coefficient for the growth of the air stagnation index variable indicates that for every increase in percent stagnation growth, productivity growth decreases by 0.0078 percentage points, or a 0.94% decrease from the mean output per employee growth rate. The two control variable coefficients are also not significant, but they are once again farther from significance than any of the four explanatory variables. However, the coefficient magnitudes of the second labor growth outcome are so small that even if I did detect any statistical significance, my results would not be economically significant.

The yearly fixed effects are the only part of this model that have any statistical significance. The R_2 values show that my model explains between 23.9 percent and 24.9 percent of the variation in labor productivity growth and between 26.0 percent and 27.25 percent of the variation in variation in output per employee growth. However, none of the variation is significantly explained by my measurements of air stagnation, even though their coefficients are notable. The F-statistics of all eight of my specifications on other hand, are all statistically significant at the 0.01 level. Therefore, I can reject the null hypothesis that the joint effect of all the variables of my model are zero. However, each overall specification may be significant not because of the air stagnations and control variables, but because of the yearly fixed effects which were the only parts of the model that had statistical significance on their own.

Conclusion

Modern economic growth has always had an impact on the environment and the United States is no exception. Prior to European settlement in 1630, the US Department of Agriculture estimates that there was 423 million hectares of forest land in the US. That area fell to around 307 million hectares by 1907 and has remained somewhat stable since then (Forest Inventory and Analysis National Program, 2019). As the world transitioned to an industrial economy in the late 19th century, the emission of air pollutants has risen steeply, with the largest increases coming after 1945 (World Resources Institute, 2013). As the concentration of pollutants continues to increase, several health studies have shown negative health outcomes as a result of these rising levels. Organizations like the WHO have shown that air pollution has a tangible, negative effect on human health. Some of the resulting issues, like cardiovascular disease and asthma, can have impacts on the labor force's ability to work. The less healthy a workforce, the less that workforce can produce. Economic researchers confirm this reality in their studies that show that air pollutants have a statistically significant negative effect on the labor force.

However, this research is hamstrung by industry's relationship with air pollution. Not only does air pollution affect industry, but industry itself causes air pollution. In order to get around this endogeneity problem, researchers have found ways of using exogenous pollution effect that do not originate from the laborers themselves. For some authors, this means focusing on a group small enough that their effect on air pollution is negligible. A single team of farm workers will not produce enough pollution in their activities to have a serious impact on the air they breathe on a daily basis. Other authors find unique ways of creating exogenous variation. Manufacturing centers may alter the ventilation in their factories and as a result, the concentration of air pollutants may change unrelated to the factory workers' production. Neighborhoods near a factory may also experience an exogenous drop in air pollution when that factory closes. In each of these specific cases, the researchers find that exogenous changes in air pollution have statistically significant negative effects on the labor force. In the case of either labor supply or labor force production, air pollution has a negative effect.

Unfortunately, the way in which previous literature has used exogenous variation to study the effects of air pollution has prevented analysts from expanding the scope of their studies. The current research is limited to specific locations or specific industries in which an exogenous local change in air pollution has an effect on the labor force. This method of getting around the endogeneity problem does not allow for a more general study on the effects of air pollution. Nowhere in the current literature is there a study on the effects of air pollution on the nationwide or statewide labor force. Fortunately, other literature has established a correlation between air stagnations and air pollution. These naturally occurring weather events trap pollutants closer to the Earth's surface and result in exogenous increases in air pollution. Furthermore, these air stagnations are not localized to a single region and are found across the United States. Since other literature has established that nationwide exogenous air stagnations are correlated with increases in air pollution, I can use data on annual air stagnations from the National Oceanic and Atmospheric Administration as a proxy for nationwide air pollution.

After running a series of regressions that use this exogenous proxy for air pollution, and while controlling for state and year fixed effects, educational attainment, and income inequality, I find no statistically significant effects of air stagnations on the labor force. Whether the outcome is that year's labor force productivity growth (which only looks at the growth of hourly productivity) or that year's output per employee growth (which also incorporates changes in the number of hours worked), none of the four air stagnation measurements have p-values less than 0.1. This may be because of the inherent weakness of the relationship between air stagnations and air pollution. While previous research has established the correlation between air pollution and air stagnations, the link may be rather weak. The study done by Kerr and Waugh (2018) demonstrates how air stagnations in the US can be correlated with air pollution, but the magnitude of this effect is small for much of the country, with the exception of the South. The entire foundation of my study depends on the positive correlation between these two measurements. If the magnitude of their relationship is weak, then my study will have a hard time finding statistically significant coefficients amongst the eight explanatory air stagnation variables. In addition, I am using state-level data for in my research, meaning I am masking a lot of important local-level variation in my models. The 48 states I use are not homogenous within their borders and this may lead to a weakness in my study.

It should be noted however, that the two coefficients that measured the minimum number of days of annual stagnation per state were the most significant, coming very close to statistical significance. Furthermore, all four variables have negative coefficients for both labor outcomes, indicating an inverse relationship between air stagnations and labor force productivity or output growth. Even though these coefficients are not significant at conventional levels, I can still use their values to study the relationship between air pollution and the labor force.

The Great Recession that began in 2007 was also undoubtedly a significant influence my study. The years from which I pull my data, 2007-2017 (the growth rates in 2008 depend on 2007), were a tumultuous period for the American labor force. The global recession and its slow subsequent recovery meant that the many of the changes in the US labor force were likely due to non-environmental economic factors (Rich, 2013). Business cycles are a strong influence on the labor force. So strong are these cycles that the effect of air stagnations may be drowned out, particularly if the magnitude of the relationship with air pollution is small. As I would expect if this confound is the case, the yearly fixed effects (which deal with these business cycles), are significant in my model in addition to the significant state fixed effects. Therefore, having a set of statistically insignificant air stagnation variables is not unintuitive. Since current literature describes the relationship between air stagnations and air pollution as significant but weak, my method of overcoming the endogeneity problem may not be enough to capture statistical significance. Economic downturn could lead to a decrease in labor force growth outcomes despite a decrease in air pollution. Similarly, economic recovery could lead to an increase in labor force growth outcomes despite an increase in air pollution. Because of these business cycles, analysis of the air pollution's effect on the labor force is challenging in this time period. Serious economic recession or recovery may outweigh any effect that air pollution has on the labor force.

Moving toward policy implications, this study alone does not warrant a massive change in policy. The results are inconclusive, but they do show some negative relationship between a proxy for air pollution and labor force growth outcomes. Given the previous literature finding statistically significant evidence that air pollution negatively affects individual industries, the results of my study could point to a negative relationship between air pollution and labor force productivity and output growth at the state level. As a result, this issue of air pollution should not be confined to a national public health problem but also a national economic one. Negative effects on the countrywide labor force could mean damage to the American economy if rising air pollutants are not addressed. Should there be any such damage, the global competitiveness of the United States may suffer. Even though my study does not provide conclusive results, it could point to a looming problem for the country.

Further research on this topic could use a different means of proxying for air pollution. For example, researchers in China who study the relationship with air stagnations and air pollution use a different measure of air stagnations. Certain atmospheric conditions in China make the relationship between the US measure for air stagnations and air pollution statistically insignificant, so they adjust and use a new measure. This same practice could be applied to the US. Rather than only sticking to the NOAA definition of an air stagnation, future research could use a different metric for collecting stagnation data. Other literature suggested that air stagnations and air pollution are more closely correlated during specific seasons. Unfortunately, the Bureau of Labor Statistics does not supply seasonal labor force data at the state level so studying the effects of air stagnations in a specific season were impossible for my study, but if that data were available it could lead to more significant results. Furthermore, the BLS only provided productivity and output data for private, nonfarm industries. Any additional research could shed more light on the effects of air pollution at the state level by incorporating data from outside this subset of the labor force. Finally, this research can be altered to look at different regions. My study looks at the lower 48 US states, but the exact same method of analysis could be used to look at more specific areas within the US or even beyond its borders. So long as there is adequate data available, these models may yield statistically significant coefficients.

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Appendix

Table 1. Descriptive Statistics

Variable	Variable Definition	Mean (Std. Deviation)
Average Stagnation	The average number of days per year that a point within a state experiences an air stagnation	50.55 (20.54)
Minimum Stagnation	The minimum number of days per year that a point within a state experiences an air stagnation	30.38 (14.27)
Maximum Stagnation	The maximum number of days per year that a point within a state experiences an air stagnation	72.60 (32.07)
Growth Rate of Stagnations	The percent annual growth of the average number of days of stagnation	1.47 (23.34)
College Graduates	The percentage of individuals (ages 25 and up) within a state that have graduated college	27.98 (5.02)
Gini Estimate	The measurement of income inequality of a state (100=perfect inequality, 0=perfect equality)	0.46 (0.019)
Productivity Growth	The percent annual growth of labor force productivity	0.98 (2.42)
Output Growth	The percent annual growth of output per worker	0.83 (2.33)

Table 2. Productivity Outcome

Variables	(1) Productivity Growth	(2) Productivity Growth	(3) Productivity Growth	(4) Productivity Growth
Average Stagnation	-0.0189	-	-	-
	(0.0190)			
Minimum Stagnation	-	-0.0232	-	-
		(0.0160)		
Maximum Stagnation	-	-	-.0165	-
			(0.0160)	
Growth Rate of Stagnations	-	-		-0.00771
				(0.00567)
College Graduates	0.210	0.212	0.210	0.444
	(0.580)	(0.573)	(0.580)	(0.537)
Gini Estimate	7.708	7.957	7.415	0.826
	(11.75)	(11.86)	(11.94)	(16.74)
Observations	480	480	480	475
Number of states	48	48	48	48
R-squared	0.239	0.240	0.240	0.249

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

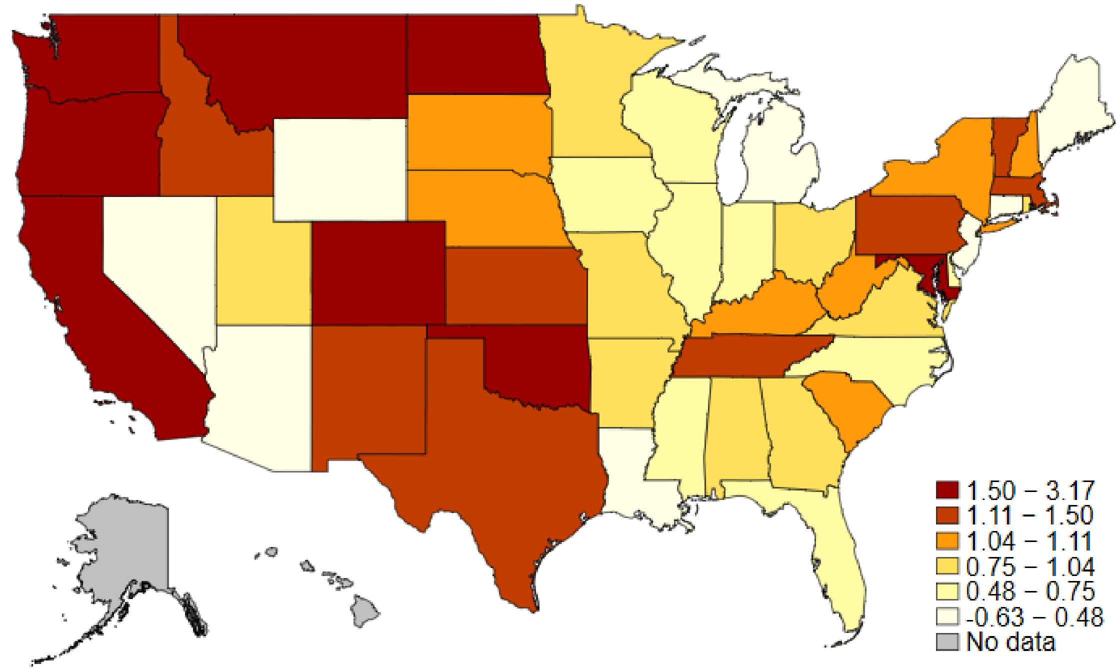
Table 3. Output Per Employee Outcome

Variables	(1) Output/Employee Growth	(2) Output/Employee Growth	(3) Output/Employee Growth	(4) Output/Employee Growth
Average Stagnation	-0.000605	-	-	-
	(0.0140)			
Minimum Stagnation	-	-0.00239	-	-
		(0.0124)		
Maximum Stagnation	-	-	-0.00461	
			(0.0127)	-
Growth Rate of Stagnations	-	-	-	-0.00737
				(0.00495)
College Graduates	0.602	0.602	0.599	0.809
	(0.598)	(0.596)	(0.599)	(0.555)
Gini Estimate	10.62	10.72	10.78	5.73
	(14.44)	(14.58)	(14.57)	(19.65)
Observations	480	480	480	475
Number of states	48	48	48	48
R-squared	0.260	0.260	0.260	0.272

Robust standard errors in parentheses

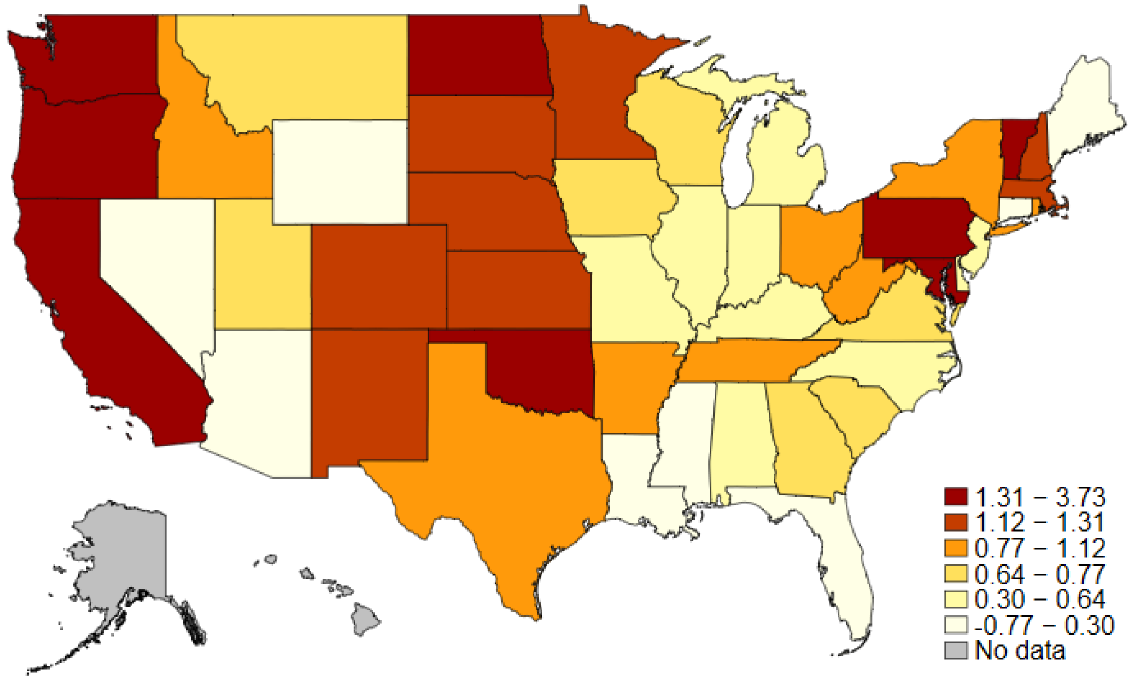
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Map 1. Labor Force Productivity Growth (2008-2017)



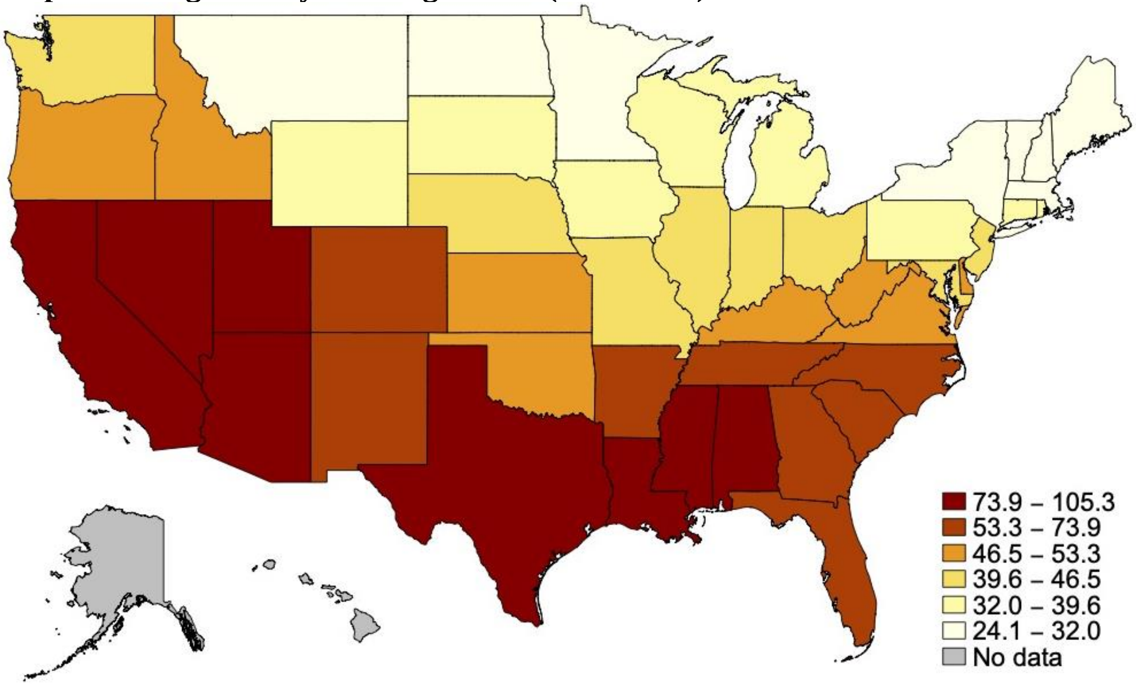
Notes: The different shading depicts different quantiles of the average labor force productivity growth across the lower 48 US states for the period 2008-2017.

Map 2. Output Growth Per Employee (2008-2017)



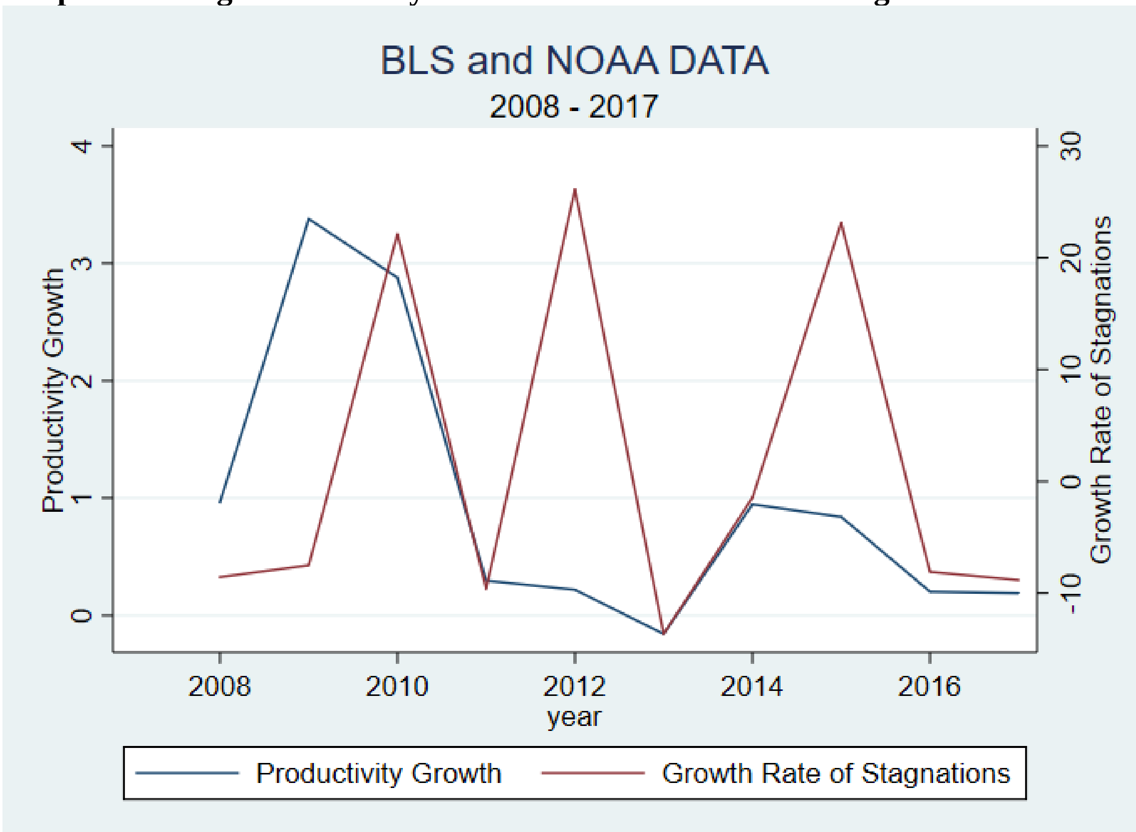
Notes: The different shading depicts different quantiles of the average output per employee growth across the lower 48 US states for the period 2008-2017.

Map 3. Average Yearly Air Stagnations (2008-2017)



Notes: The different shading depicts different quantiles of the average yearly air stagnations across the lower 48 US states for the period 2008-2017.

Graph 1. Average Productivity Growth and Growth Rate of Stagnations



Graph 2. Average Output Growth and Growth Rate of Stagnations