Fresh Air for Indiana Mothers: The Hidden Economic Benefit of Closing Coal-Fired Power Plants

Introduction

For decades, the state of Indiana has been synonymous with the coal industry. In 2022, the state consumed over 32 million tons of coal, with most of it being used for electric power generation.[1] Indiana trails only Texas and Missouri for tons of coal utilized annually and operates 34 coal-fired power plants, the most out of any state in the United States. The Environmental Information Agency lists several well-known emission risks of coal power plants: sulfur dioxide (contributes to acid rain and respiratory illnesses), nitrogen oxides (contribute to smog and respiratory illnesses), carbon dioxide (the primary greenhouse gas produced from burning fossil fuels), and mercury (linked to neurological and developmental damages). As these risks have become better publicized and understood, more stakeholders are pushing to shut down existing coal power plants.

Despite being one of the last holdouts for the coal industry, the state of Indiana plans to shut down 20 coal-fired power plants in the next 12 years, with all major utilities planning to be coal-free by 2035. Twenty-nine plants already closed in the previous decade, cutting a significant portion of NOx, SO2, and CO2. Given the risks associated with coal combustion, I quantify the localized health benefits of closing coal-burning plants to help policy-makers make informed decisions when considering mandated plant closure.

Research Question: What is the localized impact on infant mortality rate after the closure of a coal power plant?

I use government information about coal plant closure to track which counties have had plants closed along with the date, focusing on the time range of 2013-2020. I then study the

[1] U.S. EIA, Coal Data Browser, Total Consumption (Short tons), All states, Electric power (total), Commercial and institutional, Coke plants, Other industrial, Annual, 2022.

localized health outcomes for the counties that had plants close, focusing on infant mortality. I conduct a difference in differences analysis where the treatment group consists of counties where power plants were closed and the control group consists of counties where the plants remained open. This indicates the differential change in health outcomes between the treatment and control groups after the closure. I find that closing coal-fired power plants in the treated areas is associated with a marginally significant reduction in infant mortality.

While the DiD analysis offers valuable insights into the localized impacts of closing coal-fired power plants in Indiana, it's crucial to understand the limitations. This method relies on the assumption of well-defined cutoff points and treatment assignments. The pollution of coal power plants rises into the sky in smokestacks that blow into other nearby counties, having a spillover effect on counties other than the local one. Furthermore, changes in health outcomes may not appear immediately after the closure, with many effects of pollution exposure taking years of exposure to manifest. Although I focus primarily on infant mortality, the results should be interpreted cautiously considering these methodological constraints.

My analysis contributes to the field by studying a region, in which little current literature analyzes the change in health outcomes. I hope this information can be useful to policymakers in Indiana who historically have been hesitant to implement policy that encourages the closure of coal-fired power plants.

Sections 1-6, respectively, present the literature review, overview of Indiana's coal power plants and environmental policy, data description, empirical strategy, results, and conclusion.

Literature Review

A first area of related literature is on the localized impact of particulate matter and coal power plant closure on infant and childhood outcomes. Casey JA (2018) used public birth records and US EIA emissions data from 2001-2011 to evaluate the relationship between retirements of 8 coal plants and nearby preterm (gestational age of <37 weeks) birth. The difference-in-difference analyses found a 5.1-7.0% reduction in preterm birth within 5km, controlling for secular trends with mothers living 10-20 km away. In a similar analysis, Komisarow and Pakhtigian (2021) found that asthma related conditions among 0 to 4 year-olds decreased by 12% in zip codes near 3 coal-fired power plants in Chicago following their closures between 2009 and 2017. They used data on zip-code level rates of emergency department visits along with PM2.5 concentration. Komisarow and Pakhtigian (2022) continued their study of coal power plant closure and found that closures resulted in a 6% decline in absenteeism in nearby schools relative to those farther away from the power plants. This translates to .66 fewer absences per student. Treated groups were located within 10km of at least one of three plants, and all other Chicago schools were designated as controls.

Another field of literature is related to studying how wind-carried pollution impacts communities farther away from the closed coal-fired power plants. Yang (2018) studied the upwind effects of a shutdown of a power plant in New Jersey, finding that the shutdown reduced the likelihood of having low birthweight by 15%. They also found that preterm birth declined by 28%. On a similar note, Levy (2009) offers caution when studying such spillover effects of coal power plant emissions. In their study, Levy modeled the monetized damages associated with 407 coal-fired power plants in the U.S., focusing on premature mortality from PM2.5. This study found it difficult to accurately model how wind carries pollution through the atmosphere. Using the value of statistical life approach, they found that damages ranged from \$30,000 to \$500,000 per ton of PM2.5, \$500 to \$15,000 per ton of SO_2, and \$500 to \$15000 per ton of NO_x. With such variability in the results, the authors suggested future studies be cautious when studying the downwind effects, stating that it is difficult to estimate the emissions and impact of coal plants.

The final area of literature is on the general localized health and economic consequences of coal plants. Brown (2020) used spatial panel data from air quality monitor stations and coal-fired power plants to estimate the relationship between plant closure and local air quality. They found that the average levels of particulate matter within 25 and 50 mile buffers around air quality monitors declined between 7 to 14% with each closure. They also estimate that closure events are associated with a 0.6% decline in local mortality probability. On the more extreme side, Akshaya (2018) estimates that 10% increase in coal stockpiles held by power plants results in a 0.1% increase in average PM2.5 within 25 miles of the plants, with no significant increase found in other pollutants such as SO_2 and NO_2. Using coal stockpiles as an instrument, they show that a 10% increase in PM2.5 causes a 1.1% increase in adult mortality and a 3.2% increase in infant mortality.

My approach most closely follows Casey (2018), however I will be focusing on a different region (Indiana) than their study did (California). Their study also primarily focuses on birth effects and preterm birth. I expand this to include infant mortality so I can estimate the statistical value of life benefit from power plant closure. Overall, my analysis will add to the literature by studying a region, in which little current literature analyzes the change in health outcomes and economic benefit when closing coal power plants.

Background and Policy Overview

For decades, coal has played a vital role in Indiana's economy. The state is the nation's eighth largest producer of coal, yielding around 20 million tons of coal per year.[2] The vast prevalence of mines combined with the historically thriving industrial sector created immense demand for coal combustion, as this was the cheapest, most-reliable option. In the past decades, Indiana has been slow to shift its electricity generation infrastructure to cleaner fossil fuels and renewables. Although the state has shut down 20 plants in the past 12 years, Indiana still remains the nation's third largest consumer of coal.

State policymakers have generally accepted that coal is no longer in the future for Indiana, but they still debate how quickly Indiana should transition away from coal. Senate Bill 9, authored by Republican Sens. Jean Lesing, Oldenburg, LaGrange, and Glick, would require utilities to provide six months of notice to the Indiana Utility Regulatory Commission (IURC), when planning to sell, transfer, or retire an electricity generating facility. Energy activists argue against the bill, stating that such measures could slow down Indiana's transition to cleaner energy. The authors of the bill, however, maintain that these regulations will maintain the reliability of the electrical grid while making sure Indiana does not become too reliant on natural gas.

With stricter regulations, utilities planning on retiring a power plant earlier than previously planned would be required to notify the IURC, which has the power to approve or deny the closure. When denied, utilities cannot submit a new request for 180 days. The goal of Senate Bill 9 is to regulate early closures, so that coal-fired power plants are used until the very end of their life cycle.

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[2] U.S. EIA, Annual Coal Report 2021 (October 2022), Table 6, Coal Production and Number of Mines by State and Coal Rank, 2021.

Environmentalists are still concerned about increasing the barriers to early retirement, but they have found few friends in the Indiana Legislature. House Bill 1190 and Senate Bill 399 attempted to set goals and requirements around cleaning up coal ash in the floodplains of rivers and lakes. Both bills died in committee sessions earlier in 2023. Instead, house lawmakers passed House Bill 1623, which would restrict the Indiana Department of Environmental Management from implementing requirements that are stricter than national regulation. Overall, Indiana politicians have tended to favor decisions that minimize environmental regulation, while also making it more difficult for coal-fired power plants to close early. With many plants scheduled to close over the next decade, the IURC will have to weigh the costs and benefits of early retirement if a coal-fired power plant submits a request to close early. To help make more informed decisions regarding earlier retirement, I quantify some of the economic externalities of early retirement through the statistical value of life.

Data Description

The key data in my analysis is from County Health Rankings, which is a database from the University of Wisconsin Population Health Institute. This dataset tracks key indicators of health and wellbeing at the county level starting in 2010 for Indiana. I will be focusing on the data from 2014-2020. I started in 2014 because this includes the most comprehensive indicators that I would like to track. I am tracking low birth weight percentage, infant mortality rate, and age-adjusted mortality at the county level. The creators of the dataset compiled their data from all hospitals in each county in the United States. I cleaned the data by compiling the information for Indiana from each year into a singular dataframe. I choose 2016 as my cutoff because there are three large coal-fired power plants that all shut down completely in 2016. Below is a snapshot of the first entries in my dataset, the very first being the entire state.

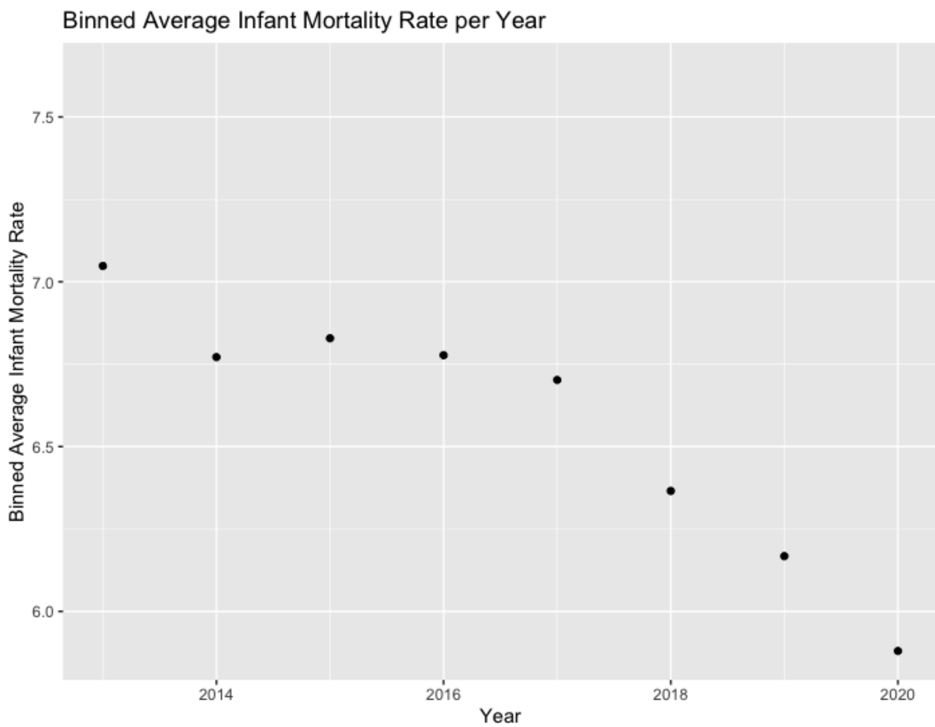
FIPS	State	County	Year	LBW_Births	Live_Births	%_LBW	Infant_mortality_rat	Total_deaths	adjusted_Mortality
18000	Indiana		2014	50269	607652	8.3	7.7	75409	382.2
18001	Indiana	Adams	2014	315	4564	6.9	8.7	319	318.8
18003	Indiana	Allen	2014	3348	37692	8.9	8.5	3571	348.4
18005	Indiana	Bartholomev	2014	584	7372	7.9	7.6	922	372.5

Below is a summary of the statistics that I am tracking:

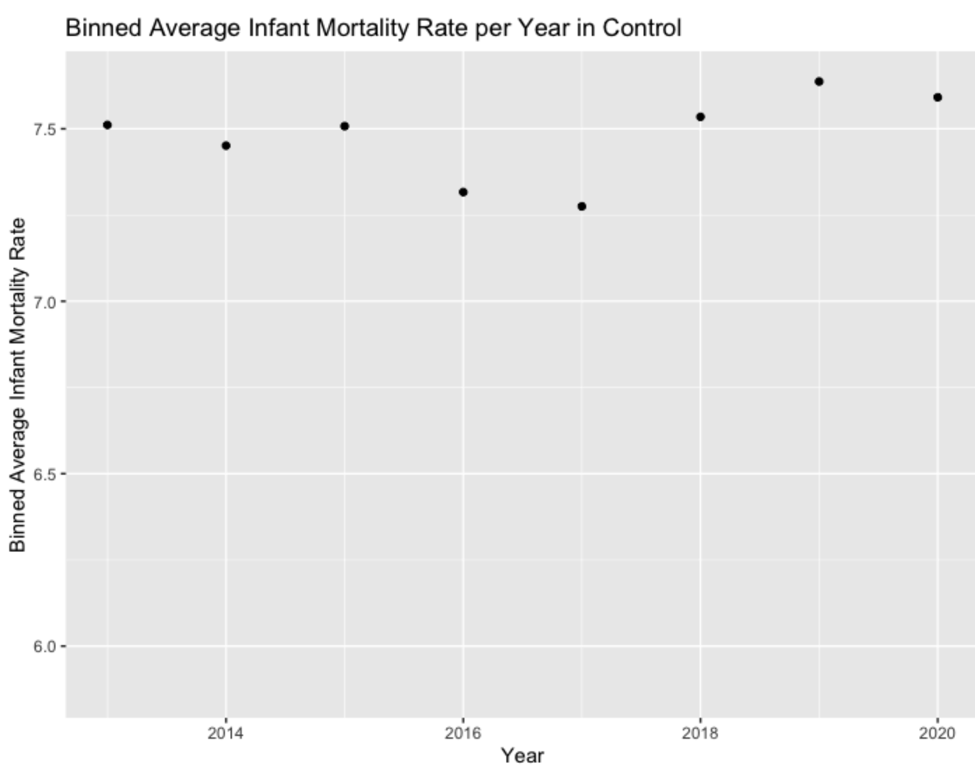
Year	LBW_min	LBW_max	LBW_std	LBW_size	Inf_mort_min	Inf_mort_max	Inf_mort_std	Inf_mort_size
2014	5.400000	9.900000	1.0043221	93	4.400000	9.900000	1.424769	49
2015	5.138889	9.760900	1.0292788	92	4.500000	10.700000	1.612583	46
2016	4.904632	9.952607	1.0012545	92	4.483635	10.005266	1.539754	47
2017	4.600812	9.828010	1.0094533	92	4.231783	9.887006	1.519711	50
2018	4.607721	10.063718	0.9412032	92	3.785385	12.682010	1.807868	48
2019	5.249344	10.159325	0.9331473	92	3.908795	13.164081	1.811645	49
2020	5.241661	10.229410	0.9421891	92	3.832117	12.529833	1.888186	49

Below is a scatterplot of the binned average of each year for infant mortality rate. I created a graph for the treatment (counties where plants closed) and control (counties where plants did not close).

Treatment Group Average (infant mortality rate per 1,000)



Control Group Average (infant mortality rate per 1,000)



Empirical Strategy

My empirical strategy involves using a Difference-in-Differences (DiD) analysis to estimate the impact of coal-fired plant closures on infant mortality rates. I use the year 2016 as the cutoff since plants closed within 30 miles of Clay, Hancock, Hendricks, Johnson, Owen, Parke, Monroe, Marion, Morgan, and Vigo county in 2016. This allows for comparison of trends before and after the closures. I conduct this regression on the variable for infant mortality and consider potential confounding variables to perform robustness checks.

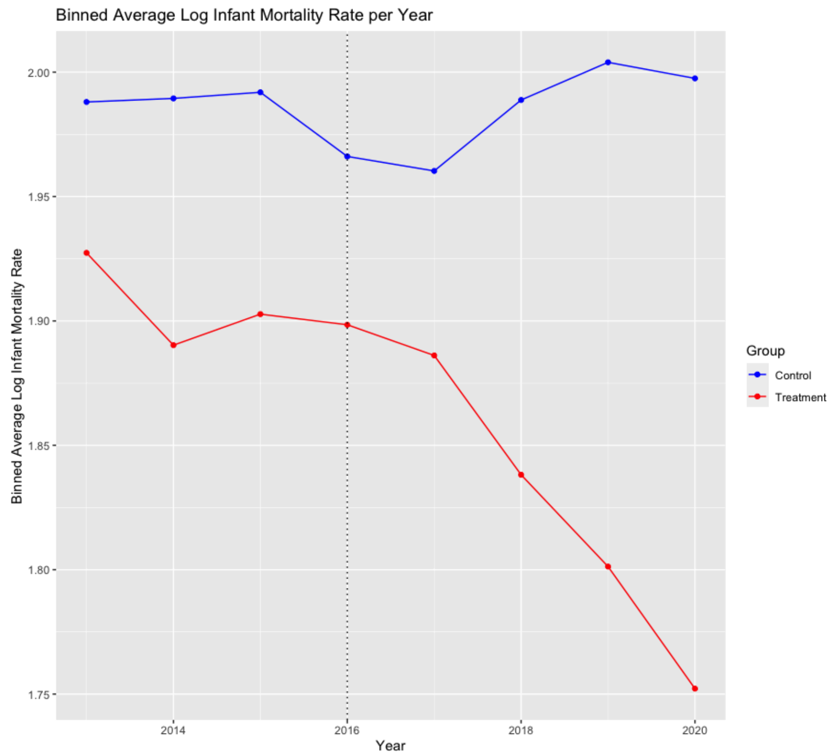
Equation:

$$Y_{it} = \beta_0 + \beta_1 CoalClosure_i + \beta_2 PostClosure_t + \beta_3 (CoalClosure_i \times PostClosure_t) + \epsilon_{it}$$

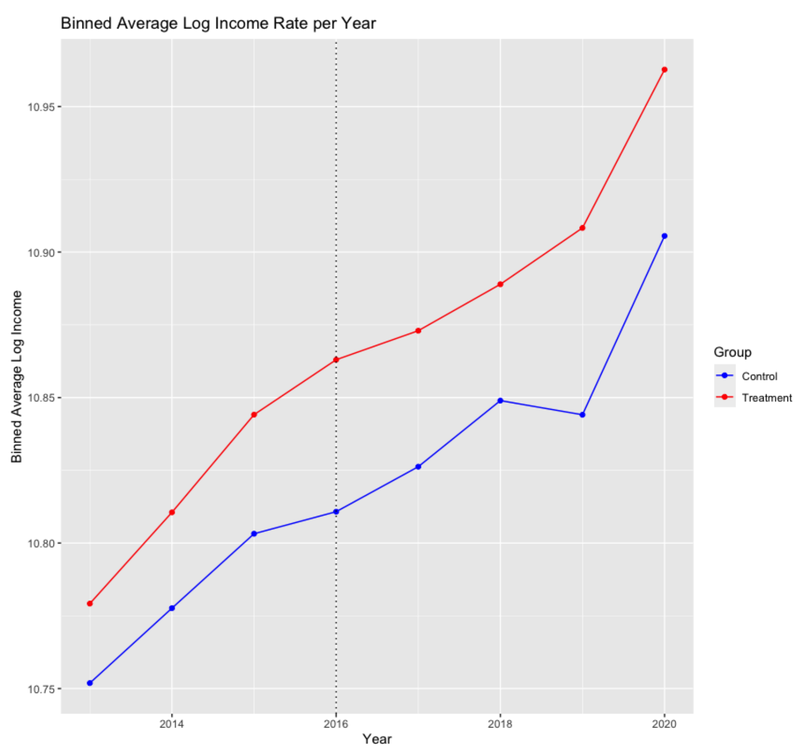
- Y_{it} represents the infant mortality rate in county i and year t
- $CoalClosure_i$ is a binary variable indicating whether a plant closed in county i
- $PostClosure_t$ is a binary variable indicating whether the year t is after closure
- ϵ_{it} is the error term

I make an assumption of parallel trends for the impact of coal power plant closure on infant mortality rate. Preceding the closure of coal power plants, this assumption postulates that the trajectories of infant mortality rates in counties treated and untreated counties would have followed similar paths. This assumption is vital in my DiD methodology, creating a counterfactual scenario where the sole divergence between treatment and control groups is the closure of coal-fired power plants. The plots below show a sanity check for the assumption of parallel trends along with a placebo test on the trend of income. Although the trend is not perfectly parallel, both groups follow very similar trends in log(infant mortality rate) prior to closure, with significant medium-term differences in infant mortality starting after the cutoff. The placebo test provides a counterfactual scenario where no real treatment effect is expected on income, serving as a reference to evaluate the credibility of the parallel trends assumption.

Parallel Trends of Log Infant Mortality Prior to Cutoff (Sharp Differences After Cutoff)



Placebo Test on Parallel Trends of Log Income (Few Differences After Cutoff)

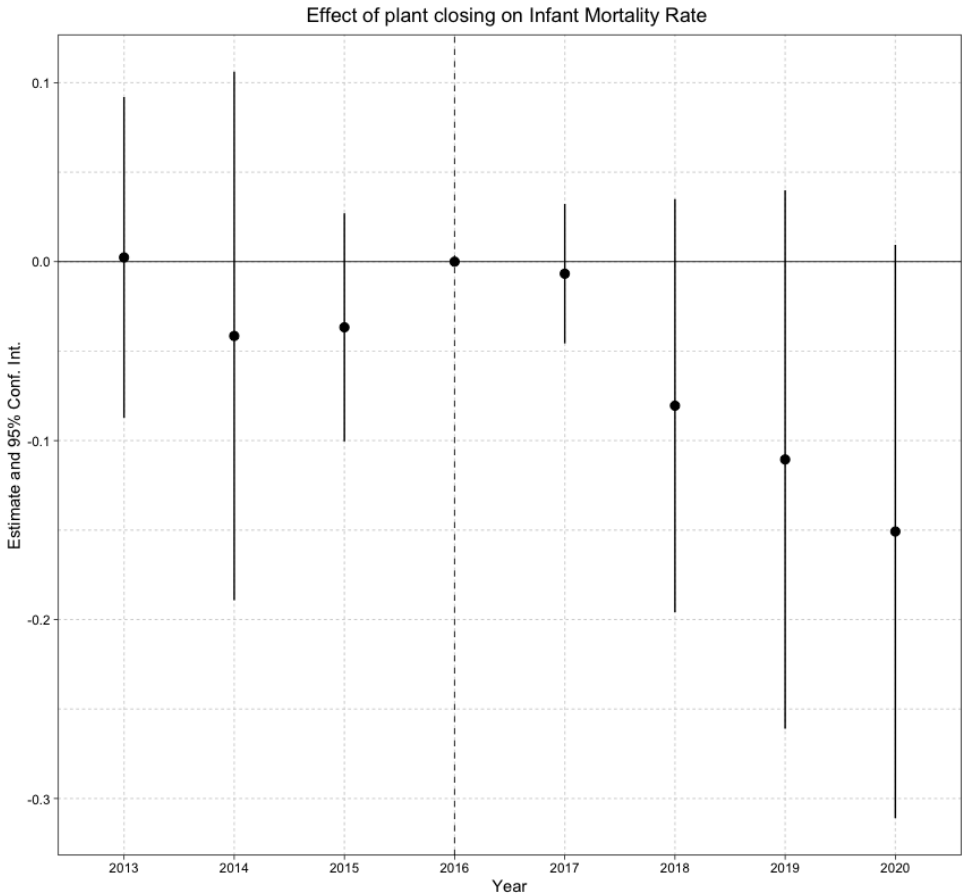


Results

My study includes an analysis of 50 counties: 8 in the treatment group and 42 in the control group. When binned by group averages, both follow parallel trends past the cutoff into the year 2017. After 2017 there is a sharp decline in infant mortality rate in the treated counties whereas infant mortality increased marginally in the control group. Overall, I find that the closure of coal power plants resulted in an 8.8% decrease in infant mortality rate in counties within 30 miles of the plant. This result is marginally significant with a p-value of 0.051, or slightly above the 0.05 significance level. The regression results are summarized below with A representing "After 2016," close_2016 representing whether a not a plant closed in a given county in 2016, and A:closed_2016 representing the interaction.

```
OLS estimation, Dep. Var.: log_inf_mort
Observations: 387
Standard-errors: Clustered (FIPS)
               Estimate Std. Error   t value  Pr(>|t|)
(Intercept)    1.983908   0.031957 62.080903 < 2.2e-16 ***
A              0.006586   0.023943  0.275083  0.784198
closed_2016   -0.078424   0.073185 -1.071584  0.288198
A:closed_2016 -0.092642   0.046571 -1.989274  0.051236 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
RMSE: 0.227662   Adj. R2: 0.033464
```

The effects over time are represented in the plot below. Although the standard error is high, I observe marginal medium term effects of coal power plant closure on infant mortality rate, especially between 2017-2020.




```
OLS estimation, Dep. Var.: log_inf_mort
Observations: 387
Fixed-effects: FIPS: 61,  Year: 8
Standard-errors: Clustered (FIPS)
                         Estimate Std. Error   t value Pr(>|t|)
Year::2013:closed_2016  0.002366   0.045728  0.051730 0.958916
Year::2014:closed_2016 -0.041519   0.075336 -0.551114 0.583602
Year::2015:closed_2016 -0.036686   0.032520 -1.128080 0.263777
Year::2017:closed_2016 -0.006732   0.019870 -0.338816 0.735931
Year::2018:closed_2016 -0.080492   0.058909 -1.366382 0.176918
Year::2019:closed_2016 -0.110548   0.076761 -1.440161 0.155020
Year::2020:closed_2016 -0.150801   0.081730 -1.845111 0.069958 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
RMSE: 0.10295     Adj. R2: 0.757377
                Within R2: 0.030825
```

Results: Explaining the Lag and Limitations

The observed delay in the decrease of infant mortality following a coal power plant closure may be partially explained by a paper by Muzhe Yang (2017), which analyzed the impact of coal power plant closure on infant birth weight. Yang found that babies born to mothers living as far as 20-30 miles away from coal power plants during pregnancy are at greater risks of low birth weight by 6.5% and very low birth weight by 17.12%. Infants with low birth weight have greater health risks. With the average length of human gestation being 40 weeks, this could partially explain why the decrease in infant mortality lags closure by one year.

Given this information, I also consider setting the cutoff year to be 2017 instead of 2016, so that the after period does not include infants that were in gestation while the coal-fired power plants were still active. When accounting for the gestation period, I find that coal power plant closure decreases the infant mortality rate by 11.8%, an even larger decrease. This result is still marginally significant with a p-value of .058. The results are summarized below.

```
OLS estimation, Dep. Var.: log_inf_mort
Observations: 387
Standard-errors: Clustered (FIPS)
                Estimate Std. Error   t value  Pr(>|t|)
(Intercept)     1.978956   0.031888 62.058669 < 2.2e-16 ***
closed_2016    -0.077237   0.072847 -1.060273  0.293270
A               0.021925   0.028454  0.770522  0.444014
closed_2016:A  -0.126446   0.065292 -1.936626  0.057505 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
RMSE: 0.227246   Adj. R2: 0.036989
```

Despite these marginally significant results, my research approach has several limitations. One issue is the high standard error and p-values that I found in my regressions, which led me to declare these results as only marginally significant. For more significant results, we should expand this research to include more counties as well as different states with coal power plant closures. Expanding the time range and studying more years other than 2016 in which coal-fired plants closed may also lead to more robust results. Those looking for further analysis should also consider analyzing other factors in their research such as county population demographics, healthcare access and quality, or what happens when plants switch from coal to natural gas.

Results: Value of Statistical Life

I used a natural experiment in Indiana when 3 coal-fired power plants closed in 2016 to quantify the relationship with infant mortality. After retirement, I find a reduction in infant mortality that is marginally significant. Given my estimate of a 12% reduction in infant mortality when considering gestation period, with a 90% confidence interval of 2% to 21%, I quantify how many lives are saved annually a year after the closure. I reduce 2017 infant mortality rate by each confidence tail percent (2% and 21%) and multiply this by county live births to see how many infant deaths would be expected with the assumed reduction.

With these calculations I find that the closure of these power plants saved between 26 to 230 infant lives. Using the value of statistical life (VSL) of $7.4 million recommended by the Environmental Protection Agency (EPA),[3] closing coal-fired power plants saved the 8 counties with closures a total between $189 million to $1.7 billion in 2017. Although this estimate depends heavily on the assumed VSL, my results show that there is a major medium term economic benefit of closing coal-fired power plants when considering the value of lives saved.

[3] *Environmental Protection Agency*
"EPA recommends that the central estimate of $7.4 million ($2006), updated to the year of the analysis, be used in all benefits analyses that seek to quantify mortality risk reduction benefits regardless of the age, income, or other population characteristics of the affected population until revised guidance becomes available"

Conclusion and Discussion

The investigation into the localized impact of coal-fired power plant closures on infant mortality rates in Indiana reveals compelling evidence of a marginally significant reduction in infant mortality following plant closure. These findings suggest an 8.8% decrease in infant mortality rates for counties within 30 miles of closed plants, a figure that becomes more substantial (11.8%), when considering the gestation period's influence. The observed delay in decline of infant mortality rates post-closure aligns with existing research linking coal plant emissions to adverse infant outcomes during pregnancy.

The findings of this study provide insights that policymakers can leverage to make more informed decisions about coal-fired power plant closures. The observed marginal but significant reduction in infant mortality rates following plant closures suggests potential health benefits associated with transitioning away from coal, especially if this is done earlier than planned. While further research is required to increase the level of significance, my results present compelling evidence to be considered in environmental policy formation. The estimation of the value of statistical life indicates large potential savings in infant lives and substantial economic benefits post-closure, offering a quantitative framework for assessing the cost-benefit analysis of early plant closure. Policymakers should consider the economic benefit of lives saved when debating legislation impacting coal power plant closure.

While this study presents important insights into the localized health impacts of coal power plant closures, it is imperative for policymakers to integrate such findings into a broader framework of environmental policy. A comprehensive study encompassing diverse regions and temporal spans would offer an even more robust foundation for policy making, ensuring the applicability of findings across varied contexts.