12/01/2024
DATA 512
Joobee Jung

Exploring the Human-Centered Impact of Air Quality on Boise's Economic Performance

Introduction

The increasing frequency and severity of wildfires have profound implications for ecological systems, public health, and economic stability. Boise, Idaho, is not exempt from these effects. As wildfires escalate, the resulting smoke and particulate matter degrade air quality, affecting residents' daily lives and the city's long-term economic prospects. Understanding these impacts is crucial for addressing the intertwined challenges of environmental degradation and economic resilience.

Figure 1: Location of Boise, Idaho
This map highlights the geographic location of Boise, the capital city of Idaho, within the Pacific Northwest region of the United States. Boise's strategic location and its significance as an economic hub are central to understanding the impact of local environmental factors, such as air quality, on the broader regional economy.

Boise's economy is anchored by industries such as manufacturing, technology, and healthcare, with Micron Technology, one of the city's largest employers, playing a pivotal role. Poor air quality, however, poses risks to public health, corporate productivity, investor confidence, and workforce stability. These challenges raise important questions about the relationship between environmental conditions and economic outcomes in Boise.

12/01/2024
DATA 512
Joobee Jung

This study investigates the link between air quality and economic performance in Boise, focusing on GDP, unemployment rates, and Micron's stock performance. These metrics offer a comprehensive view of how air quality disruptions affect both macroeconomic indicators and corporate performance. The research examines how wildfire smoke exposure impacts workforce productivity, investor sentiment, and Boise's broader economic stability.

The main research question is: **How does the relationship between air quality and economic performance manifest in Boise?** This question is significant because it explores the intersection of environmental science and economics. Poor air quality not only decreases workforce productivity and increases healthcare burdens but also disrupts corporate operations and weakens investor confidence, threatening economic stability.

The findings from this study provide valuable insights for policymakers, local businesses, and residents. The research can inform strategies to improve air quality management, invest in sustainable practices, and safeguard economic stability. For businesses like Micron, understanding these dynamics can help implement health initiatives and operational adjustments to mitigate productivity losses during periods of poor air quality.

By bridging environmental science and economics, this analysis contributes to a more resilient and sustainable Boise. It emphasizes the importance of integrating human-centered considerations into data-driven decision-making, ensuring that policies and practices address both economic and public health priorities.

12/01/2024
DATA 512
Joobee Jung

Background and Related Work

Prior Research on Air Quality and Economic Performance

The economic impacts of environmental degradation, especially air pollution, have been widely examined in various studies across different regions. These studies consistently show that poor air quality negatively affects workforce productivity, leads to higher health-related absenteeism, and erodes consumer and investor confidence. These challenges directly affect businesses like Micron Technology, which rely on a healthy, productive workforce to maintain operational efficiency and profitability.

Air pollution not only harms human health but also imposes significant economic costs. For example, reduced workforce productivity, increased absenteeism, and rising healthcare costs together diminish economic output. This emphasizes the need for human-centered interventions that address both the economic and health-related aspects of environmental degradation. Such interventions should prioritize practical strategies that address these interrelated challenges.

Several studies have quantified the relationship between air pollution and economic performance. For instance, increased levels of particulate matter (PM2.5) are associated with a decline in real GDP per capita, with an estimated 0.8% reduction for every additional microgram of PM2.5 per cubic meter. Studies such as *The Relationship between Economic Growth and Air Pollution—A Regional Comparison between China and South Korea* delve into how economic growth and air pollution interact. These studies support the Environmental Kuznets Curve (EKC) hypothesis, which suggests that pollution initially increases with economic growth but decreases once nations reach certain income thresholds and invest in cleaner technologies.

These findings underscore the importance of transitioning to clean energy, adopting technological innovations, and implementing public health policies to balance economic growth with environmental sustainability. Although these insights are based on global contexts, they provide valuable frameworks for understanding similar dynamics in Boise, Idaho.

Research Question and Hypotheses

Building upon these studies, this research seeks to answer the following central question: **How does air quality impact Boise's economic performance?**

This question is addressed by exploring three dimensions:

1. **GDP Trends**: Examining correlations between air quality fluctuations and Boise's GDP.
2. **Unemployment Rates**: Investigating the role of air quality in shaping workforce dynamics and unemployment trends.
3. **Micron Technology Stock Price**: Assessing how air quality affects corporate performance and, in turn, regional economic outcomes.

The primary hypothesis of this study is that poor air quality significantly impacts economic performance, with unemployment rates and Micron Technology's stock price acting as key mediators of this relationship. The secondary hypothesis posits that there is a strong correlation between unemployment rates and GDP, as workforce productivity is a fundamental determinant of economic output.

The previous research supports the hypothesis that air quality influences Boise's economic performance. For instance, studies linking environmental factors to corporate performance suggest that poor air quality may reduce workforce productivity and dampen investor sentiment. Furthermore, incorporating unemployment rates into this analysis aligns with established findings that employment metrics strongly correlate with GDP. This integrative approach provides a robust framework for analyzing Boise's economic dynamics.

Wildfire Smoke Estimation Model

A linear regression model was employed to estimate smoke levels from wildfires in Boise. This model identifies correlations between wildfire characteristics and their potential impact on air quality. The key methodological steps in this process included encoding categorical fire types as numeric values to quantify their influence on smoke levels. The coefficients were then normalized to clarify the impact of each fire type. Finally, smoke estimates were calculated using a formula that incorporates three factors: the area affected by the wildfire (measured in GIS hectares), the average distance from Boise to the wildfire, and a normalized weight assigned to different fire types based on their estimated smoke output.

The resulting smoke estimates were merged with AQI data for validation and analysis. A time-series plot was generated to compare these smoke estimates with observed AQI values, allowing for a direct evaluation of model accuracy. This visualization normalized the data to highlight trends and patterns, demonstrating the reliability of the smoke estimation model in capturing key dynamics.

$$\text{smoke\_estimate} = \frac{\text{GIS\_Hectares}}{\text{average\_distance\_miles}} \times \text{normalized\_weight\_fire\_type}$$

Figure 2: Smoke Estimation Model

12/01/2024
DATA 512
Joobee Jung

This model estimates smoke levels based on the following variables:

- **GIS_Hectares**: The area affected by wildfires, measured in hectares.
- **average_distance_miles**: The distance from the wildfire to Boise, measured in miles.
- **normalized_weight_fire_type**: A weight assigned to fire types based on their estimated smoke output.

By merging these datasets and applying this model, the analysis establishes a robust foundation for linking environmental conditions to economic performance.

12/01/2024
DATA 512
Joobee Jung

Methodology

The chosen metrics—GDP, unemployment rates, and Micron Technology's stock prices—provide a comprehensive view of Boise's economic landscape. GDP is a widely recognized indicator of economic health, representing the overall performance of Boise's economy. By analyzing its relationship with air quality, the study aims to uncover how environmental conditions impact economic output at a macro level. Unemployment rates are a fundamental determinant of GDP. Changes in unemployment can indicate shifts in workforce productivity, making it a crucial variable for understanding the indirect economic impacts of air quality. Micron Technology's stock prices reflect the financial health of one of Boise's largest employers, which plays a key role in the city's economy. With over 5,000 employees, Micron's stock performance serves as a proxy for corporate productivity and investor confidence, both of which are susceptible to environmental disruptions.

The analysis utilized a polynomial regression model (degree 2) to capture the non-linear relationships between air quality and economic factors. While linear regression models are straightforward and interpretable, they often fail to account for the complexities present in real-world data. In contrast, polynomial regression accommodates curvature and volatility in relationships, making it especially suitable for capturing the fluctuating trends in Micron Technology's stock prices and modeling the long-term, non-constant impacts of air quality on GDP. This choice was further validated through rigorous model evaluation, where the polynomial regression demonstrated superior performance over linear models, resulting in an R^2 value improvement of 200%.

Analytical Approach

1. Correlation Analysis

The analysis began by calculating the correlation coefficients between the selected features—AQI, unemployment rates, Micron Technology stock prices, and GDP. This step identified the relative importance of each variable in shaping Boise's economic dynamics. Correlations were normalized to establish feature weights, reflecting the significance of each factor in the subsequent regression model.

2. Polynomial Regression

A degree-2 polynomial regression model was developed to explore the non-linear relationships between air quality and economic factors. This model was particularly effective in capturing the dynamic and volatile nature of stock prices, as well as reflecting the gradual, cumulative effects of air quality on GDP over time. The model was trained and tested using an 80/20 train-test split, and its performance was evaluated using Mean Squared Error (MSE) and R-squared (R^2) metrics.

12/01/2024
DATA 512
Joobee Jung

3. GDP Forecasting

The polynomial regression model was used to forecast Boise's GDP for the next 25 years. Forecasts incorporated anticipated trends in AQI, unemployment rates, and Micron's stock performance, offering a forward-looking perspective on Boise's economic trajectory.

The study's design prioritized human-centered outcomes by focusing on metrics that directly impact Boise's residents and workforce. By linking air quality to economic and public health dimensions, the research highlights the interconnectedness of environmental sustainability and societal well-being. The inclusion of unemployment rates and corporate performance reflects a commitment to understanding how environmental conditions affect both individual livelihoods and the broader community.

To reduce biases, the analysis accounted for external factors such as global economic trends and policy changes that could independently influence GDP, unemployment, and stock performance. This approach aimed to isolate the specific impacts of air quality, minimizing misinterpretation and ensuring fair representation of results.

12/01/2024
DATA 512
Joobee Jung

Findings

The analysis revealed significant insights into the interplay between air quality and Boise's economic performance. These findings are supported by data visualizations, correlation analysis, and forecasting models, illustrating both the direct and indirect impacts of air quality on key economic indicators.

a. Distribution of Wildfires by Distance

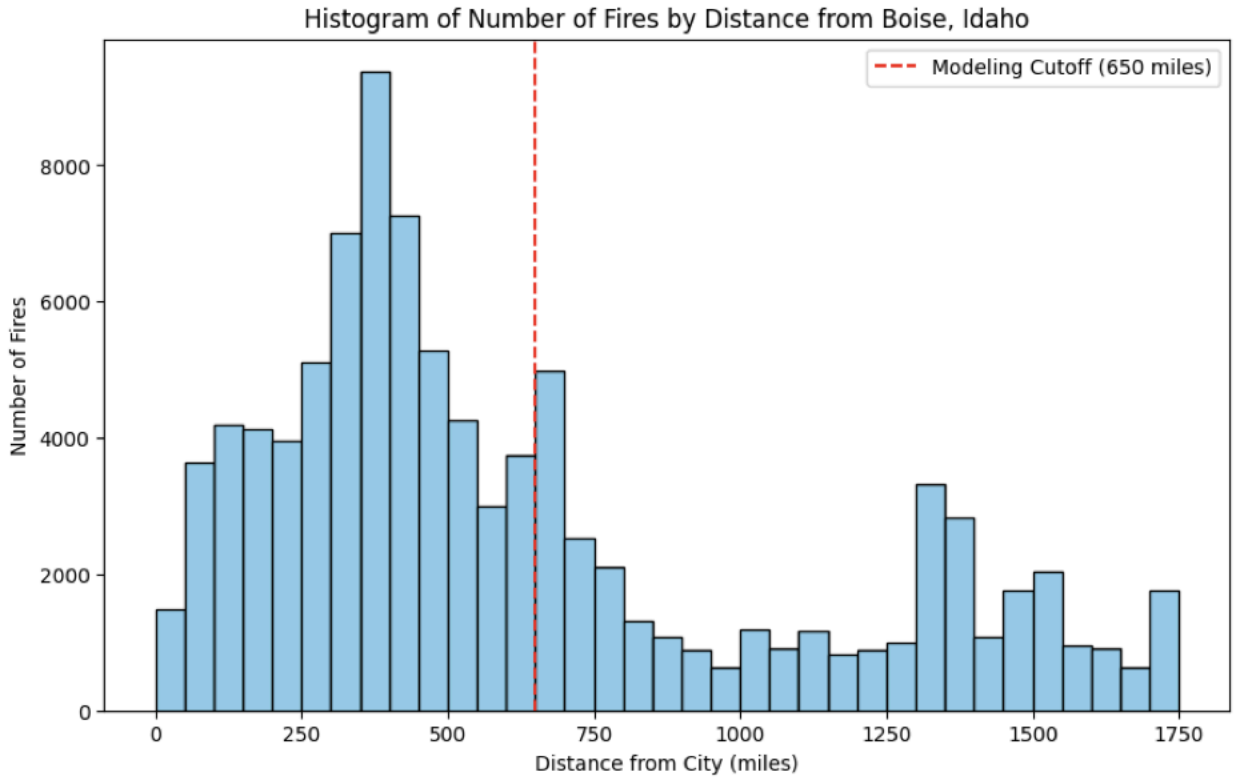

Figure 3: Histogram of Number of Fires by Distance

A histogram was generated to visualize the distribution of wildfires based on their distance from Boise, with a cutoff of 650 miles.

The x-axis represents the distance from Boise, divided into 50-mile intervals, while the y-axis shows the number of wildfires recorded. The histogram reveals that the majority of wildfires occur with a cutoff of 650 miles. This proximity underscores the importance of monitoring wildfire activity near urban areas, as these fires have a more significant impact on air quality.

12/01/2024
DATA 512
Joobee Jung

b. Annual Trends in Acres Burned

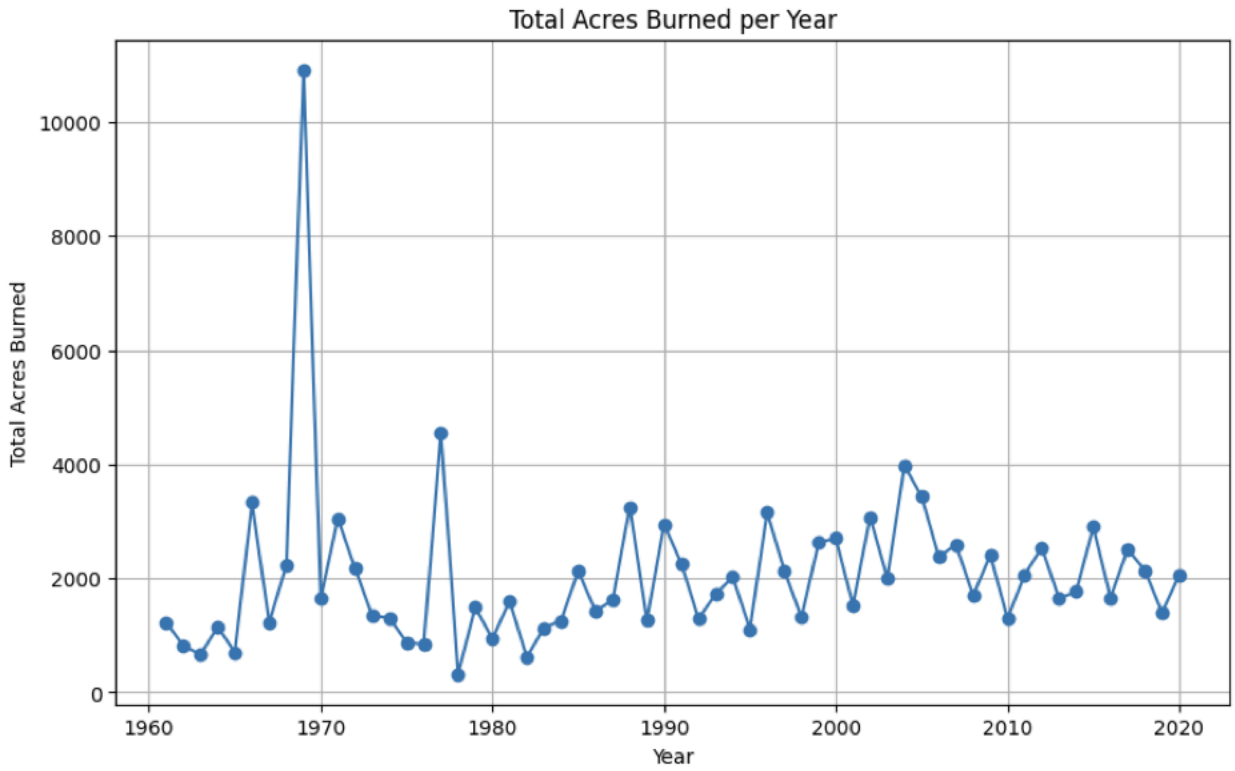

Figure 4: Time Series of Total Acres Burned per Year

A time-series plot displaying the total acres burned annually by wildfires provided insights into wildfire activity trends.

The x-axis represents the years, while the y-axis indicates the total acres burned, averaged annually. The data reveals a consistent increase in wildfire activity over time, reflecting a concerning trend of escalating fire severity. These findings align with broader regional patterns, indicating that climate change and other environmental factors are contributing to the intensification of wildfires.

12/01/2024
DATA 512
Joobee Jung

c. Fire Smoke and AQI Trends

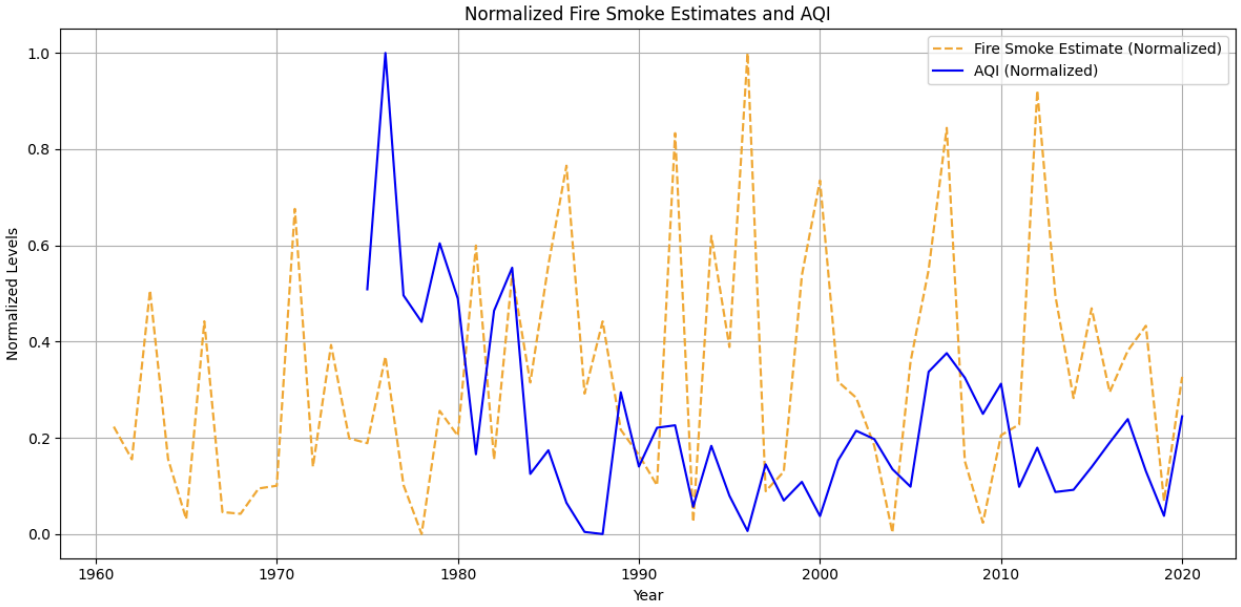

Figure 5: Time Series of Fire Smoke Estimates and AQI Estimates

The relationship between estimated smoke levels from wildfires and actual AQI measurements was analyzed using a time-series plot.

Smoke levels were estimated using a formula that incorporates wildfire size (measured in GIS hectares), distance from Boise, and fire type. These estimates were validated against AQI data from monitoring stations. Data normalization allowed for a direct comparison of trends over time. The time-series plot reveals a strong alignment between the smoke estimates and AQI measurements, confirming the accuracy of the model. This trend highlights the direct impact of wildfire activity on Boise's air quality, with larger and closer fires contributing more significantly to AQI spikes.

12/01/2024
DATA 512
Joobee Jung

Correlation Analysis

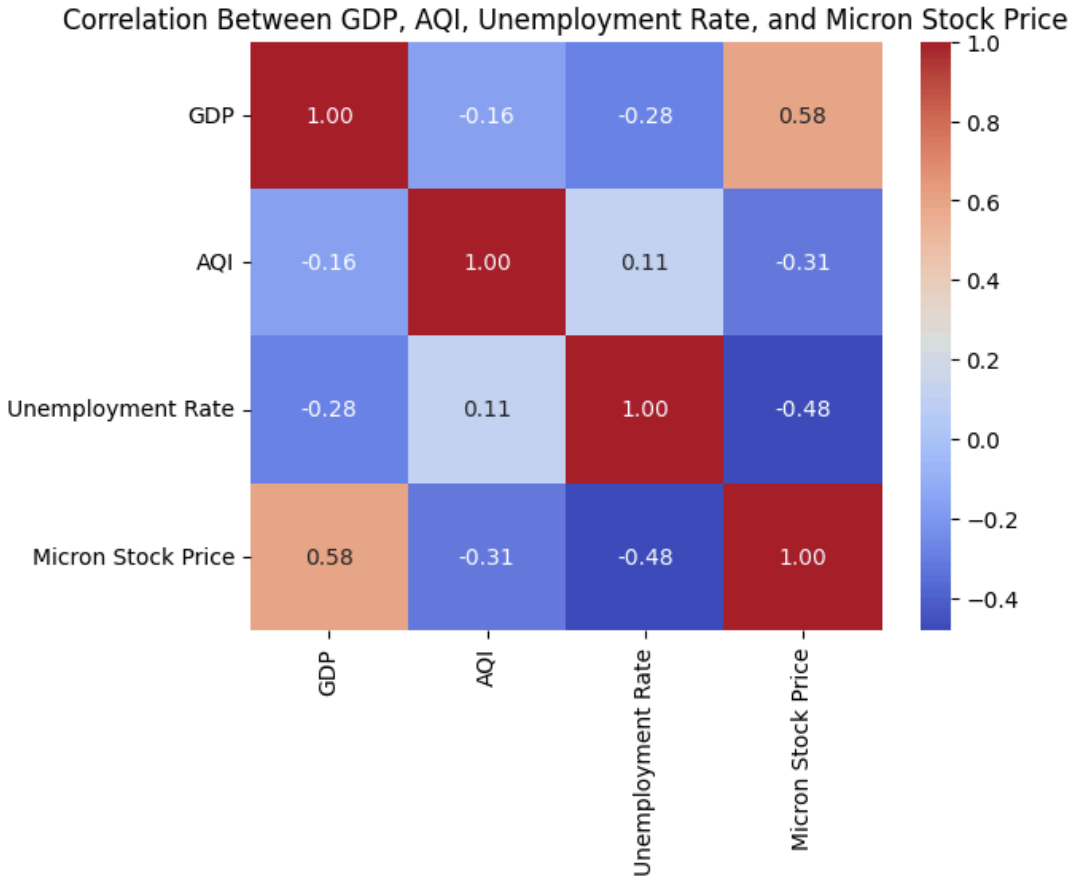

Figure 6: Correlation Analysis of Air Quality, GDP, Unemployment rate, and Micron Stock Price

The correlation analysis provided quantitative insights into the relationships between air quality, economic indicators, and corporate performance.

1. **AQI and GDP**: A weak negative correlation (-0.16) was observed, indicating that while air quality impacts economic performance, its effect is relatively modest compared to other factors.
2. **Unemployment Rate and GDP**: A strong negative correlation (-0.28) was identified, confirming that higher unemployment rates significantly reduce GDP.
3. **Micron Technology Stock Price and GDP**: A strong positive correlation (0.58) highlights the critical role of Micron Technology in Boise's economy. Fluctuations in Micron's stock price serve as a robust indicator of local economic health.

12/01/2024
DATA 512
Joobee Jung

The polynomial regression model outperformed linear models, with an R-squared value improvement of 200%. This demonstrated its ability to capture the non-linear relationships between air quality and economic factors.

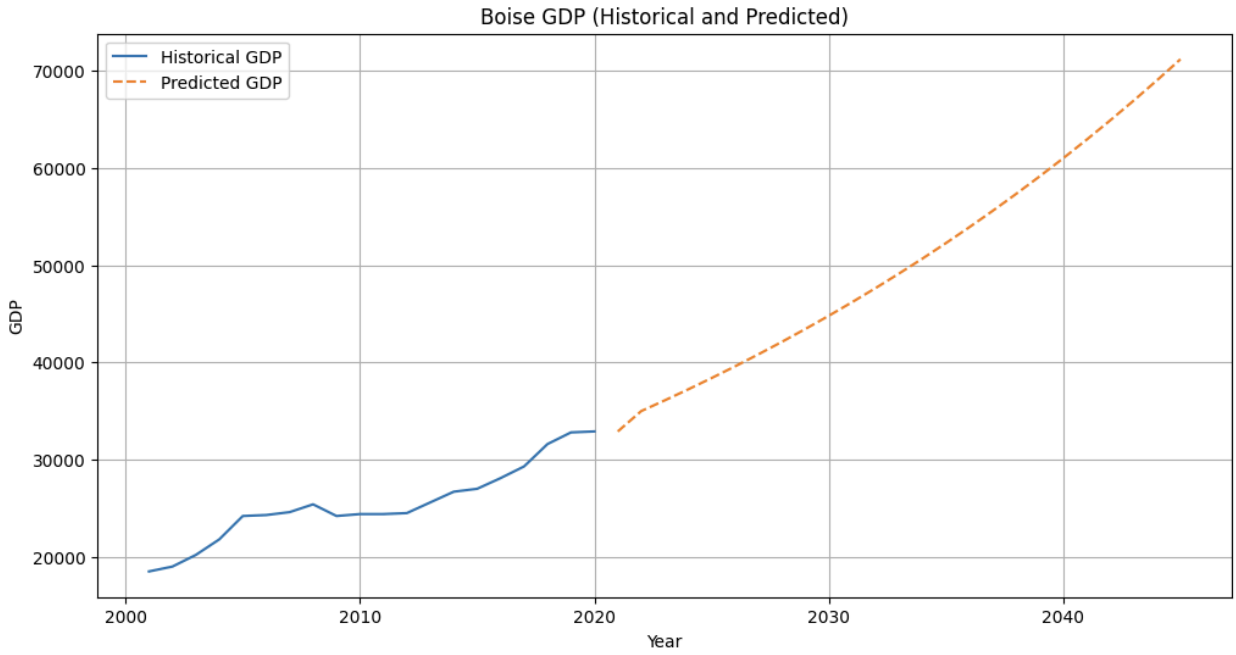

Figure 7: Projections of Boise's GDP Over the Next 25 Years

This plot shows the projected trends for Boise's GDP over the next 25 years. The projections incorporate anticipated trends in AQI, unemployment rates, and Micron Technology's stock performance.

Using the regression model and exponential smoothing, projections for Boise's GDP over the next 25 years were developed, incorporating anticipated trends in AQI, unemployment rates, and Micron's stock performance.

12/01/2024
DATA 512
Joobee Jung

Discussion/Implications

The findings of this study reveal significant connections between air quality and Boise's economic performance, underscoring the critical role of environmental factors in shaping economic resilience and public health. While the correlation between air quality (AQI) and GDP is relatively weak, the analysis highlights that indirect effects—such as those mediated by unemployment rates and corporate performance—are more pronounced. These results offer actionable insights for various stakeholders and emphasize the importance of adopting proactive measures to mitigate air quality issues.

Key Implications for Stakeholders

City Council and Mayor

The city's leadership plays a crucial role in implementing policies to address air quality challenges. Based on the findings, it is recommended that the city enhance wildfire management strategies. This could include implementing controlled burns and improving forest management to reduce the frequency and severity of wildfires.

City Residents

Public participation is essential for achieving long-term improvements in air quality. To engage residents, it is important to launch awareness campaigns focused on preventing human-triggered wildfires. Educating the public about behaviors that contribute to wildfires, such as improper disposal of burning materials or unattended campfires, will help minimize these risks.

Micron Technology

As one of the largest employers in Boise, Micron Technology is uniquely positioned to lead by example in mitigating the effects of poor air quality on the workforce. Businesses, including Micron, should consider implementing enhanced remote work policies during periods of poor air quality to protect employee health and maintain productivity. Additionally, businesses should install advanced indoor air filtration systems in office spaces to improve indoor air quality during wildfire seasons or other times when outdoor air quality is compromised. By maintaining productivity and safeguarding employee well-being, businesses can minimize disruptions to Boise's economic ecosystem.

Addressing Boise's air quality requires immediate action. In the short term (1–2 years), focus on wildfire management, public awareness campaigns, and air quality monitoring infrastructure. In the long term (3–5 years), transition to clean energy, strengthen sustainability efforts, and assess progress through data analysis. Prompt action will safeguard public health and support sustainable growth.

12/01/2024
DATA 512
Joobee Jung

Reflections

This study demonstrates human-centered data science by integrating diverse datasets, prioritizing ethics, and focusing on outcomes that benefit Boise. It examines the link between air quality, workforce productivity, and public health, ensuring recommendations reflect residents' experiences. Public datasets were used with proper citations for transparency. Findings were communicated to policymakers, businesses, and the public, offering actionable recommendations that support sustainable economic and environmental practices.

The findings underscore the importance of adopting proactive measures to address air quality issues in Boise. For Micron Technology, implementing workplace health initiatives during wildfire seasons can help maintain productivity and safeguard employees. For policymakers, investing in wildfire management and deploying comprehensive air quality monitoring systems can prevent future economic disruptions.

By integrating environmental science with economic analysis, this study provides a roadmap for fostering resilience against environmental challenges. It also highlights how human-centered data science can drive meaningful change, ensuring that policies and practices prioritize both economic stability and public health.

12/01/2024
DATA 512
Joobee Jung

Limitations

While this study provides valuable insights into the relationship between air quality and Boise's economic performance, there are several limitations that must be acknowledged:

1. Data Quality and Granularity

The datasets used in this analysis—Boise's GDP, AQI, unemployment rates, and Micron stock prices—are aggregated, which can obscure localized variations in both economic and environmental conditions. The GDP data is available on a yearly basis, which limits the ability to capture finer temporal fluctuations that could provide more detailed insights into the short-term effects of air quality on economic performance. Daily or monthly economic data could offer a more accurate representation.

2. External Factors Influencing Economic Performance

Economic outcomes are influenced by a wide range of factors beyond air quality, which were not fully controlled for in this analysis. Notable external factors include worldwide economic conditions, such as shifts in global trade or commodity prices, which can significantly impact local GDP. These factors may either mask or amplify the effects of air quality on Boise's economy. Technological advancements, particularly in industries like semiconductor manufacturing, could also drive economic growth in Boise, independent of air quality conditions. Additionally, events such as pandemics, financial crises, or geopolitical instability can disrupt economic patterns, making it challenging to isolate the specific effects of air quality on economic performance.

3. Model Assumptions

The polynomial regression model assumes a non-linear relationship between air quality and economic performance, which may not hold in the long term. While it fits short-term data well, it may not accurately predict future trends under changing conditions. The model's GDP forecasts rely on historical trends and assumptions about AQI, unemployment, and Micron stock performance, so these predictions should be viewed with caution due to the uncertainty of future environmental and economic conditions.

12/01/2024
DATA 512
Joobee Jung

Conclusion

This study set out to explore the relationship between air quality and Boise's economic performance, with a focus on understanding how environmental factors, specifically air quality, influence key economic indicators such as GDP, unemployment rates, and corporate performance. The research question addressed was: **How does air quality impact Boise's economic performance?**

The primary hypothesis was that poor air quality negatively impacts Boise's GDP through reduced workforce productivity and health. This hypothesis was partially supported by the findings, which revealed that air quality, while impactful, has a more subtle influence on economic outcomes compared to other factors. The study confirmed that while air quality plays a role in shaping Boise's economic performance, more direct influences—such as unemployment rates and corporate performance, particularly Micron Technology's stock price—have a more pronounced effect on GDP.

The results emphasize the importance of considering a variety of interconnected factors when assessing the economic impact of environmental conditions. Unemployment rates, which are strongly linked to GDP, and corporate performance—represented by Micron's stock fluctuations—are key drivers of economic activity that can amplify or mitigate the effects of air quality. This aligns with the broader perspective of human-centered data science, which prioritizes the integration of various data points to understand the real-world impacts of environmental and social issues on human well-being.

The study employed advanced statistical techniques, including polynomial regression and forecasting models, to analyze the complex relationships between air quality and economic performance. The use of polynomial regression, specifically, enhanced the model's ability to account for non-linear trends and interactions between variables, such as the fluctuating nature of stock prices and the gradual, cumulative effects of poor air quality on the economy. By integrating these techniques with human-centered data—such as unemployment rates, corporate performance, and GDP—this study offers a nuanced understanding of how environmental factors intersect with economic dynamics.

Importantly, this research highlights the application of human-centered data science principles by considering the broader implications of the findings on community health, workforce productivity, and long-term economic resilience. The study demonstrates the significance of actionable outcomes, focusing on how data can inform public policy, business strategies, and community initiatives aimed at improving both environmental quality and economic stability.

The findings underscore the need for policies that address both economic growth and environmental sustainability, particularly in a context like Boise where air quality and the

performance of major employers like Micron Technology are intertwined with the city's overall economic health. The study advocates for targeted interventions, such as investing in clean technologies, improving wildfire management, and promoting public health initiatives, which could help mitigate the economic consequences of poor air quality.

While this study has contributed valuable insights, there are several areas for future research. One such area is the incorporation of additional variables. Future studies could benefit from including factors such as healthcare costs, educational attainment, and technological advancements, which may further explain economic trends. Additionally, long-term monitoring through longitudinal studies that track changes over time could provide deeper insights into the long-term effects of air quality on economic resilience and public health.

In summary, this study highlights the subtle yet significant role that air quality plays in Boise's economic performance, while also emphasizing the importance of incorporating multiple, interrelated factors in the analysis. By applying human-centered data science principles, the study provides a framework for future research and actionable insights that can guide policymakers, businesses, and community leaders in their efforts to address the dual challenges of environmental degradation and economic sustainability.

Reference

1. Kim, D., & Park, S. (2020). The Relationship between Economic Growth and Air Pollution—A Regional Comparison between China and South Korea. International Journal of Environmental Research and Public Health, 17(9), 3223. https://doi.org/10.3390/ijerph17093223
2. Zaidi, S. A. H., Saidi, K., & Mehmood, U. (2019). Are Air Pollution, Economic and Non-Economic Factors Associated with Per Capita Health Expenditures? Evidence from Emerging Economies. International Journal of Environmental Research and Public Health, 16(13), 2300. https://doi.org/10.3390/ijerph16132300
3. Zhang, L., Wang, Y., & Chen, X. (2023). Air Pollution Control or Economic Development? Empirical Evidence from Enterprises with Production Restrictions. Journal of Environmental Management, 337, 117829. https://doi.org/10.1016/j.jenvman.2023.117829
4. EPA Air Quality API: Provides historical air quality index (AQI) measurements. Documentation

12/01/2024
DATA 512
Joobee Jung

Data Sources

1. Boise GDP Data: Sourced from FRED. https://fred.stlouisfed.org/series/RGMP14260
2. Wildland Fire Dataset: Based on the Combined Wildland Fire Datasets for the United States and Certain Territories (1800s-Present) collected by the US Geological Survey. Access the dataset here.
3. Unemployment Rates: Obtained from local workforce statistics. https://www.bls.gov/eag/eag.id_boisecity_msa.htm
4. Micron Stock Prices: Historical data from Yahoo Finance. https://finance.yahoo.com/quote/MU/