Wildfire Impacts on New Haven: Air Quality, Employment, and Economic Resilience

1. Introduction

Wildfires, traditionally considered a localized concern, have far-reaching consequences due to the pervasive effects of wildfire smoke. In cities like New Haven, Connecticut, where air quality and economic activity are critical components of urban life, the indirect effects of wildfires pose significant challenges. The presence of wildfire smoke can degrade air quality and lead to disruptions in various industries, particularly those reliant on outdoor operations or sensitive to environmental changes. Central to this analysis is the development of a wildfire impact score, which integrates wildfire size, proximity, and PM2.5 levels to provide a measurable metric for assessing the influence of wildfire activity on New Haven.

This study explores the economic and environmental implications of wildfire activity on New Haven, focusing on two key aspects:

1. The relationship between wildfire activity, proximity, and local air quality.
2. The impact of degraded air quality on critical economic sectors such as manufacturing and wholesale trade.

By providing insights into these dynamics, the study equips policymakers and industry stakeholders with actionable recommendations to mitigate the adverse effects of wildfire smoke and bolster resilience.

2. Background and Related Work

Existing Research

The environmental and health impacts of wildfire smoke are well-documented, with studies from the Environmental Protection Agency (EPA) highlighting correlations between smoke exposure and increased respiratory illnesses. These health consequences often translate into broader economic disruptions, but less attention has been paid to the specific effects on urban economies and industry performance.

This study extends the existing body of work by focusing on the economic ramifications of wildfire smoke in New Haven, a city not directly exposed to wildfires but significantly affected by their secondary effects. Previous studies on economic resilience to environmental disruptions informed the selection of analytical methods, including regression analysis to identify industry-specific vulnerabilities.

Hypotheses and Research Questions

- **Hypothesis :** Proximity to wildfires and smoke exposure (PM2.5 levels) are significant predictors of economic disruptions in New Haven.

- **Research Questions:**
1. How do wildfire activity and proximity correlate with PM2.5 levels in New Haven?
2. Which economic sectors are most vulnerable to wildfire-induced disruptions?
3. What proactive measures can reduce the economic impact of wildfires on New Haven?

Datasets and Related Work

The analysis integrates datasets from multiple reliable sources:

1. **EPA AQS API** ([source](#)): Provides PM2.5 data to quantify smoke exposure.
2. **Connecticut Department of Labor** ([source](#)): Supplies employment and wage data by industry, enabling sector-specific analyses.

3. **Economic Data** ([source](#)): This comprehensive dataset offers demographic, economic, and social indicators for New Haven

These datasets enable the analysis of the relationship between wildfire activity, air quality, and economic indicators.

3. Methodology

Analytical Framework

1. **Wildfire Impact Score Calculation:**
● A composite score combining PM2.5 levels, wildfire size, and proximity to New Haven was developed to estimate yearly wildfire impact.
● This metric allowed for consistent comparisons across years and alignment with economic data.
● This score provides a standardized way to quantify the intensity of wildfire effects on the city. The formula assigns greater weight to nearby and larger wildfires, reflecting their disproportionate impact on air quality.
2. **Linear Regression Analysis:**
● Regression models assessed the effects of wildfire impact scores on:
    ○ Facility counts ("Units") across industries.
    ○ Total annual wages within major economic sectors.
3. **Sector-Specific Vulnerability Analysis:**
● Industries were ranked based on statistical significance (p-values) and the magnitude of disruption (coefficients).

Ethical Considerations

Human-centered data principles guided the study design:

● Open-source datasets ensured transparency and reproducibility.
● The analysis avoided speculative conclusions by focusing on measurable metrics such as PM2.5 levels and economic outputs.

4. Findings

Air Quality Trends

- **PM2.5 Correlation with Wildfire Activity:** Higher PM2.5 levels coincided with years of significant wildfire activity, particularly during the summer months. For example, 2018 and 2021 experienced sharp increases in PM2.5 levels due to wildfire smoke from nearby states.
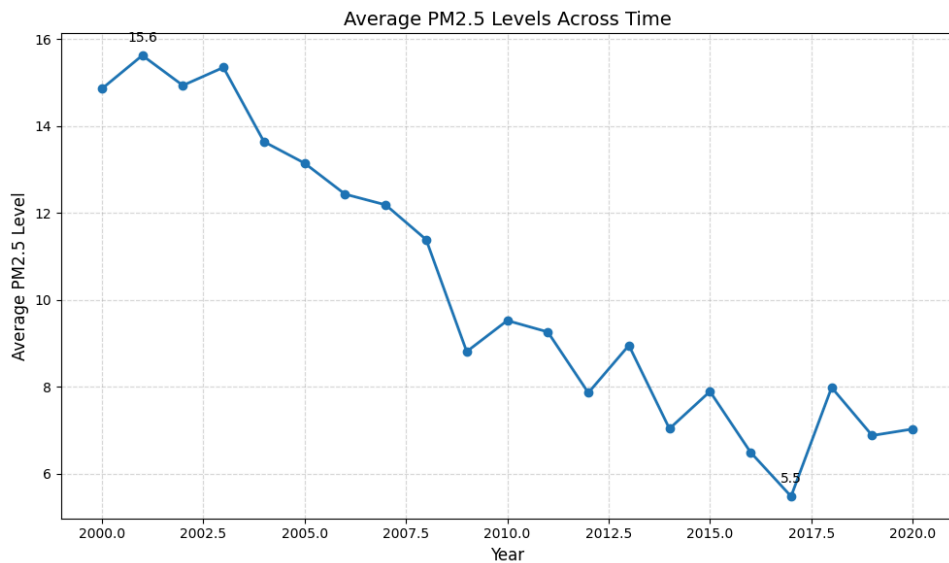
- **Proximity Matters:** Closer wildfires had a disproportionately larger impact on air quality, with inverse correlations observed between distance and PM2.5 levels.
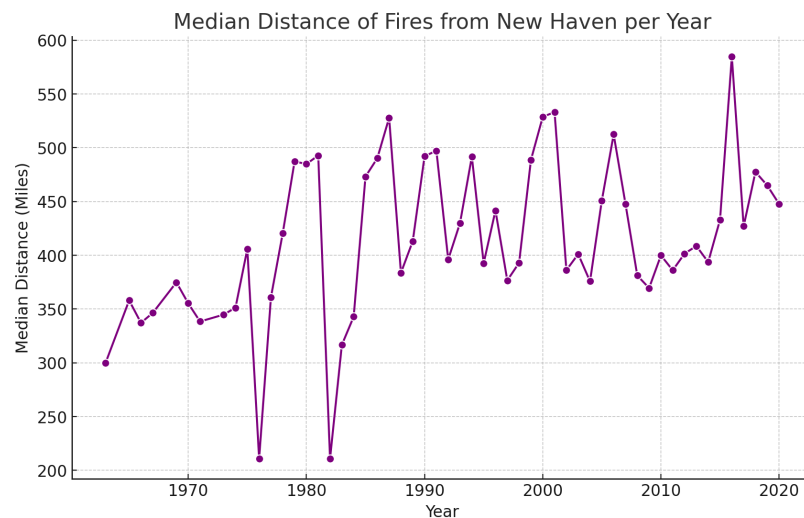
- **Impact Score:** The wildfire impact score revealed a strong correlation between proximity to wildfires and PM2.5 levels, underscoring the outsized effect of nearby fires on New Haven's air quality. For instance, years with higher impact scores, such as 2021, coincided with significant air quality degradation.
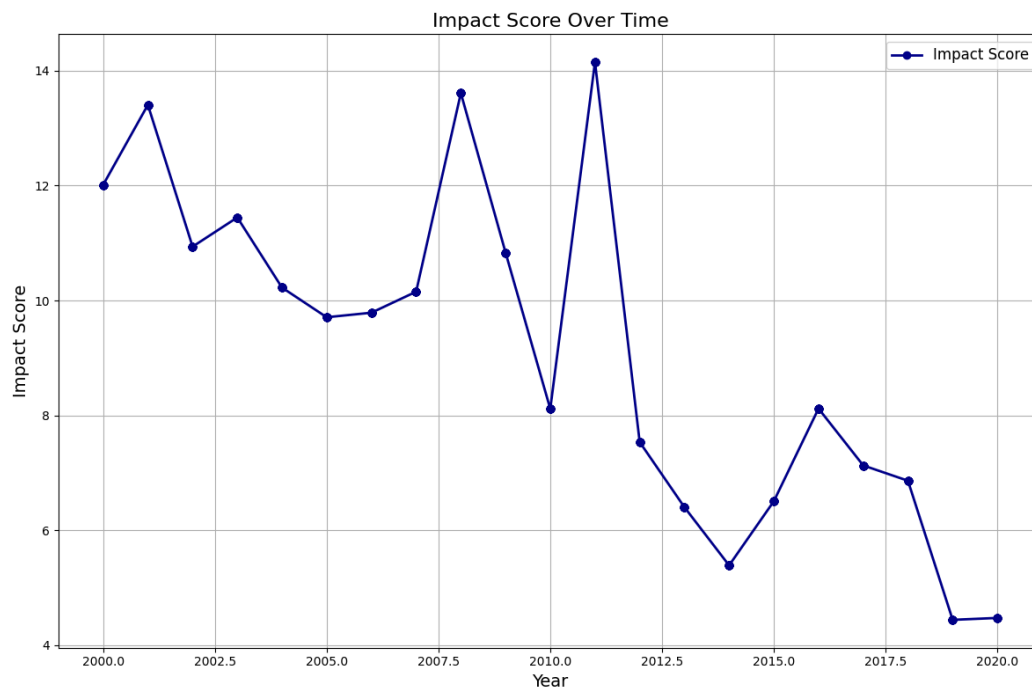
Economic Impacts

Regression analyses used the wildfire impact score as a key independent variable, demonstrating its predictive power in identifying economic vulnerabilities. Industries with higher exposure, as indicated by the impact score, showed statistically significant disruptions in facility counts and spending.

Facility Counts ("Units")

- Manufacturing saw a statistically significant decline of **8.5 units** (p-value = 0.033) during high-impact years. This disruption reflects the sector's sensitivity to environmental and operational challenges caused by smoke.

- Other sectors, including Construction, experienced moderate reductions, indicating broader vulnerabilities in outdoor-reliant industries.

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|    | NAICS Code  | p_value_year | p_value_impact_score | coefficient_year | coefficient_impact_score | Industry     |
+====+=============+==============+=====================+=================+=======================+===============+
| 4  | ('31',)     | 1.32157e-08  |           0.0337099 |        -1.70613 |              -8.51358 | Manufacturing |
+----+-------------+--------------+---------------------+-----------------+-----------------------+---------------+
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Total Annual Wages

- **Wholesale Trade:** Wages increased by **$37 million** (p-value = 0.012), likely driven by logistical demands during smoke events.
- **State Government:** Increased spending by **$51 million** (p-value = 0.041), reflecting emergency measures and wildfire management costs.

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+----+-------------+--------------+---------------------+-----------------+-----------------------+------------------+
|    | NAICS Code  | p_value_year | p_value_impact_score | coefficient_year | coefficient_impact_score | Industry        |
+====+=============+==============+=====================+=================+=======================+==================+
| 3  | ('42',)     | 0.00022112   |          0.00984669 |        3.2192e+06 |             3.67227e+06 | Wholesale Trade  |
+----+-------------+--------------+---------------------+-----------------+-----------------------+------------------+
| 18 | ('G0',)     | 6.12417e-09  |           0.0429356 |        1.7815e+07 |             6.88948e+06 | Total Government |
+----+-------------+--------------+---------------------+-----------------+-----------------------+------------------+
| 20 | ('G2',)     | 6.64609e-07  |           0.0656913 |        9.45663e+06 |             4.52552e+06 | State Government |
+----+-------------+--------------+---------------------+-----------------+-----------------------+------------------+
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5. Discussion and Implications

Key Implications

1. **Manufacturing Vulnerabilities:** The significant reduction in manufacturing facilities underscores the need for fire-resistant infrastructure and operational redundancies to safeguard this critical sector.
2. **State Government Role:** The increase in government spending highlights the importance of proactive measures to prevent wildfires and manage their consequences.
3. **Seasonal Risks:** The alignment of high wildfire activity with summer underscores the need for targeted interventions during these months to minimize economic disruptions.

Human-Centered Reflections

This study prioritizes actionable insights for decision-makers by:

- Highlighting the sectors most at risk to enable targeted resource allocation.
- Focusing on long-term strategies to build resilience, particularly for vulnerable industries such as manufacturing.

6. Limitations

1. **Data Aggregation:** Yearly aggregation limits the ability to capture short-term or seasonal trends and specific wildfire events.
2. **Confounding Variables:** Factors such as economic recessions or global disruptions (e.g., COVID-19) were not explicitly controlled but may have influenced the results.
3. **Assumptions in Impact Score:** The wildfire impact score assumes a linear relationship between PM2.5 levels and economic outcomes, which may oversimplify complex dynamics.

7. Conclusion

This study demonstrates the significant impact of wildfire smoke on New Haven's air quality and its economy. Key findings include:

- **Impact on Manufacturing:** Manufacturing facilities showed measurable declines, emphasizing the need for fire-resistant infrastructure and operational adaptations.
- **Role of State Government:** Increased state government spending highlights the importance of proactive wildfire prevention and management strategies.

Recommendations

1. **Fire Protection for Manufacturing:** Investing in additional fire-resistant infrastructure and operational redundancies will help mitigate facility losses during smoke events.
2. **Proactive State Measures:** Enhanced wildfire prevention programs, coupled with targeted funding for affected industries, will reduce economic vulnerabilities.

3. **Air Quality Monitoring:** Expanding real-time monitoring systems will help industries and residents prepare for and respond to high-smoke periods effectively.

By focusing on these strategies, New Haven can build resilience against the growing challenges posed by wildfires and their secondary effects.