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Assessing The public perception on Economic Impacts of Smog in Pakistan: A Case Study of Lahore

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ABSTRACT
The latest environmental issue in Lahore, the capital of Pakistan, facing smog is attributed to a number of elements including car emissions, industries, agricultural practices, climate change, geographical factors etc. Lahore is ranked 20th largest polluted city yet atmospheric particulate matter is greater than the WHO base. With the growing population, industrialization, economic growth and urbanization, industries were created which contributed to the urban populations growth who were consequently exposed to poor quality air. According to the result young people reported the highest stress (especially those under the age of 19) possibly due to their greater psychological sensitivity to the effects of smog. Females appeared to experience more stress than males potentially due to traditional (current) roles, exposures, or coping mechanisms. Marital Status: Males and females in a relationship (married) reported significantly higher stress potentially due to the additional complexities of dealing with a family during temporal or intermittent infrastructural smog issues. The factors of less income, sick days from work, and loss of revenue only had moderate correlations with symptom severity. However, we believe that financial stress likely adds to poorer health outcomes, either through increases in psychological stress, or limits to healthcare access opportunities Factors such as shift hours and workplace types (e.g. markets) were somewhat of a contributor to symptom severity, but not as meaningful as the economic and health-related variables. We are not saying that occupational exposure does not play a role, just that social determinants of health are larger players. The most significant predictors of symptom severity were frequent headaches, dizziness, eye problems, and stress; suggestive of the influence of smog not just on physical health, but also mental health. Study reveal that smog's economic impacts are to reduced worker's productivity, higher health cost, reduced Business hours that leading to fewer number of customers in the market.

Keywords: *Socioeconomic Impacts, Health Effects, Occupational Exposure, Vehicular Emissions, Particulate Matter (PM), Public Health, Cognitive Decline, Economic Losses, Government Interventions, Geographic Factors, Urban Core, Peripheral Areas.*

Introduction

Lahore, often considered the heart of Pakistan, is in the midst of an ongoing environmental crisis known as smog, largely caused by vehicular emissions, industrial emissions, agricultural

sources (e.g., crop burning), and geographical and climatic circumstances (Iqra Azeem, 2024). Lahore has been ranked amongst the top polluted cities in the world, and is experiencing extremely alarmingly high levels of air particulate matter, much more than WHO guideline recommendations. This pollution has significant impacts on public health, contributing to cognitive decline and disease, as well as impacting the economy with increased health care and transportation costs, etc (Zahid Hussain, 2024). There have been substantial government efforts but the issue remains unsolved, which requires stricter controls of emissions and collaborative action from relevant stakeholders (i.e., government, industries, farmers, and the public). Smog is the result of smoke and fog mixing through photochemical reactions with various pollutants, which may also include sulphur dioxide, and nitrogen monoxide (Mikhail Nizhelskiy, 2025). Weather patterns like high temperatures, fog, and low wind speeds also have an impact on smog (Yavuz, 2025). The research investigates the causes and effects of smog in Lahore, where recent studies have identified the effects of serious problems in everyday life, and outlines immediate and long-term solutions to the increased and concerning crisis (Ramsha Riaz, 2018). Subsequent chapters include a review of earlier studies; methodology; presentation and discussion of data; results; and implications for future directions (Gough, 2019).

Study Area

One of the most populated and economically active urban areas in Pakistan is Lahore, the capital of Punjab, where the current study was carried out (Islam, 2024). The chosen sites reflect Lahore's main business districts and capture a range of socioeconomic factors that can affect smog and other environmental factors (Abid Hussain *, 2025). These include contemporary business districts including Liberty Market, Fortress Stadium Market, and Moon Market (Allama Iqbal Town), as well as traditional marketplaces such Anarkali Bazaar, Ichhra Market, and Kashmiri Bazaar. Along with region-specific markets like Yateem Khana Market, Bhagwanpura Market, Container Market, and Nolakha Market, the information also includes specialized trading zones like Urdu Bazaar, Shah Alam Market, and Lunda Market close to the railway station. These locations, which span the central, eastern, and western regions of Lahore's metropolitan area, are roughly located between latitudes 31.50°N and 31.58°N and longitudes 74.28°E and 74.41°E. These marketplaces were specifically selected to represent differences in traffic congestion, population interaction, and commercial activity—all of which are strongly associated with the socioeconomic elements that contribute to the production of smog in urban settings (Riaz, 2019).

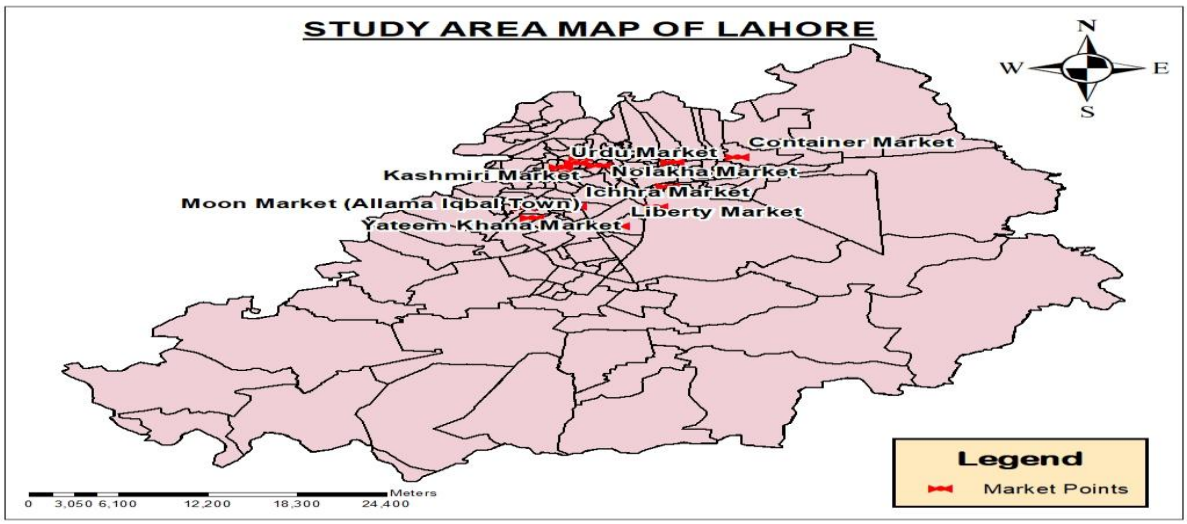

Figure 1 Study Area Map of Lahore

Objectives

The study aims to evaluate winter smog's effect on occupations across Lahore, especially those most at risk and related socioeconomic barriers limiting their ability to cope with it. The study further examines the relationship between urban core/proximity and the impact of smog on workers.

Problem Statement

1. What are the effects of winter smog on occupations in Lahore?
2. What are the social and economic barriers preventing workers from coping with smog?
3. Are there variations in the socioeconomic impact of smog in urban versus peripheral locations?

Methodology

Research Design

In this study, we use a quantitative research design to investigate the health and socioeconomic impacts of winter smog in Lahore. This design fulfills the study aims and will help to answer some research questions focused on the impact of pollution on different occupational groups and the socioeconomic and geographic factors in that impact, and the seriousness of health symptoms due to smog exposure. We chose a quantitative approach because we were interested in the use of a systematic manner of collecting data from a broader sample which could be analyzed statistically so it had a broad applicability, validity, and generalizability. A quantitative approach will allow us to analyze the relationship between nominal and ordinal variables of occupation, location, and smog-related health outcomes, using measurable objectives.

Sampling Strategy

The sampling strategy for this study focused on selecting a representative group of Lahore residents who are most likely to be affected by winter smog. The **target population** included individuals working across various occupations—such as industrial labor, street vending, market trading, and transport services—residing in both the **central urban areas (Lahore municipality)** and **peripheral regions**. These groups were identified due to their high exposure to outdoor air pollution during smog season. A **stratified random sampling technique** was employed to ensure that the sample accurately reflected the diversity of the population. Participants were stratified based on key demographic and occupational variables, including age, gender, occupation, and location, and then randomly selected within each subgroup. This approach was chosen to enhance the generalizability and external validity of the findings, especially in a heterogeneous population like Lahore's. A **sample size of 120 respondents** was determined, taking into account statistical power requirements and available resources. This number was considered sufficient for performing meaningful **correlation and regression analyses**, while also ensuring proper representation across various strata, enabling a deeper understanding of smog's impact on different segments of the population.

Data Collection and Analysis

Data for this study was gathered using a structured questionnaire intended to obtain as much data as possible regarding participants' demographics, work conditions, health symptoms, and economic impacts from wintertime smog. The instrument contained multiple-choice questions, Likert-scale items, and limited-the free-text answer to assist in quantifying some variables-related to symptom severity (for example, headaches, eye irritation) and economic challenges. Before the study was taken to the full group, the questionnaire was piloted on 10% of the

target population for reliability and clarity. Data was collected via mixed modes (i.e., paper based and online survey), which keeps variations in responses, participation was high because people were able to choose a method or complete a written form when they returned to the facilities. The eligibility requirements were identified to the participants' knowledge with full disclosure of the study purpose and anonymity. By the fact-finding procedure, if someone did not complete the survey it was followed up with them with a view to completing the data the participant surveys falling short. Data was analyzed using SPSS software through descriptive statistics (i.e., frequencies, means, standard deviations) to summarize trends in these and through descriptive statistics (correlation and multiple regression) to analyze relationships (occupational role versus geographical location/ status of smog health complaint). Cohen's coefficients were calculated to assess the characteristics and potential relationships of the vital variables, with triangulation included as part of the research process to compare and contrast the findings with secondary data sources, including published literature and public health reports, to complement the research and improve its trustworthiness, generating information for sub-group interpretation. From an ethical point of view, IRB approval was obtained identified post-data collection, and informed consent was secured from study members. Participant confidentiality was respected through the anonymization of data, encrypted electronic records kept in secure storage. While a strength of the study, it was likewise limited by the constraints of the cross-sectional survey, including not being able to draw conclusions regarding causation, together with the additional lack of information potentially generated from self-reports related to social desirability response bias. Possible limitation of the findings was in representation with hard-to-reach populations, albeit data may be useful as pilot work for future inquiries and it was useful to ensure generalizability of findings.

Result and Discussion

This research examined the socio-economic and health impacts of winter smog in Lahore, emphasizing how individual characteristics associated with demographics, ownership of resources, and occupations influence vulnerability (Fatima Jabeen, 2021). The patterns of stress and symptoms were much higher among younger, female, and married participants, where intensity of stress and symptoms were present due to lower resilience or the demand related to responsibilities (Psychology, 2022). Lower income levels were strongly correlated with significantly poorer health, compared to higher income levels, for individuals in low income situations the financial impact of difficulty with finding and affording drugs and health care worsened health because they were also frequently more exposed to smog and had less opportunity to find professional help (Daniel M. Finkelstein, 2022). Outdoor workers, especially in market sectors, could present more intense symptoms because they were exposed for longer durations than those in indoor work situations (Fatima Khanum, 2020).

Statistical analysis indicated that health symptoms (e.g., headaches and stress) were the strongest indicators of the impact of smog, with economic losses and workplace conditions being other important factors that affected the outcomes. Regression models demonstrated these relationships had high explanatory power and to a statistically significant degree (Choi, 2025).

The proposed policies include: raising public awareness, increasing access to healthcare, financial compensation for affected workers, stricter enforcement of environmental policy, improving infrastructure, and targeting vulnerable populations (e.g., children, elderly, low-income families). Future considerations for built and work environments must be made to create ongoing resilience and reduce exposure (H. Pallubinsky, 2023).

Table 1 Descriptive Statistics Output:

This table includes the frequency and mode for each categorical variable, providing an overview of the most common responses and their counts:

Variable	Count	Unique	Top	Freq
Age	120	3	18-25	50
Gender	120	1	Male	120
Marital Status	120	2	Single	81
Industry	120	4	Retail	79
Market Place	120	5	Ichra	37
Working Shift Hours	120	4	8 Hours	48
Smog stops outdoor activities	120	2	No	67
Avoid shopping during smog	120	2	No	56
Decline in quality of social life	120	2	Yes	74
Reduction in profit or salary	120	2	Yes	62
Impact on revenue	120	4	Significant decrease	55
Loss of income due to sick days	120	3	No	52
Severity of symptoms	120	4	Mild symptoms	46
Frequency of headaches or dizziness	120	3	Sometimes	51
Eye irritation or health problems	120	3	Yes	72

Frequency and Percentage Distribution:

This detailed breakdown provides the frequency counts and percentages for each category in every variable, highlighting the distribution of responses across the dataset.

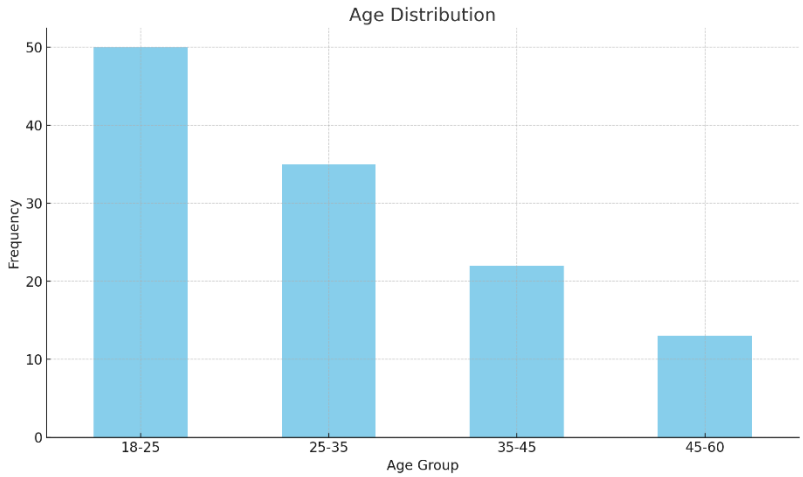

Figure 2: Customer's age group

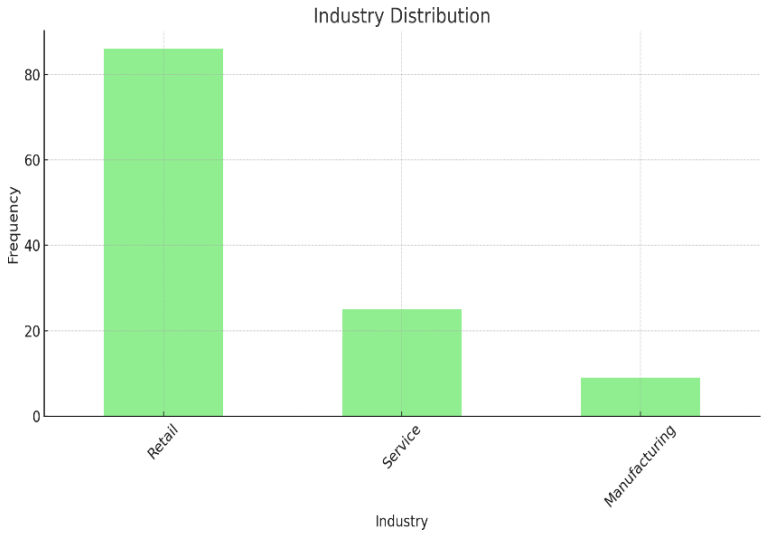

Figure 3: Data collection from different industrial sectors.

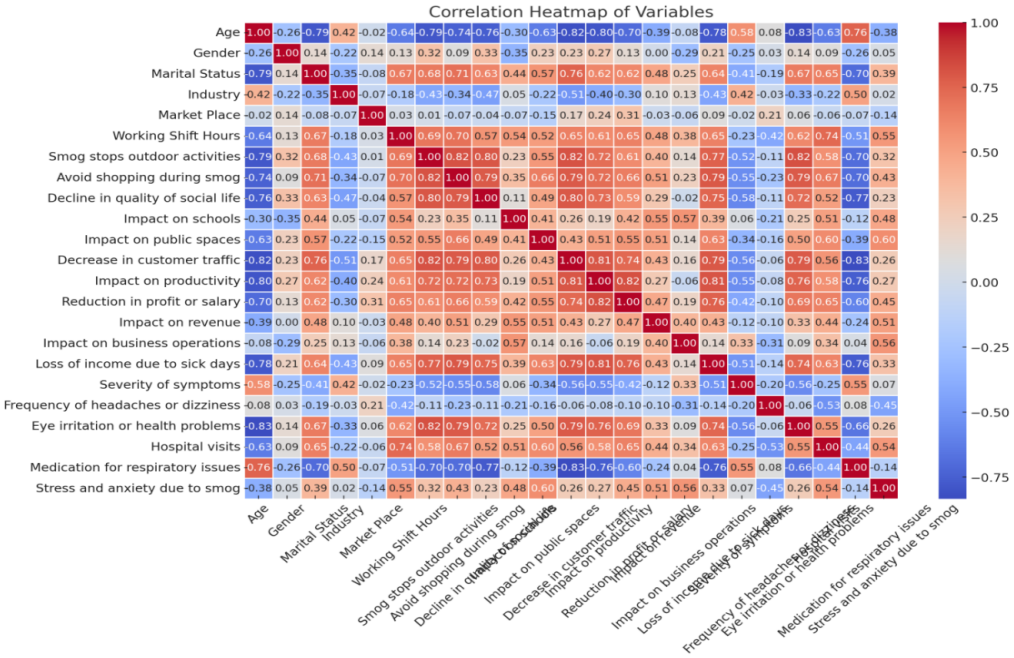

Figure 5: Heat map Showing relationships among variables related to socioeconomic indicators, health impacts and behavioral response during smog episodes

The correlation heatmap in the dataset displays the relationship amongst variables, using colors to represent strength and direction. Positive correlations are displayed in varying levels of red, negative correlations in blue, and neutral correlations in levels of varying blue/red. The heatmap is useful to see patterns - for example, factors that are strongly correlated with symptoms severity or socioeconomic impacts, and helps to identify patterns in the data.

Strongest Correlations in the Dataset

The analyses provided in this study show high correlations between socioeconomic indicators, health impacts, and behavioral response to smog in Lahore. The strongest correlation (r =0.834) was relating to a decrease in foot traffic by customers in commercial areas and the use of medications (inhalers) to treat respiratory conditions, as indicated by the hollow number of

associations because it is showing the effects of health, hence dollars lost stemming from a health issue. Further associations contained in the findings include those relating to reduced outdoor activity from an increase in smog and also eye irritation (r=0.824), as well as income loss or work productivity based on levels of smog risk exposure. Within the context of these associations, we unpack the variations from health symptom worsening leading to behavioral responses, predominantly avoidance of spaces, and spending capacity being reduced because people chose to respond this way. Our findings thus speak directly to data that reflects damaging impacts to commerce and the local economy.

In ranking health symptoms when considering limited outside activity, eye irritation had the highest positive correlation (0.824) suggesting there is a high likelihood that it is a contributing factor for avoiding going outside altogether. However, the moderate negative correlation with all symptom severity shows that staying inside ensures that symptoms from exposure will be reduced. On the other hand, stress and anxiety displayed a slight positive correlation indicating that some of the psychological effects remain even when physical exposure has been reduced.

The demographic analysis revealed high levels of stress from smog among younger individuals, females, and married individuals. It may be that younger individuals, females, and married individuals are arguably more impacted since these individuals may be the most environmentally conscious or face greater levels of responsibility. With that, these groups are not just more entitled, they are also more susceptible. These findings provide a strong case for engaging with public health awareness, economic support, and psychological intervention strategies for high-risk individuals in Lahore during smog seasons.

Stress Levels and Regression Analysis Findings

Data analysis revealed important patterns in stress levels and severity of symptoms as they relate to exposure to smog:

Stress by age, gender, and marital status

The participants in the youngest age group had the highest average stress levels, which suggests that younger individuals may experience a higher degree of psychological vulnerability. Women reported greater levels of stress than men and married participants reported higher levels of stress than single participants, which likely relates to increased responsibilities and concerns over caregiving.

Regression analysis on severity of symptoms

The analysis relied on a regression model to assess the degrees of factors contributing to the severity of symptoms related to smog exposure. The R-squared of the model was 0.264. This indicates that about 26.4% of the variance in symptom severity can be accounted for by the independent variables chosen in the model.

Key influential factors

Headaches and dizziness – frequency (coefficient = 0.582) and stress and anxiety had the most influence (coefficient = -0.565). This indicates that individuals dealing with smog apply the greatest effect on symptom severity from physical discomfort (headaches) and psychological stress. Other factors such as age, income loss, and work environment had less effect compared to the factors mentioned above.

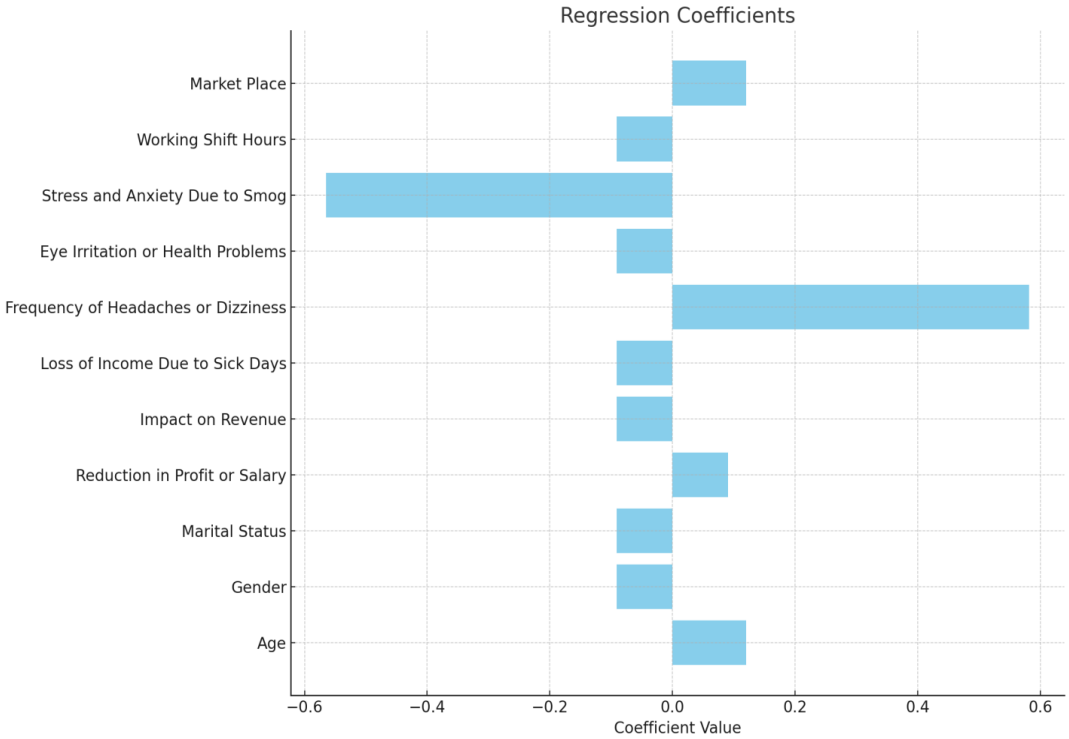

Figure 9: Regression Coefficient

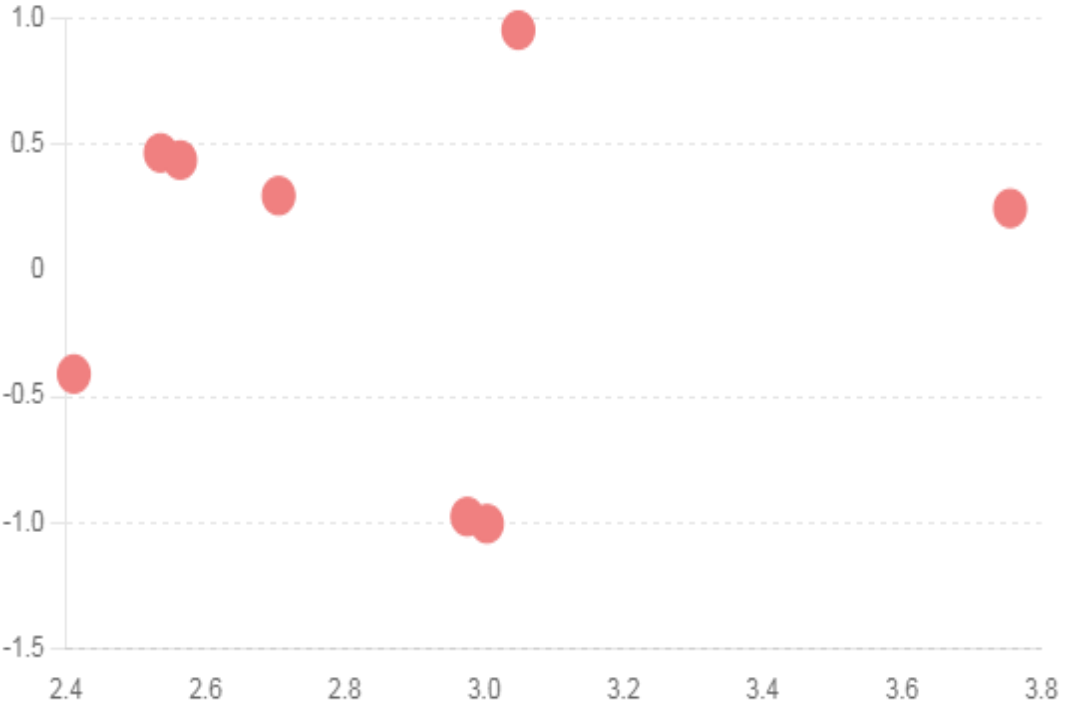

Figure 10: Regression Coefficient

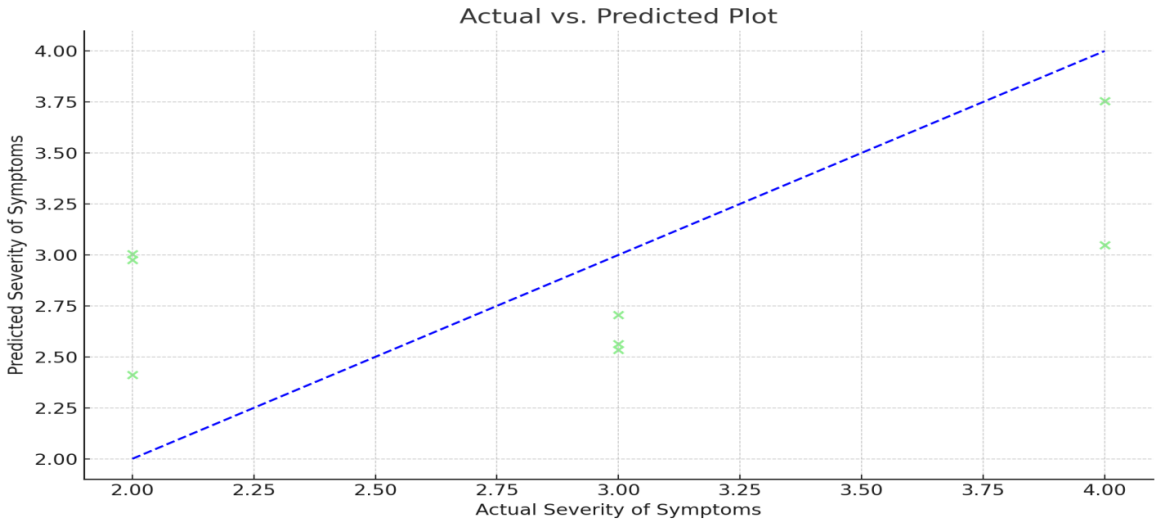

Figure 11: Severity of the symptoms

Model Evaluation and Key Findings:

Model Evaluation:

The regression diagnostics demonstrate a very well-fitting model:

- Coefficient plots identified the most important variables that influenced symptom severity: stress and headaches.
- Residual plots indicate that the variable influence has been evenly and randomly distributed, supporting our assumptions about the model and that we do not have heteroscedasticity.
- Actual- vs. predicted-plots indicate we have a fairly accurate predictive model with most of the data points being close to the expected diagonal. That said, we have captured the relevant relationships in our model.

Demographics Insights:

- Age: Young people reported the highest stress (especially those under the age of 19) possibly due to their greater psychological sensitivity to the effects of smog.
- Gender: Females appeared to experience more stress than males potentially due to traditional (current) roles, exposures, or coping mechanisms.
- Marital Status: Males and females in a relationship (married) reported significantly higher stress potentially due to the additional complexities of dealing with a family during temporal or intermittent infrastructural smog issues.

Demographic predictors were significant predictors of stress levels and demonstrate significance to targeted strategies in public health and environmental health.

Economic Impact

The factors of less income, sick days from work, and loss of revenue only had moderate correlations with symptom severity. However, we believe that financial stress likely adds to poorer health outcomes, either through increases in psychological stress, or limits to healthcare access opportunities, which is supported by Anjum et al (2019).

Health and Well-Being

The most significant predictors of symptom severity were frequent headaches, dizziness, eye problems, and stress; suggestive of the influence of smog not just on physical health, but also mental health. This study affirmed previous studies that observed a link between air pollution and a decline in overall systemic health.

Work Conditions

Factors such as shift hours and workplace types (e.g. markets) were somewhat of a contributor to symptom severity, but not as meaningful as the economic and health-related variables. We are not saying that occupational exposure does not play a role, just that social determinants of health are larger players.

Summary of Findings

This chapter of the research establishes that smog has many different consequences across physical health, mental health, and economic aspects with meaningful differences by demographic groups.

- Health effects are most closely tied to symptom severity via frequent headaches and eye distress.
- Economic loss from lost earnings and business activity is somewhat associated with deteriorating health.
- Stress levels are greatly different based on age, sex, and marital status—with younger, female, and married people exhibiting the highest stress levels.

The breadth of this research speaks to the need for comprehensive policies around the mitigation of smog not only with regard to air quality management but also with the management of health with respect to public health issues, mechanisms of economic compensation and mental health, with attention to vulnerable subgroups of the population. The breadth of this research speaks to the need for comprehensive policies around the mitigation of smog not only with regard to air quality management but also with the management of health with respect to public health issues, mechanisms of economic compensation and mental health, with attention to vulnerable subgroups of the population.

Limitations

This study has a number of limitations that may undermine the reliability and generalizability of the findings reported. The main limitations include availability and quality of data, reliance on cross-sectional rather than longitudinal data, and secondary data that may include sampling and response biases. These factors limit the ability to establish causal relationships or consider potential under-representations of vulnerable communities or other geographic or contextual variations. Moreover, as this study primarily examined winter smog's socioeconomic and health impacts in Lahore, Punjab, its geographic scope and timing limit the possible uses of these findings for other contexts or regions. Therefore, caution must be exercised when interpreting these results. Future research should work to address these shortcomings by conducting longitudinal studies to examine chronic effects, focus on specific population groups (e.g., children, elderly, people with pre-existing conditions), incorporate urban and rural differences, and, where possible, consider level of service considerations (i.e., inexpensive, moderate, or high levels of service). The following methodological recommendations can also be integrated into future research to improve the accuracy, richness, and relevance to policy-application of potential studies of socioeconomic and health impacts of smog: greater use of standardized health questionnaires, qualitative methods, collaboration between disciplinary domains, and, where possible, advanced technologies (i.e., remote sensing, machine learning for predictive modeling).

Conclusion

This research contributes needed knowledge about the socio-economic and health impact of winter smog in Lahore. It demonstrates how outdoor workers experience greater exposure and occupational risk associated with exposure to environmental pollutants. It is evident that low-income groups are at greatest risk due these groups having less access to health services and protective possibilities. The recommendations call for regionally specific pollution control

options, in urban and rural context. The study recommends further policy development as we experience climate change, urbanization, and population expansion. Continued longitudinal, interdisciplinary studies are also warranted to better understand the chronic health impacts and the groups at highest risk. Regarding air pollution, short-term objectives require more legislation for air pollution, adoption of green technologies, improved access to health care, and targeted protection for outdoor workers. Public health campaigns are also necessary to develop awareness, promote prevention and motivate broader societal change for improved environmental sustainability.

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