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# Health and Economic Impact of Air Pollution in Delhi

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## NCAER Working Paper

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### Abstract

Many cities in urban India, particularly the metros, are major hotspots of air pollution with a PM 2.5 concentration level ranging above the permissible limits defined by the WHO for most of the year. Since the transport sector is a major source of air pollution in urban India, the Government of India adopted BS-VI emission standards in 2016 for all major on-road vehicle categories. The rollout of clean fuel (BS-VI) in India began in the capital city Delhi, the most polluted city of India.

In this context, this paper attempts to analyse the economic cost of air pollution in the States of Delhi/Haryana through a primary survey of households in order to understand whether the introduction of clean fuel has reduced the pollution. While Delhi is our treatment group for this analysis, Haryana is our control group, as clean fuel was still not rolled out in the latter State when the primary survey was undertaken.

We find a decreasing trend in the self-reported short and long-term health illnesses among respondents in Delhi while similar differences have not been noted in Narnaul, Haryana. Moreover, the cumulative economic cost of pollution from health expenditure, productivity loss, and contingent valuation is found to be lower in Delhi than in Haryana.

**Keywords: A**ir pollution, Delhi, Health and Economic Cost, Haryana, BS-VI fuel

**JEL Classification:** I18, Q51, Q52, Q53, Q58

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## 1. Introduction

India is one the countries with the highest exposure to particulate matter (PM) 2.5 in the world. The mean PM 2.5 level was 89.9 μg/m$^3$ in 2017 with pollution being the highest in Delhi followed by Uttar Pradesh, Bihar, and Haryana (Balakrishnan et al., 2019). No doubt, the high levels of air pollution take a toll on the health of people in India. In a recent study, it has been shown that an average Indian could have continued to live for an additional 5.2 years if the global air pollution standards are maintained (Health Effects Institute, 2019). Another study conducted by researchers at the International Food Policy Research Institute (IFPRI, 2019) pegs the economic cost of exposure to air pollution from crop residue burning at $35 billion, or nearly Rs 2.35 lakh crore annually, for the three north Indian States of Punjab, Haryana, and Delhi.

While we do not question the basic premise that air pollution has an adverse health impact, we are sceptical about the figures quoted and the methodology adopted in estimating the cost. For instance, IFPRI has used India's fourth District Level Health Survey data to correlate pollution with health impact. However, this health survey does not cover all the diseases linked to air pollution. In India, most studies use cost estimates from developed countries and then deflate the numbers using the Purchasing Power Parity (PPP) conversion approach to arrive at the economic costs of pollution. However, this approach has a major flaw as it overlooks how human immunity develops in the polluted and non-polluted areas. Completely overlooking this fact may lead to an over-estimation of the adverse impacts of pollution.

Given these lacunae, we have undertaken a primary survey in Delhi/Haryana to understand the following economic burden of air pollution through an analysis of the direct and indirect costs by calculating productivity losses and welfare losses based on the number of days missed at work and the cost of health treatments and daily wages. The survey was undertaken following the launching of clean fuel in Delhi to understand the impact of clean fuel on Delhi's population. Understanding air pollution originating from the transport sector is of paramount importance as nearly 40 per cent of the air pollution comes from this source. Delhi is our treatment group for the survey. Since dirty fuel (BS-IV) was distributed in Haryana during the survey period, we have also undertaken a parallel survey in Haryana for comparative analysis, which is our control group.

The structure of the rest of the paper is as follows. Section 2 briefly discusses the various approaches to measure the economic cost of air pollution. The subsequent sections discuss the survey framework adopted to collate the data along with the basic feature of our questionnaire. Section 4 discusses our results and the Section 5 provides the concluding remarks.

## 2. Measuring the Economic Costs of Air Pollution

The socio-economic burden of any disease is measured in terms of both the financial and non-financial costs faced by individuals. However, our focus is on the financial aspects of air pollution characterised by the direct treatment cost and indirect cost of loss employment.

Three approaches are adopted in literature for measuring the economic costs of air pollution. These are discussed in detail below.

### *2.1. The Cost of Illness Approach*

'Cost of illness' studies are primarily common in medical literature, which identify and measure the costs associated with a particular disease. These include *the direct, indirect, and intangible costs* associated with an illness. While health care costs are related to estimation of the medical care expenditures for diagnosis and treatment, the non-health costs include those incurred on transportation, household expenditures, and other informal care of any kind. The goal of a cost of illness analysis is to evaluate the economic burden that illnesses impose on society as a whole (Jo, 2014). Therefore, the aim is to itemise, value, and add the costs entailed in dealing with a particular problem to inform policymakers about the real monetary impacts caused by a disease (Jefferson et al., 2000). This value represents the cost to the society that can be mitigated with a health care intervention.

### *2.2. Productivity Loss Approach*

Productivity loss does not necessarily represent a loss of income to the individuals but is a loss to the economy. Workers missing out on the days at work due to health-related disabilities and the associated loss of income gives a societal perspective to the burden of disease. Productivity loss can be incorporated into economic evaluations, along with the premature mortality costs for informed policy decision. This approach assumes that individuals have the potential to produce a stream of outputs over their working lives, which may be reduced due to illness. The work time lost is then valued at the market wage rate reflecting the value to the society (Pearce, 2016).

### *2.3. Welfare Loss Approach*

Economic valuations are primarily undertaken with the objective of cost-benefit analyses, which help the government to measure the social costs of any policy that are not reflected in the existing markets and prices but are still crucial to people's well-being.

There are a few studies that attempt to estimate the economic cost of air pollution in the context of developing countries. To the best of our understanding, the following list provides a comprehensive picture of the studies undertaken to highlight Indian values.

- According to the Global Burden of Disease Study (2015), the worldwide number of premature deaths is approximately 3 million per year, of which India's share is about 18 per cent of the global burden of disease (Forouzanfar et al., 2015; Giannadaki et al., 2016; Lelieveld et al., 2015).
- Etchie et al. (2017) estimated that PM 2.5 pollution in India resulted in an economic loss of US $2.2 billion (95 per cent CI: 1.7, 2.8) per year. Their calculation of economic cost used the statistical value of life years measured at US $602,000 by OECD (2014).
- Ghude et al. (2016) found that PM 2.5 exposure led to about 5,70,000 premature mortalities in India in 2011. With a Value in Statistical Life (VSL) for India computed at US $1.1 million in 2011 adjusted by GDP per capita on a PPP basis, the total economic cost due to premature mortality could have been about US $640 billion in 2011. The associated loss in life years is estimated at 3.4 years for all of India, with the highest value of about 6.2 years found for Delhi.

The Institute of Health Metrics and Evaluation (IHME) estimated the air pollution-related premature deaths in India to be 692,425 in 2010. Based on these numbers and using the PPP-adjusted VSL figures of US $0.602 million, OECD (2014) estimated that the economic cost of deaths from ambient air pollution amounted to US $416,704 million.

As the above figures indicate, all the studies have mostly depended on the value derived from the developed country surveys. The survey sample of the developed countries can be structurally different from that of the Indian population with regard to their exposure to pollution, as well as the knowledge and understanding of the health effects of air pollution.

An important and innovative contribution of this paper is the welfare analysis and estimation of the Value of Life Years Lost (VOLY) due to air pollution mortality based on a contingent valuation survey administered in India.

## 3. Survey Framework and Questionnaire Design

The survey was conducted in two phases at six places in Delhi NCR and also at Narnaul, Haryana, for the purpose of comparing the BS-IV and BS-VI regimes. Throughout the project report, we will refer to these two phases as Phase I and Phase II. Phase I of the survey took place in the month of March 2019 whereas Phase II was conducted in the months of November–December 2019. The rationale behind conducting two phases was not only to allow the capture of the air quality of Delhi, but also to assess if these seasonal differences led to any significant change in the nature of the disease experienced by the respondents and therefore, any implications in health expenditure patterns.

The study (during both Phase I and Phase II) focused on the people who are severely, moderately, and least exposed to air pollution. The following groups were selected for the study:

- Bus drivers and conductors;
- Office staff;
- Street vendors;
- Construction workers; and
- Construction control group.

These groups were selected in order to capture the level of exposure to pollution among the most exposed groups like bus drivers, conductors, and street vendors who spend the whole day working outside in the open; and the least exposed group, that is, office staff, who spend their day working inside in a cleaner, less polluted environment. Selecting the construction worker was important to facilitate an insight about the kind of pollution that exists in the construction industry and also in terms of the ways in which it is different from the pollution effects caused by vehicular emission. Also, a group of villagers with limited exposure to pollution was selected as a part of control group. Table 1 presents the distribution of the sample surveyed by occupation.

The sampling size included 150 each of bus drivers, office staff, and street vendors. The remaining constituents in the sample who were surveyed were 100 construction workers and 50 control group villagers. This comprises 600 samples for each period of the study. It is, however, important to mention that the group of *bus drivers* comprise AC bus drivers, non-AC bus drivers, and also the bus conductors. For brevity, we provide their distribution along with that of the other study subjects.

**Table 1: Occupation-wise Distribution of the Sample**

| | Phase I (%) | Phase II (%) | Phase I (%) | Phase II (%) |
|---|---|---|---|---|
| AC bus drivers | 1.61 | 0.8 | - | - |
| Non-AC bus drivers | 14.61 | 19.6 | 14.04 | 9.8 |
| Bus conductors | 9.47 | 13.9 | 28.07 | 27.4 |
| Office staff | 24.24 | 24.16 | 31.58 | 32.9 |
| Street vendors | 23.11 | 19.5 | 26.32 | 29.6 |
| Construction workers | 16.37 | 10.2 | - | - |
| Construction control | 10.59 | 11.6 | - | - |
| Total | 100 | 100 | 100 | 100 |

*Source*: Computed by the authors.

DTC bus depots and busy streets across Delhi with clusters of street vendors were our primary sites for sample collection.

In Phase II, the goal was to track down as many Phase I respondents as possible. Using the personal identification information, we tried to establish contact with the respondents. We were able to track down 283 of the 623 of the Phase I respondents (about 44 per cent of the total).

The questionnaire comprised a combined set of questions focusing on the demographic, economic, and social costs, and the types of health problems faced by the respondents. The cost includes both direct expenditure as well as indirect costs incurred by the people by capturing the number of days of work they missed due to sickness related to air pollution. In order to measure the Willingness to Pay (WTP) for reduced air pollution by the respondents, the questionnaire also focused on whether the respondents were willing to pay anything for improvement in air quality or not, and if not, why.

We conducted surveys through Computer Assisted Personal Interview (CAPI) after intensive training of the enumerators.

## 4. Analysis of the Results

### *4.1. From the Cost of Illness Approaches*

The survey aims to understand the nature of health care expenditure incurred by the respondents due to probable diseases related to air pollution during the three months preceding the date of the survey. The questionnaire lists air pollution-related diseases and asks the respondents to delineate their health care utilisation pattern in relation to those diseases. The pattern of utilisation may involve self-care, consultation, or hospitalisation for those diseases, and the total expenditure incurred on treating them. The cost of health care would also change in accordance with the different health service providers (private or public) approached for the treatment. In addition to the cost of drugs and consultation fee, the expenditure incurred on transportation also gives an idea of the frequency of visits to the doctor and the other additional non-health expenditure burdens imposed by the disease.

Table 2 and Figure 1 highlight the average monthly health expenditure borne by different surveyed groups in both Delhi and Narnaul. In addition to information related to Phase I and Phase II, a column with information from the two phases of data appended together is also provided. The questionnaire asked the following question:

*"On average what is your monthly health expenditure?"*

As seen in both Table 2 and Figure 1, 45 per cent of the respondents in Delhi reported a meagre average health expenditure of Rs. 0–100; the average monthly health care expenditure incurred by a majority of them (67 per cent) was below Rs. 500. In the case of Narnaul, the respondents reportedly incurred a higher average health expenditure, with 36 per cent of them reporting a monthly health expenditure of Rs. 0–100, and about 13 per cent and 9 per cent spending Rs. 1000–5000, and more than Rs. 5000 per month, respectively, on an average, on health care. When these numbers are compared with the corresponding numbers from Phase II, it is seen that for both Narnaul and Delhi, the percentage of sampled individuals in the lower health expenditure categories increased. Almost about 50 per cent of the appended sampled individuals incurred expenditure in the category of Rs 0–Rs 100 in Delhi, whereas the corresponding number was 44 per cent for Narnaul.

**Table 2: Average Health Expenditure Incurred by the Sampled Population**

| **Average Health Expenditure (Rs)** | **Phase I (%)** | | **Phase II (%)** | | **Appended (%)** | |
|---|---|---|---|---|---|---|
| | ***Delhi*** | ***Narnaul*** | ***Delhi*** | ***Narnaul*** | ***Delhi*** | ***Narnaul*** |
| 0–100 | 45 | 36 | 54 | 48 | 50 | 44 |
| 101–500 | 22 | 21 | 21 | 29 | 22 | 25 |
| 501–1000 | 16 | 22 | 13 | 11 | 14 | 15 |
| 1001–5000 | 14 | 13 | 9 | 10 | 11 | 11 |
| >5000 | 3 | 9 | 4 | 2 | 3 | 5 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 |

*Source*: Computed by the authors.

The mean health expenditures of the three months preceding the survey encompass the total health costs entailed in treating air pollution-borne diseases. Each individual was asked if he/she had suffered from any of the air pollution-borne diseases listed in the questionnaire, during the last season. Depending on their responses, they were further asked about the concomitant actions they must have taken for treatment of those diseases. The specific questions pertaining to this information, as asked in the questionnaire, are depicted in the box below:

*Whether you suffered from the following diseases during this season?*

*The list of diseases presented to them are as follows:*

- *i) Eye/Nose/Throat Irritation/Allergies*
- *ii) Breathlessness*
- *iii) Cough/Wheezing*
- *iv) Headaches*
- *v) Asthma Episodes*
- *vi) Chronic Bronchitis*
- *vii) Cardiovascular*
- *viii) Skin Allergies*

*"Total Expenses due to pollution-borne diseases (This includes: Doctor Visit; Medicines; Diagnostic charges; Hospitalisation costs)."*

Conditional on their responses, they were asked the following questions subsequently:

*If they sought self-care;*

*If they sought consultation; and*

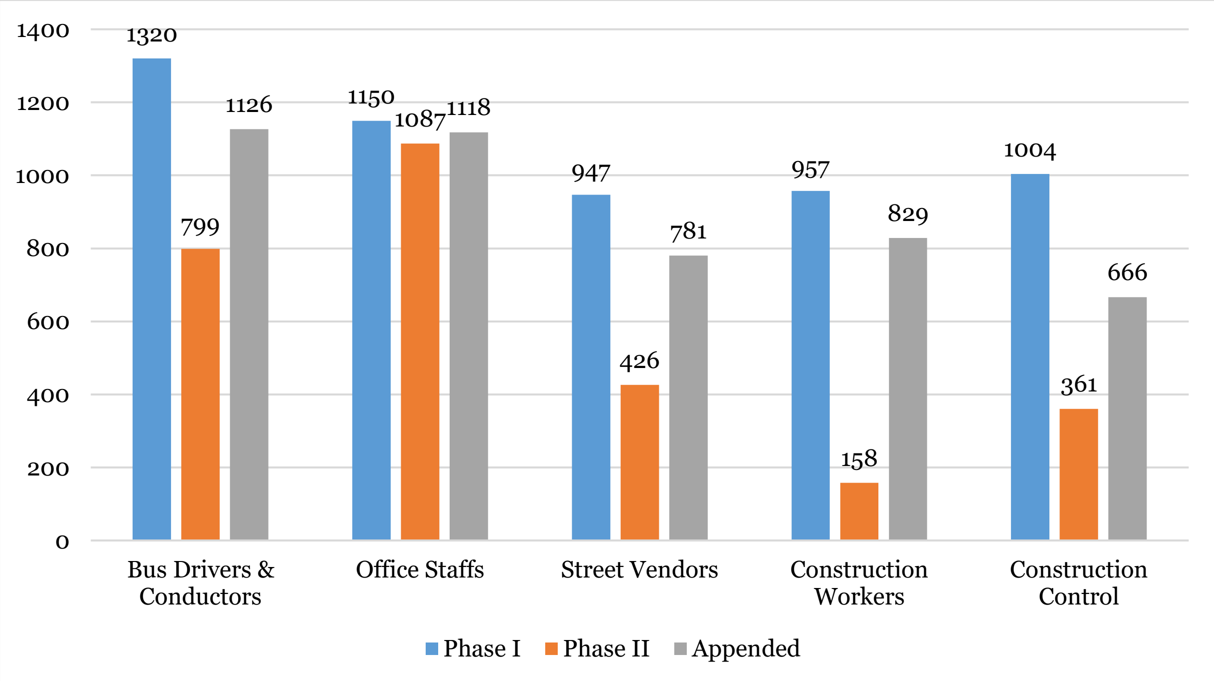
*If they were hospitalised.*

Figure 1 depicts the health expenditures specific to air pollution and related diseases for Delhi. Also, the mean amounts categorised by different occupational groups illustrate the impact of pollution on the exposed versus the non-exposed groups. The figure shows that for the Delhi sample, the mean health expenditure among the different survey groups has decreased for all the study groups. *Bus drivers and conductors,* comprising one of the major groups exposed to air pollution incurred the highest medical health expenditure, that is, an amount of Rs. 1,320 in Phase I, which decreased to Rs. 799 in Phase II. The corresponding figure for *office staff* at the DTC offices was Rs. 1,150 in Phase I, which again decreased to Rs. 1,087 in the following phase. *Street vendors*, who are believed to be the most vulnerable group as they face the maximum exposure to pollution, are seen to be incurring the lowest expenditure, at Rs. 947, which too had fallen to Rs. 426 in the next phase. Therefore, while interpreting the expenditure figures, one should look at the health expenditure figures with caution conditional on the ability of the respective groups to avail of health care services. The lower health expenditure incurred by the street vendors belonging to the most exposed group can be a case for that.

However, it is also important to acknowledge that construction workers are also constantly exposed to pollution, but the magnitudes of their exposure are assumed to be significantly lower than those of the rest of the groups. The health care expenditure is also seen to be falling for them which points to the overall trend of a decrease in health care expenses in the sampled population. This trend is also true for the Narnaul sample.

As noted earlier, the values are important as they reflect the health utilisation patterns of the different groups. However, the cost of health care is directly proportional to the uptake of health care services and can only serve as an indicator for the utilisation patterns. Thus, these values should not be used to arrive at any conclusions about the overall health status of individuals, which would require a more systematic and in-depth understanding of the data set.

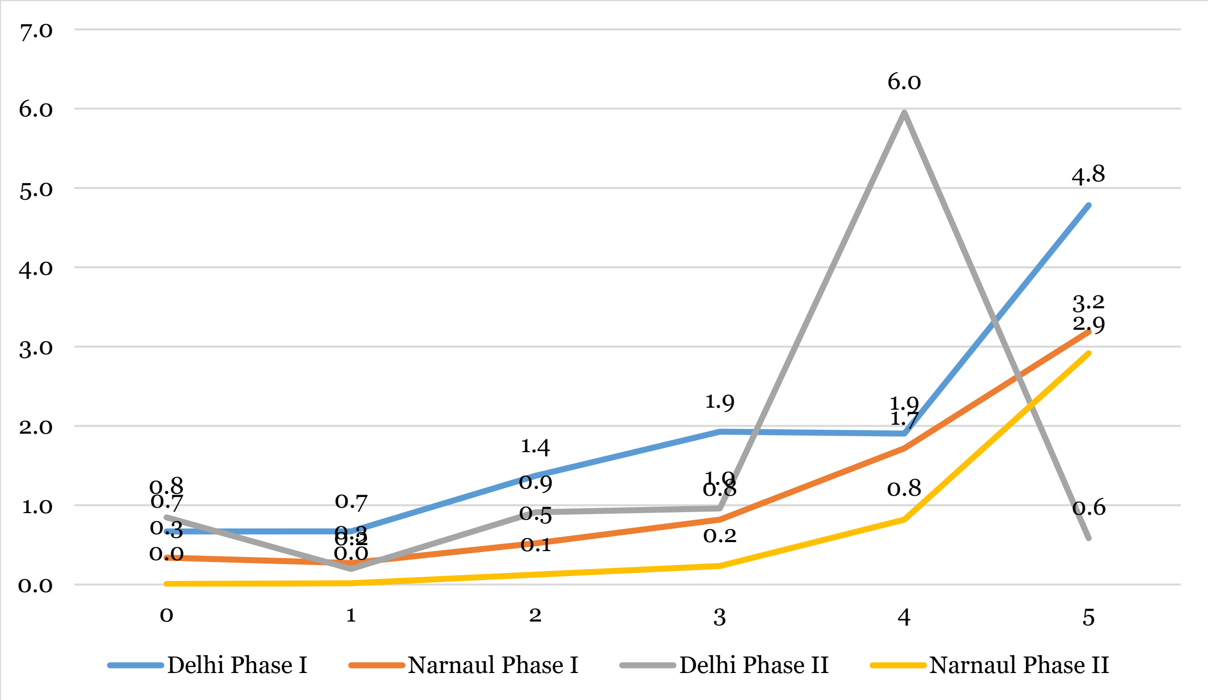
**Figure 1: Mean Health Expenditures (Rs) Incurred by Respondents in Phases I and II (Delhi Sample)**




*Source*: Computed by the authors.

The share of health expenditure as a percentage of income indicates the magnitude of the health care burden being suffered by individuals. As the number of health problems increases, the percentage of health expenditure to the corresponding income level increases monotonically. The horizontal axis in Figure 2 gives the number of health problems being suffered by the respondents, whereas the vertical axis refers to the average percentage of income spent by the respondents, respectively, for the associated number of health illnesses. As this figure shows, results for Delhi and Narnaul are similar when it comes to health problems less than 3, that is, individuals are spending less than one percentage of their income even when they are suffering with more than two diseases whereas in the case of individuals suffering from four or more health issues, the share of income spent on expenditure can be as high as 5.95 per cent (Delhi Phase II) or 3.19 per cent (Narnaul Phase I).

**Figure 2: Mean Health Expenditure as a Percentage of Income by the Number of Health Problems**




*Source*: Computed by the authors.

Apart from the health expenditures, the non-health expenditures such as transportation charges too constitute a significant proportion of the total costs. In this context, the respondents were asked the following question:

> [What were the] *total transportation expenses incurred by you to receive medical care*?
> *(this also includes transportation cost of family members if they accompanied you).*

The mean values of the transportation costs recorded for respondents in the Delhi and Narnaul samples are also accounted for while estimating the total health expenditure. Therefore, the total health expense is the sum of the medical expenditure cost and transportation cost. As Table 3 shows, the respondents of both Narnaul and Delhi have recorded a significantly lower health expenditure than that reported in Phase I. The amounts for Delhi are Rs. 1,403 and Rs. 876 for Phase I and Phase II, respectively, whereas the corresponding figures for Narnaul are Rs. 1,188 and Rs. 122, respectively.

**Table 3: Significance Testing**

| Health Expense (Sample estimates) | Health Expenses (Rs) | |
|---|---|---|
| | *New Delhi* | *Narnaul* |
| Phase I | 1,403.03 | 1,188.08 |
| Phase II | 876.97 | 122.68 |
| Appended | 1210.43 | 524.03 |
| P-Value | 0.0027 | 0.0074 |

*Source*: Computed by the authors.

The average expenditure in Table 3 is the sample estimate obtained from the survey, which is then weighted to project an approximate amount of health expenditure that is likely to be incurred in New Delhi and Haryana.

The estimation of respiratory prevalence for these two States was out of the scope of this project. Therefore, we rely on the literature review and extrapolated prevalence rates from the published literature (see from Salvi et al., 2018). The Global Burden of Disease (GBD) study came up with modelled estimates of the number of chronic respiratory diseases likely to be occurring in Indian States. Using these GBD estimates, especially for Chronic Obstructive Pulmonary Disorder (COPD) and asthma, and our sample estimates of the average amount of health care expenditure, we provide a crude projection of the total direct cost likely to be associated with air pollution for the States of New Delhi and Haryana (Table 4). It must, however, be acknowledged that these are crude figures, especially given the limited number of samples from Haryana.

**Table 4: Total Weighted Health Expense of New Delhi and Haryana Resulting from Respiratory Illnesses (Rs billion)**

| Total Health Expenses | Delhi | | | Haryana | | |
|---|---|---|---|---|---|---|
| | *Phase I* | *Phase II* | *Appended* | *Phase I* | *Phase II* | *Appended* |
| Sensitivity 1 | 1.18 | 1.001 | 1.02 | 1.66 | 0.171 | 0.73 |
| Sensitivity 2 | 0.62 | 0.531 | 0.54 | 0.95 | 0.098 | 0.42 |

*Source:* Computed by the authors.
*Note*: The figures for Delhi are 8,43,000 and 4,47,000, respectively, for COPD and asthma, while those for Haryana are 1,401,000 and 804,000, respectively, for COPD and asthma in Haryana. Sensitivity 1 and Sensitivity 2, respectively, used these two figures for each of the State.

### *4.2. Income Elasticity*

Income elasticity is estimated to give the readers an idea of how individuals at different levels of income respond to health expenditures. The elasticity is estimated by using a double log model while controlling for the demographic characteristics. The model used is as follows:

$$\log(HealthExpense) = \alpha + \beta \log(income) + \delta X_i + \epsilon$$

where $\beta$ corresponds to the income elasticity of health expenditure, $\epsilon$ is the error term, $X_i$ is the vector of individual variables and $\delta$ is the vector of unknown parameters. Table 5 shows that health expenditure is income-inelastic (e<1). This holds true for all the phases and also for the appended data set. If income increases by Rs 100, health expenditure in Delhi (Narnaul) will increase by Rs 24 (Rs 29), which is Rs 26 (Rs 46) when we account for control variables.

**Table 5: Income Elasticity of Health Expenses**

| Income Elasticity/ Variables | Delhi | | | Narnaul | | |
|---|---|---|---|---|---|---|
| | ***Phase I*** | ***Phase II*** | ***Appended*** | ***Phase I*** | ***Phase II*** | ***Appended*** |
| Only income | 0.29 | 0.26 | 0.24 | 0.20 | 0.27 | 0.29 |
| With demographic variables | 0.24 | 0.31 | 0.26 | 0.30 | 0.80 | 0.46 |

*Source:* Computed by the authors.
*Note:* The demographic variables used in the model other than income are age, occupation, health problems, house ownership, and education.

### *4.3. Productivity Loss*

For estimating the productivity loss and the foregone labour output, the number of missed work-days due to diseases related to pollution and income are the primary interest variables. The survey asks the respondents specifically if they have missed out on the days at work due to any air pollution-related diseases.[1] The following question was posed to the respondents:

"How many days during this winter season have you taken leave due to air pollution related health problems?"

In both the phases, a majority of the respondents did not miss any work-day due to reasons related to pollution. However, 10.16 per cent (9.18 per cent) of the respondents in Delhi and 12.73 per cent (7.78 per cent) of the respondents in Narnaul in the respective phases said that they had missed 1–3 days of work. In Delhi, we also see at least 11 per cent and 9 per cent of the respondents having missed work for more than 5 days (Table 6).

The distribution looks similar in the case of the Narnaul population, wherein about 79 per cent of the respondents had not taken any leave of absence and 4 per cent had missed 6–10 days of work due to illnesses related to air pollution.

[1]However, it is important to mention at this point that in the productivity loss calculation, no distinction has been made between the seasonal, contractual, and full-time employees.

**Table 6: Number of Missed Work-days due to Air Pollution-borne Diseases (Percentage of the Sample)**

| Days Missed | Phase I (%) | | Phase II (%) | |
|---|---|---|---|---|
| | *Delhi* | *Narnaul* | *Delhi* | *Narnaul* |
| 0 days | 77.90 | 78.0 | 82.13 | 92.22 |
| 1–3 days | 10.16 | 12.73 | 9.18 | 7.78 |
| 4–5 days | 4.03 | 5.45 | 4.35 | 0 |
| 6–10 days | 3.87 | 3.18 | 2.42 | 0 |
| 11–15 days | 1.77 | 0 | 0.97 | 0 |
| More than 15 days | 2.26 | 0 | 0.97 | 0 |

*Source:* Computed by authors.

Using the human capital approach methodology, we have estimated the average productivity loss for Delhi and Narnaul separately for Phase I and Phase II. The mean productivity loss calculation used the midpoint of the average number of days missed at the workplace and the average income reported by respondents of different occupation groups.

Different scenarios have been simulated, which indicates a range of productivity loss estimates, given in Figure 3.[2] These are based on alterative assumptions, as articulated here.

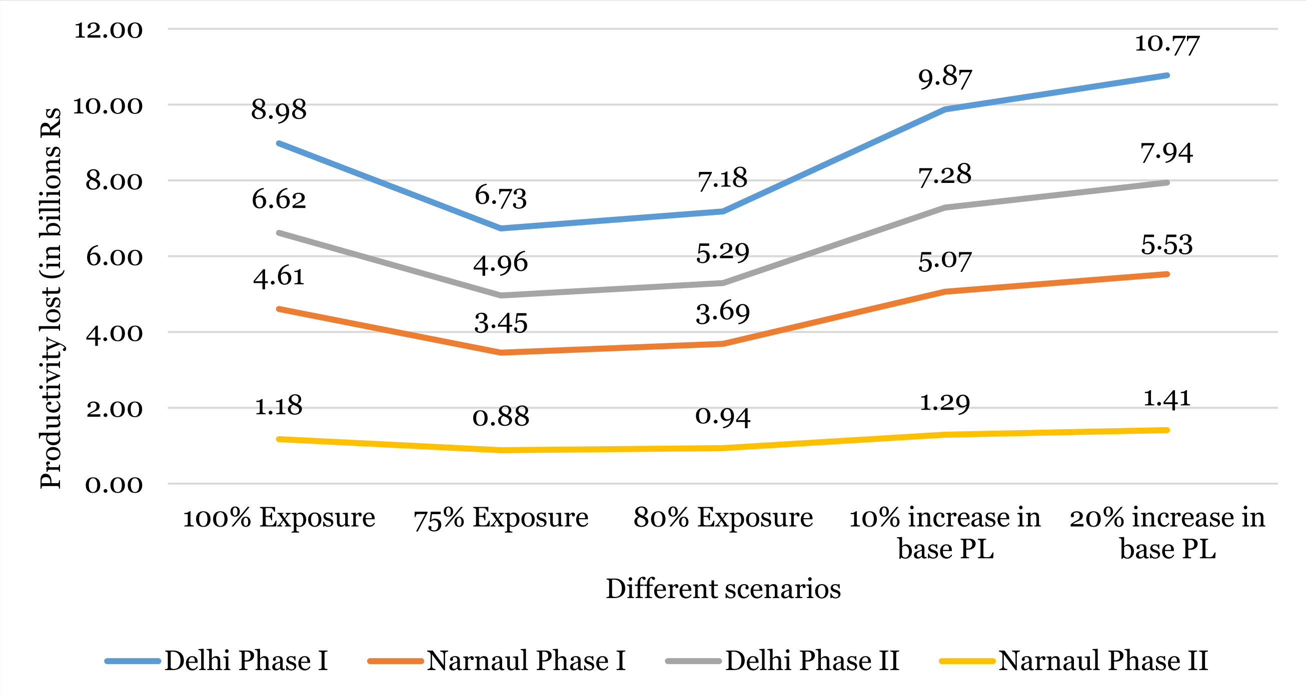
i. All members of the entire labour force of Delhi and Haryana[3] are exposed to pollution and will, therefore, suffer from similar effects.
ii. 75 per cent of the labour force is exposed to air pollution.
iii. 80 per cent of the labour force is exposed to air pollution.
iv. A 10 per cent increase in the mean productivity loss is assumed to account for the demographic dividend.
v. A 20 per cent increase in the mean productivity loss is assumed to account for the demographic dividend.
vi. The productivity figure has been adjusted using the per capita income of Delhi and in terms of the labour force and unemployment rates.

Using all the simulated conditions, it is seen that the mean productivity loss ranges from Rs. 8.98 billion to Rs. 10.73 billion for Delhi in Phase I, which decreased to Rs. 6.62 billion to Rs. 7.94 billion in the subsequent phase. The trend is also similar for Narnaul, where the productivity loss that ranged between Rs. 4.61 and Rs. 5.53 billion in the first phase, declined to Rs. 1.18 – Rs. 1.14 billion in the following phase. It is, however,

[2] However, it is important to mention at this point that in the productivity loss calculation, no distinction has been made between the seasonal, contractual, and full-time employees.
Phase I, which is about Rs. 134 more than the sample estimates. This narrow range of productivity loss provides the sensitivity of the results.
[3] In the latest NSSO data of 2011–12, the labour force is 5.9 million, http://www.ihdindia.org/hdidelhi/pdf/Statitical%20Bulletin_Work%20and%20Livelihoods.pdf.

important to note that the average productivity loss values are derived from the leaves taken during the last three months. Hence the simulated productivity value gives the productivity loss figures of the last three months.

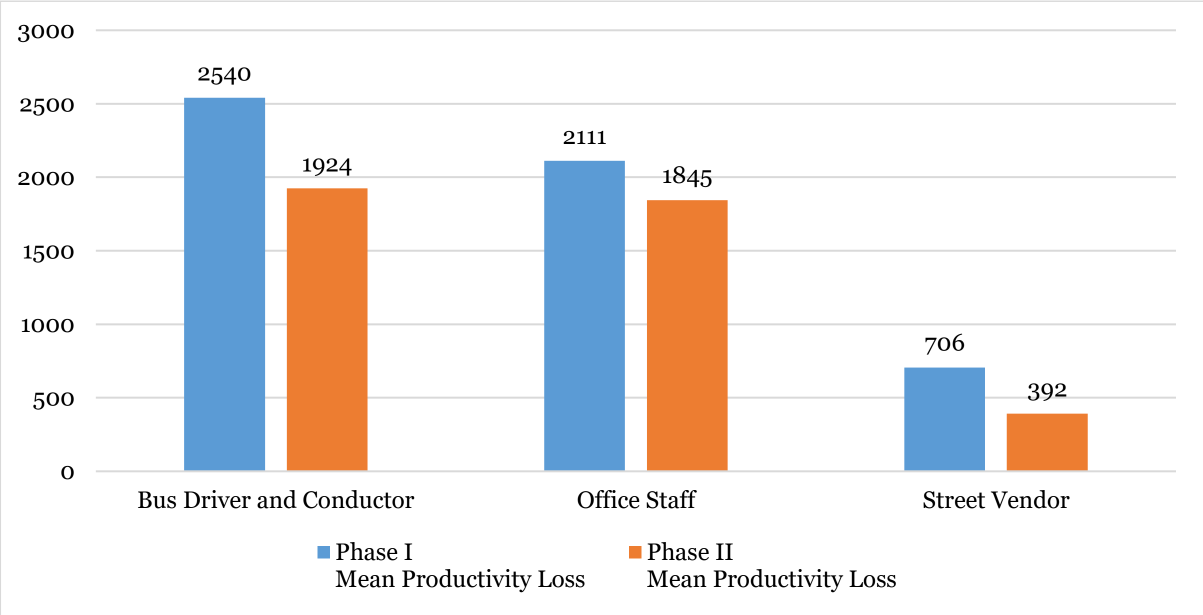
**Figure 3: Simulated Productivity Lost (Rs billion)**




*Source:* Computed by authors.

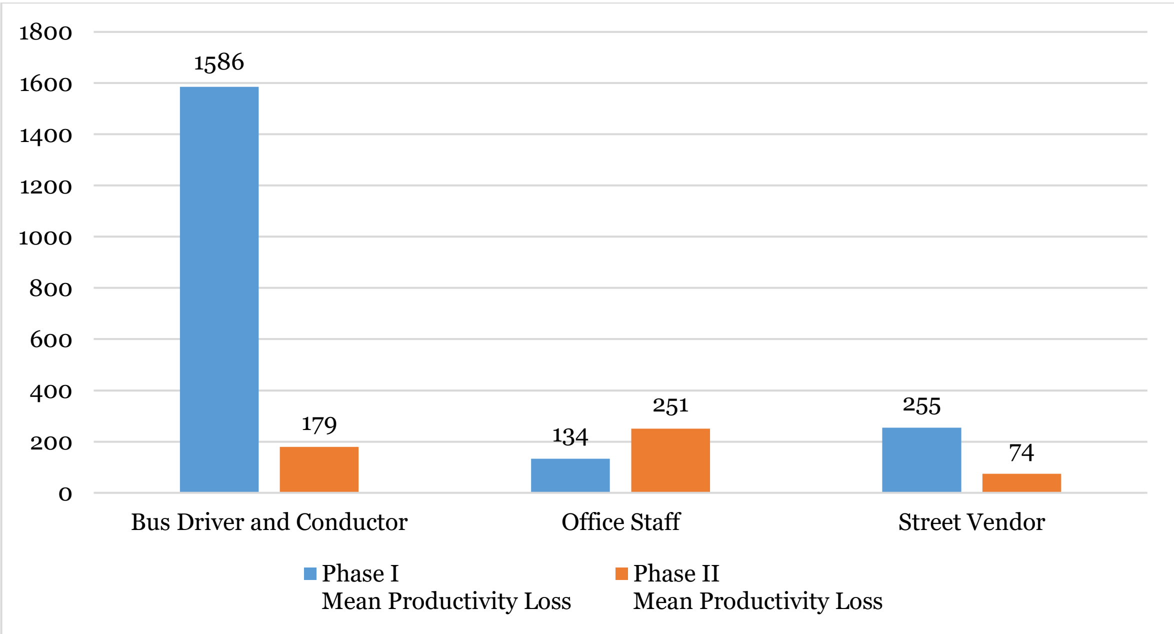
If we disaggregate the productivity loss by the occupational groups in, we find that the losses are higher for all the groups in Phase 1 in comparison to Phase II (see Figures 4 and 5). For example, in the case of *bus drivers and conductors*, the average loss decreased from Rs 2,540 to Rs 1,924 which was Rs 2,111 versus Rs 1,845 for *office staff* and Rs 706 versus Rs 392 for *street vendors*. The trend is similar even for the Narnaul samples except for *office staff* for whom the mean productivity losses is marginally higher in Phase II as compared to Phase I.

**Figure 4: Productivity Losses (in Rs.) by Occupational Groups (Delhi)**




*Source:* Computed by the authors.

**Figure 5: Productivity Losses (in Rs) by Occupational Groups (Narnaul)**




*Source:* Computed by the authors.

### *4.4. Welfare Analysis*

The important steps in the welfare analysis involve:

i) A contingent valuation survey (also referred to as 'willingness to pay survey);

ii) Calculating the Value of Life Years (VOLY) using the willingness to pay measures (WTP); and

iii) Using the VOLY and premature mortality figures to arrive at the economic cost of air pollution.

The methodology has been adopted from Desaigues et al. (2007), wherein a welfare analysis of nine countries, including France, Spain, the UK, Denmark, Germany, Switzerland, the Czech Republic, Hungary, and Poland gives a mean VOLY of 41,000 Euros for three months of life expectancy gain.

The theoretical understanding behind the calculation of VOLY is explained below. The expected utility function (*EU*) of an individual relates the utility that he derives from the consumption of any good given by *U(y)* and the disutility derived from the risk of mortality from air pollution (r). The expected utility function is:

*EU (y, r) = (1 – r) U(y).*

In the event of introduction of a policy from the government which proposes a reduction in the risk of pollution, and therefore, indirectly a reduction in the risk of dying, then under the contingent valuation exercise, individuals are asked whether they want to trade off some amount of their present consumption for a reduction in the level of risk from r to r` such that the expected utility remains the same.

*EU (y, r) = (1 – r) U(y) = EU (y-WTP, r`); r`<r*

The non-parametric WTP group-wise numbers of the sample population are used to estimate the VOLY. The calculation uses the gender-wise life expectancy figures and the age of the individuals to arrive at the values. The formula used is as follows:

$$VOLY_k = (WTP_{1,k} * 12) * (LE_i - age)$$

where $VOLY_k$ represents the value of life years for different groups, $WTP_{1,k}$ records the willingness to pay for one year of additional Life Expectancy (LE), $(LE_i - age)$ is the remaining LE of each individual where the $LE_i$ values are gender-specific. Multiplying by 12 gives the annual VOLY figures.

#### *4.4.1. Steps in Calculating the VOLY*

In the literature cited above, which refereed the economic cost in India, it is important to acknowledge that air pollution is primarily based on the estimation of the value of statistical life and on the premature mortality figures. While arriving at the value of statistical life and making it meaningful for the Indian scenario, earlier studies have used adjustment factors such as the PPP conversion, percentage change in the real GDP per capita growth rate, inflation indices, and income elasticity to arrive at the VSL figure for India. This adjusted VSL is then multiplied with the estimated number of premature deaths to obtain the economic costs. This approach has the following limitations:

i) The developed country sample is structurally different from that of India. The demographics and the cultural background of individuals in the two countries are significantly different.

ii) The awareness levels and educational backgrounds of the individuals will lead to different responses in the WTP value, which significantly influences the estimation.

iii) The importance that people place on air pollution depends on the level of understanding of pollution and health, in general.

iv) With different endowments and differences in their perceived valuation to pollution, estimates of mortality from air pollution in the developed countries can differ significantly from those in India.

In the light of the above concerns, it is important to undertake a contingent valuation survey in India to estimate the VOLY for the Indian population. In view of the wide heterogeneity of the population across India, it is not certain if the groups surveyed for the project would aptly represent the population in general. It is also being acknowledged that these groups belong to the lower strata of the socio-demographic class and characteristics. Nevertheless, we proceed with estimating the welfare loss or economic costs using the WTP estimates from our sample survey. In that regards, the following steps are deemed important at arriving at welfare loss.

- Welfare analysis estimation asks individuals to indirectly value a government policy for achieving cleaner air through the valuation of premature mortality. As Viscusi, 1993; Cropper, 2000; OECD, 2012, put it, individuals, through their measure of valuation, estimate the threat of air pollution perpetrates both on society and also on themselves. Hence, valuation captures the trade-offs that individuals are willing to make to reduce their chances of dying. The amount neither represents any single person's life or death, nor a normative analysis of the societal valuation of the death, but is only a perceived valuation of the mortality risks associated with pollution. The welfare analysis is done using the WTP approach, which monetises the individuals' perceived risk from air pollution. The first step, therefore, involves asking if the survey participants are ready to pay a certain amount per month to ensure better air quality in the region and subsequently a better quality of life. This is also called contingent valuation analysis.
- However, before the respondents are asked the question regarding their WTP, they are made aware of the good that they are valuing through a script. This script is called *Cheap Talk* in the contingent valuation literature, which describes the good to be valued, the benefits that the wilful contribution will bring to the individual and to the society. It also explains the opportunity cost associated with making such payments.
- WTP figures are used to calculate VOLY, which is computed as the stated mean WTP/month/individual multiplied by 12 to get the annual WTP. In order to get the WTP over their remaining lifetime, the VOLY as the present value is multiplied with their remaining life length. For brevity, the discount rate is assumed to be zero and the remaining life years are calculated on the basis of the average life expectancy for each age class minus their present age.
- The VOLY figures are then multiplied with the country-specific estimated premature death figures to obtain the economic cost lost due to pollution.

## Box 1: Contingent Valuation Script

A recently published report of the Indian Council of Medical Research, 2018, reveals the following facts:

- In 2017, air pollution accounted for 12.4 lakhs deaths in India.
- As many as 6.7 lakh deaths were due to outdoor air pollution.
- Life expectancy in India would have been 1.7 years higher if the air pollution levels were under control.
- Ensuring healthy air to breathe will reduce both the individual and societal health expenses.

The Government is actively seeking steps through policy measures aimed at reducing the level of pollution. One such policy measure is upgradation of the fuel economy of India.

Following are some aspects of the current standards (BS-IV):

- Concentrations of PM 2.5 in Indian cities are much higher than the recommended limit by the World Health Organisation (WHO).
- The PM 2.5 emission is 5 times higher under BS-IV as compared to international standards.
- The air pollution mortality rate has increased significantly.
- Health standards of the general population are continuously deteriorating due to the exposure to pollution.
- The average life expectancy is ever declining.

Following are the proposed standards under BS-VI, which is an alternative fuel and clean fuel for

- BS-VI regulations are likely to reduce potentially dangerous NOx emissions by 25 per cent in petrol engine vehicles and by 68 per cent in diesel engine vehicles.
- Particulate matter emissions have been anticipated to decrease drastically—by over 80 per cent—in diesel engine vehicles.
- The proposed fuel is a better quality one with reduced emission rates.
- All the developed nations use this advanced fuel and have achieved significant reductions in their emission and health standards.

This improvement in the fuel economy will bring in some health benefits. In terms of health benefits, we will primarily focus on the expected gain in Life Expectancy (LE). We will now explain to you what LE means and how air pollution can impact LE. LE is the number of years you can expect to live, depending on how old you are now. The daily inhalation of air pollutants gradually damages the body and accelerates the aging process. Individuals of all ages who are already more vulnerable because they suffer from respiratory or cardiovascular illnesses are more sensitive to air pollution because it aggravates the symptoms. An improvement in air quality would lead to an increase in the LE of the general population. Hence, a gain in LE is not only an increase in the number of years of living but also an improvement in the quality of living through the years of survival.

All these lead to a reduction in LE, it is not merely cutting a few months of poor health.

You should also know that your LE depends on several factors such as biological, social, your lifestyle, behavioural factors such as smoking habits, exercising, healthy foods, medical factors, and also on environmental factors. You can think of air pollution as one such environmental factor that can have a major effect on LE, this has been scientifically proved in recent years.

To obtain these benefits all the sectors of the economy will have to respect new reduced pollutant emission levels. Therefore, if a policy for reducing air pollution is implemented, all polluters will have to respect stricter emission limits to improve air quality. All sectors of the economy will need to increase their efforts to reduce pollution by modifying production processes, producing improved cars which are less polluting, etc. Let me tell you that Government of India and Supreme Court have already ordered that there will be improved fuel for cars from April 2020.

To enjoy this cleaner air and as a part of maintaining the environment, we all may need to pay some amount from our daily living expenses. Think of this amount as something that will insure you against the adverse effects of pollution. Like for medical insurance, you pay a certain amount or premium anticipating that you will receive some benefits if your health deteriorates. Similarly, this is an upfront amount that you will be paying to secure better health. Therefore, if we ask how much you are willing to pay for having one more year of good quality of life… what is going to be your answer? Choose one of the following values shown. These are the bid amounts respondents were asked to choose from: 100, 150, 300, 500, 800, 1000, 1500, 3000.

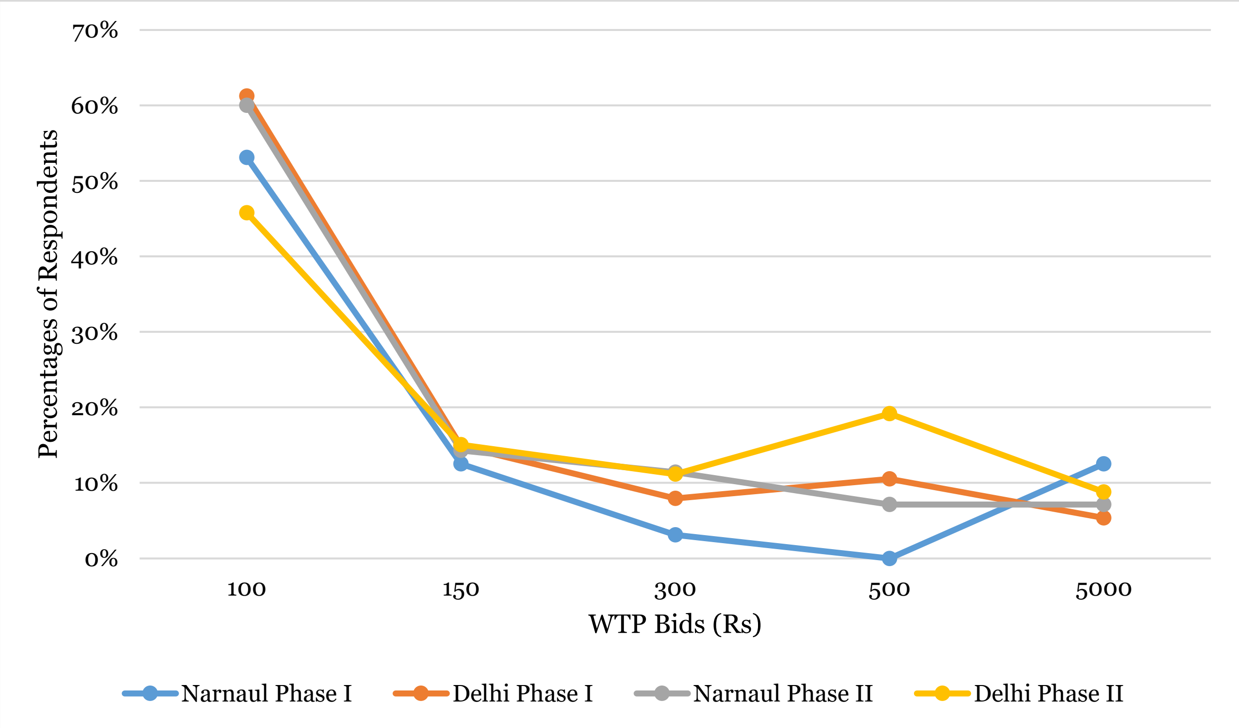
In both the phases, more than 80 per cent of the respondents agreed to pay for a policy ensuring better air quality. For those who were not willing to pay, a general distrust about the effectiveness of government policy is seen as one of the major reasons for their lack of willingness to pay. Of the different bids that were presented to the respondents to choose from, we see a shift in the distribution of respondents towards choosing a higher amount in Table 7 and Figure 6. This is indicative of the fact that more and more people are placing a higher value on cleaner air. This shift in the distribution can be because of the attention that air pollution gets in the winter season, which is also when the Phase II of the survey took place. The gravity of the situation is extensively discussed in the media during this time and hence the general awareness among people is usually very high, leading to placing of a greater value on improved air quality.

**Table 7: Percentages of Respondents by Their Willingness to Pay for Cleaner Air**

| | Delhi | | Narnaul | |
|---|---|---|---|---|
| **WTP Bids (Rs)** | ***Phase I*** | ***Phase II*** | ***Phase I*** | ***Phase II*** |
| 100 | 61 | 46 | 53 | 60 |
| 150 | 15 | 15 | 13 | 14 |
| 300 | 8 | 11 | 3 | 11 |
| 500 | 11 | 19 | 0 | 7 |
| 5000 | 5 | 9 | 13 | 7 |

*Source:* Computed by the authors.

**Figure 6: Percentages of Respondents by Their WTP**




*Source:* Computed by the authors.

Table 8 gives the mean VOLY figures for all the groups individually for both the Delhi and Narnaul samples. The table provides two important results: (a) For all the occupational groups of Delhi, the VOLY in Phase II is higher than that estimated in Phase I. In other words, this implies imply that all the groups surveyed in Delhi have valued cleaner air and the benefits from it more than the groups in Narnaul. This also reiterates our findings from Table 7, which shows that people are placing a higher value on improved air quality in Delhi than those in Narnaul.

**Table 8: Value of Life Years (Rs)**

| Occupation | Phase I | | Phase II | | Appended | |
|---|---|---|---|---|---|---|
| | ***Delhi*** | ***Narnaul*** | ***Delhi*** | ***Narnaul*** | ***Delhi*** | ***Narnaul*** |
| Bus driver and conductor | 76,978 | 1,19,280 | 1,01,444 | 80,258 | 89,306 | 92,065 |
| Office staff | 60,428 | 96,840 | 79,349 | 77,310 | 69,992 | 84,650 |
| Street vendor | 89,494 | 1,21,680 | 1,09,727 | 84,471 | 1,00,604 | 95,877 |
| Construction worker | 88,568 | - | 1,27,103 | - | 1,06,089 | - |
| Construction control | 86,907 | - | 1,14,010 | - | 1,00,604 | - |

*Source:* Computed by the authors.

The average VOLY figures are then weighted using the premature mortality numbers from the GBD study by Balakrishnan et al. (2019) to yield a range of the economic cost of deaths from ambient air pollution in Delhi and Haryana, respectively. The GBD study records premature mortality due to ambient air pollution for all the States and Union Territories of India, which was 11,732 for Delhi and 19,788 for Haryana in 2017.

The welfare loss is calculated as below:

$$Welfare\ loss_{states} = n * Average\ VOLY_{states}$$

The estimates show that the approximate economic costs or the amounts lost by Delhi and Haryana, respectively, in 2017 are Rs 0.91 billion and Rs 1.54 billion.[4]

### *4.5. Cumulative Figures of the Losses*

In Table 9 and Figure 7, we compile all the macro figures of health expenditure, productivity, and valuation. This table shows that in the context of the observed changes regarding health expenditure and productivity loss, both Delhi and Narnaul have seen a significant decrease in magnitude in Phase II as compared to Phase I due to the perceived valuation of better-quality air increases in the next phase. The reasons for this decrease are greater awareness of the harmful effects of air pollution and a higher media coverage of the same in the months of November and December when air pollution is at its peak. Given that both Delhi and Narnaul see a similar decrease in the health cost prompts us to believe that the entire benefits in Delhi may not be purely due to this fuel change but that other seasonal factors too are at play that are driving the results.

We may recollect that these health and productivity questions have reference to their values pertaining to the last three months preceding the survey. Therefore, the respondents were referring to the most polluted months of December, January, and February, while responding to the question on health costs in Phase I. For Phase II, on the other hand, they were referring to the months of August, September, and October. In these months, when winter is setting in and air pollution is still not in its peak, the

[4] Data for the premature mortality figures have been extracted from the Institute for Health Metrics and Evaluation (2013), The Global Burden of Disease (GBD) report. The premature mortality rate in 2017 was 11,732 for Delhi and 19,788 for Haryana.

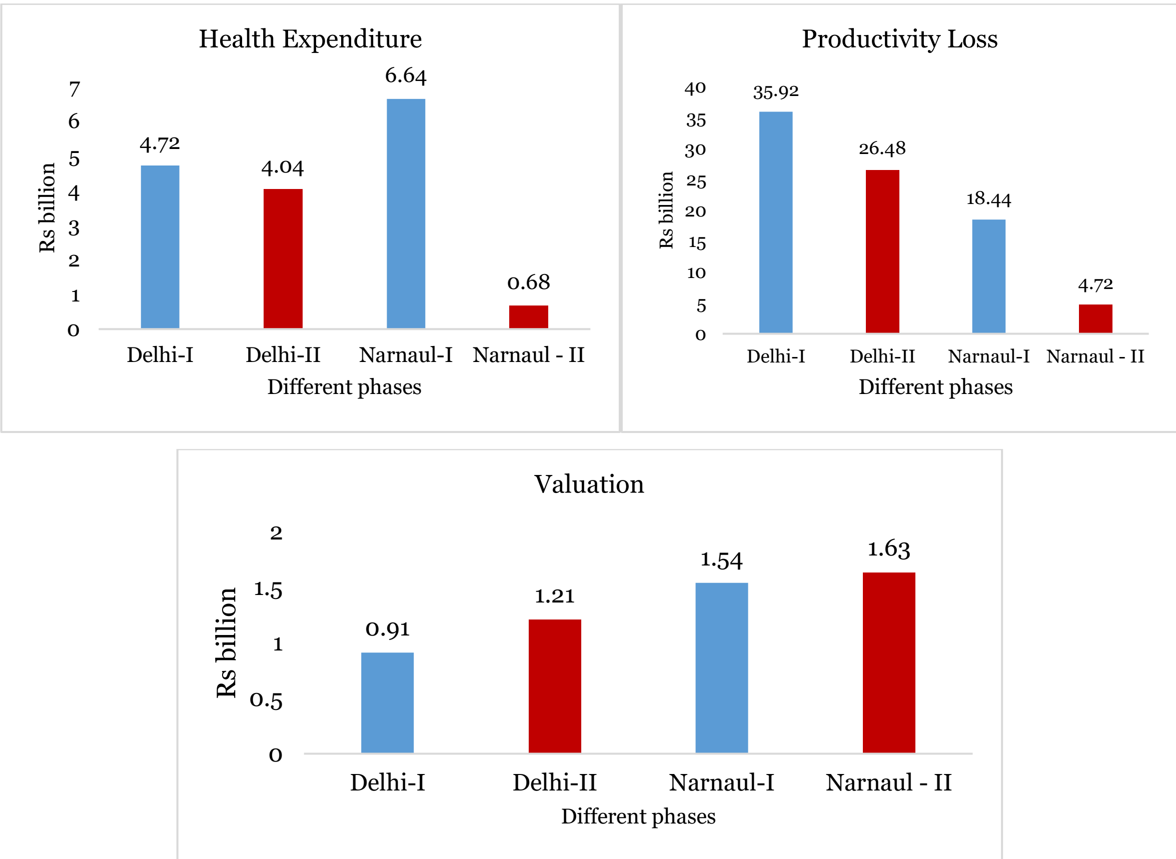
health effects of the same starts building up from November. Hence, it is not surprising to see the post-November effects being picked up in Phase I.

**Table 9: Compiling the Macro Figures (Rs billion)**

| | Delhi | | Narnaul | | Appended | |
|---|---|---|---|---|---|---|
| | ***Phase I*** | ***Phase II*** | ***Phase I*** | ***Phase II*** | ***Delhi*** | ***Narnaul*** |
| Health expenditure | 4.72 | 4.04 | 6.64 | 0.68 | 4.08 | 2.92 |
| Productivity loss | 35.92 | 26.48 | 18.44 | 4.72 | 31.28 | 10.32 |
| Valuation | 0.91 | 1.21 | 1.54 | 1.63 | 1.06 | 1.85 |

*Source:* Computed by the authors.

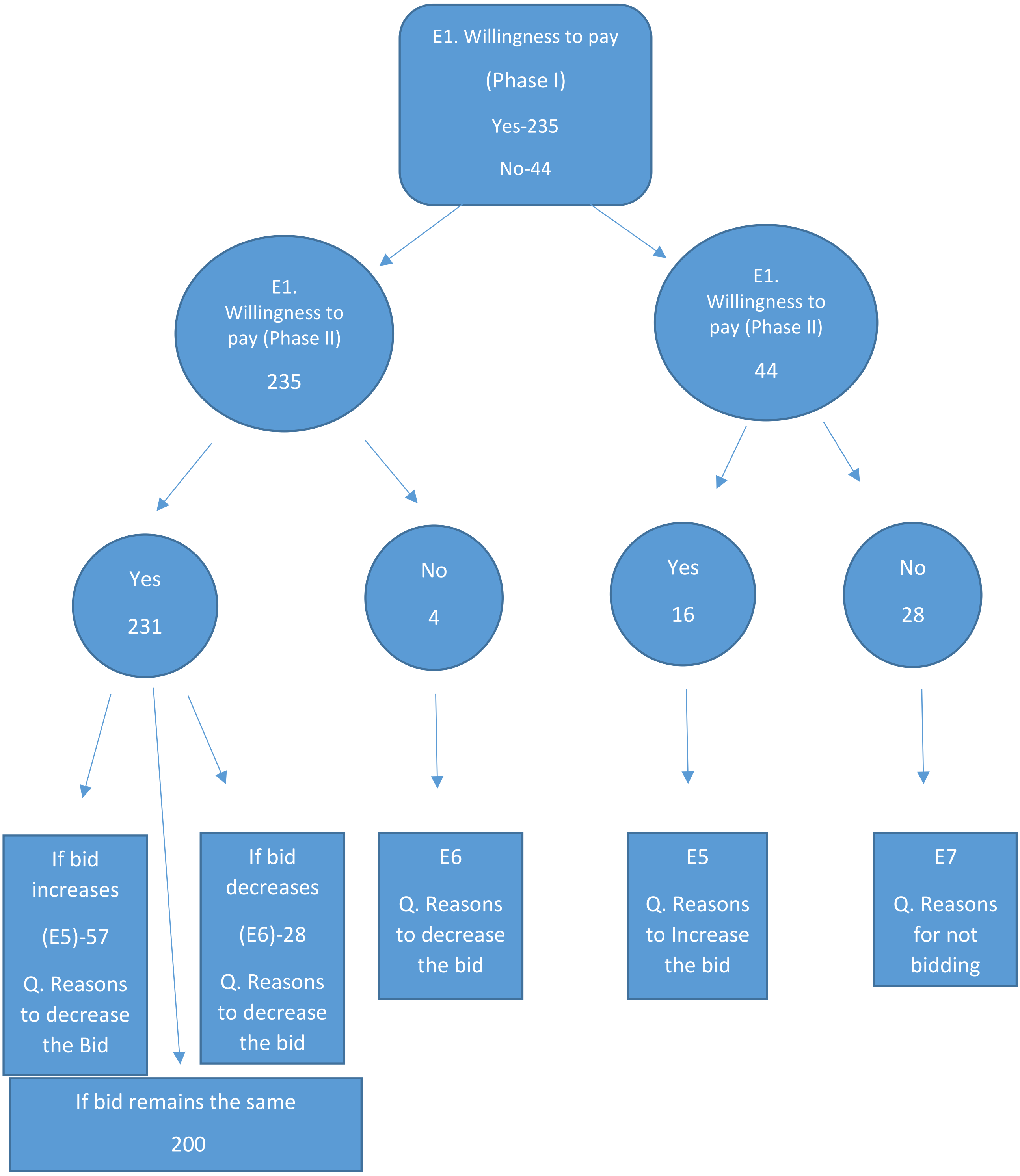
**Figure 7: Changes in Phase I and Phase II on Health, Productivity, and Valuation Parameters**




*Source*: Computed by the authors.

In both the phases, the respondents were asked about their willingness to pay for cleaner air, which would increase their life expectancy by one year. While administrating the question, the enumerators quietly observed their previous responses without letting them know the same. After the responses on the WTP are received, the enumerators informed them about their WTP in Phase I. In case their WTP figures were lower than what they had quoted earlier, we asked them the reasons as to why they had flipped. We provided them the reasons for their changed in responses. The sequence in which the questions were asked is depicted in Figure 8.

**Figure 8: Sequence of Willingness to Pay Questions**




*Source:* Design of the survey questionnaire.

In Table 10, we see a higher percentage of respondents choosing the lower bids. There is a shift in the distribution, such as a higher percentage of the respondents choosing a higher value of bids in both Delhi and in Narnaul in Phase II as compared to what they had responded in Phase I.

**Table 10: Percentage of Respondents by Their WTP for Cleaner Air**

| WTP Bids (Rs) | Phase I | | Phase II | |
|---|---|---|---|---|
| | *Delhi* | *Delhi* | *Narnaul* | *Narnaul* |
| 100 | 56 | 45 | 50 | 42 |
| 150 | 21 | 20 | 20 | 16 |
| 300 | 8 | 12 | 10 | 17 |
| 500 | 10 | 15 | 0 | 0 |
| 5000 | 5 | 8 | 20 | 25 |

*Source:* Computed by the authors.

## 5. Concluding Remarks

- In terms of the self-rated health status among respondents, we see a decreasing trend in the short- and long-term health illnesses, as recorded in Delhi in Phase II. However, similar differences have not been noted in Narnaul.
- With regard to the health expenditure patterns, we also find a significant decline in health expenditure among all the groups in Phase II as compared to Phase I. This is, however, true for both the fuel exposure group and the non-fuel exposure group. When we look at specific groups, it is the street vendors that report the lowest health expenditure despite being the most exposed group to pollution. This might be because of their inability to avail of medical care. The cost of health care is directly proportional to the uptake of health care services and can only serve as an indicator for the utilisation patterns. Further, a similar trend is seen among the non-fuel exposure groups, which indicates that there are other factors at work and therefore attributing the benefits entirely to BS-VI might not be correct.
- In addition to the health cost, the productivity loss is also found to be significantly lower in Phase II as compared to the earlier phase. This is true for all the groups studied. However, readers should note that the weighted measures of health and productivity are crude macroeconomic estimates and should be interpreted with caution.
- The reasoning holds true for the higher perceived WTP measure. When individuals are asked to value the perceived benefits of improved air quality, the social returns of less polluted air are valued more in Phase II in comparison to Phase I. This can also be due to seasonal effects. The more individuals are aware of the good that they are valuing, the higher is the importance that they place on them. Therefore, we believe that the social awareness on air pollution intensified by the media attention that the subject receives during peak pollution season has led to this increased valuation.
- Economic comparisons between the States under study in respect of the cost of pollution should be assessed with caution as the two States under focus are not similar to each other in their socio-economic and demographic profile-.

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