Estimation of Welfare Losses from Urban Air Pollution Using Panel Data from Household Health Diaries

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1. Introduction

Air Pollution is a major environmental problem in both developed and developing countries. The harmful effects of air pollution include corrosion of metals and buildings, reduction in visibility, degradation of soil due to acid rain, depletion of ozone layer, global warming and damages to human health. However, researchers are more concerned with damages to human health as human capital is the primary contributor to economic welfare of the society. The health effects are more intense in urban cities with significant emission sources, unfavorable dispersion characteristics and high population densities. Many health problems like eye irritation, respiratory illnesses etc may be directly attributable to exposure to air pollution. If not treated well in time acute illnesses may become chronic due to prolonged and continuous exposure to air pollution. The air pollution induced illnesses result in increased expenditures on mitigating activities and loss in wages to people. Welfare gains would occur if air quality is improved to the safe level.

A link between exposure to air pollution and health related social cost has already been established[2]. Studies in the past have used transfer benefit approach to estimate the willingness to pay for an improved air quality (Alberini and Krupnick 1997) in developing countries. However, this method does not take into consideration the country specific socio economic characteristics, baseline health, behavioral responses, pollution levels, characteristics of pollutants, weather conditions etc. and therefore may yield misleading results. So, to obtain more reliable estimates of welfare gain of air pollution, the country/area specific detailed studies are required to be undertaken. Though, it is not possible to measure all the costs of air pollution with precision but even approximate

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[2] See Dickie and Gerking 1991; Dockery et al., 1993; Alberini and Cropper et al. 1997; Alberini and Krupnick 1997; 2000; Kumar and Rao 2001; Murty et al 2003.

estimates may help justifying actions taken and cost incurred to abate air pollution. Few important studies have been summarized below.

Ostro (1983) estimated dose response function to assess the impact of particulates and sulfates on morbidity in USA. To measure this association the study took into consideration work days lost (WLD) for employed people and restricted activity days (RAD) for the combined sample of adults and other non-workers. The key results indicated that one percent increase in particulates would increase WLD by about 0.45% and RAD by 0.31% for all people in the age group of 18-65 years. The evidence suggests that an association between air pollution and health is stronger and more severe in developing countries due to poor nutrition, low awareness and unhygienic conditions. As a result people may have to incur more cost towards health care in these countries (*Chestnut, et al.*, 1997). *Lvovsky et al* (1998) analyzed health damages from exposure to the high levels of particulates in 126 cities worldwide where the annual mean levels exceeded 50 ($\mu g/m^3$). Using meta-analytical technique the results of dose-response relationship were extrapolated to various cities suffering from the higher levels of air pollution in different parts of the world. To assess the health damages comprehensively the study included mortality, morbidity and chronic illnesses. It was concluded that India suffered from a disproportionably heavy burden of urban air pollution by international comparison. In terms of monetary value and as a share of percapita GDP, health damages due to the exposure to particulates were estimated as 9 percent for India.

Based on Gerking and Stanely (1986) model and using the dose-response method, *Kumar and Rao* (2001) measured economic benefits of air quality improvement in Panipat Thermal Power Station Colony in India. They estimated medical care function (a binary response variable based on one month's recall period) in association with the pollution variable (PM_{10}), monthly income, health status, age, years of schooling etc. In this study the estimated medical care cost is supposed to illustrate peoples' willingness to pay (WTP) for the reduced levels of PM_{10} in the ambient air. Income and health status variables were significant determinants of WTP for improved air quality. The estimated WTP ranged from

Rs.21 to Rs.52.5 per month for a sixty seven percent reduction in ambient mean concentration in PM_{10} level (required to meet World Heath Organization standards).

Murty et al (2003) estimated household health production function model for measuring economic benefits from reduced air pollution in Indian urban cities of Delhi and Kolkata. Using six months' data relating to sick days, averting and mitigating activities they estimated a system of simultaneous equations using the method of three stage least square (*3SLS).* The results showed that if the current level of suspended particulate matter (SPM) were reduced to safe level the total per annum monetary gain to the urban populations of Delhi and Kolkata would be Rs. 4897 million and Rs. 3000 million respectively.

The present study analyzes welfare gains due to higher levels of air pollution in the urban city of Kanpur, one of the urban conglomerations in India. The city is known as the "Commercial Capital" of Uttar Pradesh. However, over the years it has acquired the notoriety of being one of the most polluted cities in the country. The maximum weekly average concentration of PM_{10} in Kanpur was 224 ($\mu g/m^3$) in 2004[3] whereas the safe levels recommended by the World Health Organization (WHO)[4] and the National Ambient Air Quality Standards (NAAQS) were 20 ($\mu g/m^3$) and 60 ($\mu g/m^3$) respectively. The WHO has currently revised its standard to 20 ($\mu g/m^3$).

2. Study Site

Kanpur is the largest and most populous industrial city in the state of Uttar Pradesh in India. The area of Kanpur urban agglomeration[5] is 305.27 sq. km and its population density is 9756 per square kilometre (2001 Population Census Data). The annual average growth rate of population is 3.5 percent (national average being 1.54 percent/annum) during 1991-2001. The percentage of the workforce involved in the primary, industrial and service sectors are 4 per cent, 31 per cent and 65 per cent respectively.

[3] The year of the present study.
[4] World Health Organization -2000.

[5] Area of urban agglomeration comprises Kanpur Municipal Corporation, Cantonment, Armapur Industrial Estate, Railway Colony, Chakeri and the Indian Institute of Technology–as reported in Kanpur City Development Plan, 2006.

Kanpur is famous for its cotton, woollen and leather industries. Most of the heavy and large-scale industries like fertilizer unit, ordinance and gun factories and power plant are located in the southwest part of the city and a cluster of tanneries along Ganga River in Jajmau Industrial Estate is situated in the Northeast part. These industrial units contribute significantly to air pollution. A Thermal Power Plant of 264 MW capacity has two small boilers operating on obsolete technology producing a large amount of fly ash that causes an increase in the level of Particulate Matter in the ambient air. Transportation in Kanpur comprises about 0.2 million petrol/diesel driven vehicles which contribute about 142 MT of pollutants per day. Another major source of pollution is a long M. G. rail track passing through the city with residential and industrial areas located on either side. The railway line has seventeen manned level crossings known as Gumtis. The level of PM_{10} increases to five to six times higher than the National Ambient Air Quality Standards (NAAQS)[6] on these crossings on passing of the train. Households too contribute to air pollution in Kanpur city. Most of the households living in slum settlements and LIG colonies use inefficient fuel such as coal, wood, kerosene etc for the purposes of cooking and space heating generating localized smoke that affects visibility and causes eye irritation.

The estimated pollution load from domestic fuel is 5.5 MT/Day. According to CPCB sources about 60 percent of the geographical area, particularly the densely populated central part of Kanpur is severely affected by air pollution problems[7]. Kanpur has been identified as one of the hotspots in India[8].

Referring to the findings of a World Bank study (2006), the "Time" magazine reported that the industrial city of Kanpur had been placed as the seventh most polluted city in terms of air pollution in the world. Furthermore, a report that detailed the most polluted cities in four Asian countries ranked Kanpur on the top. It was indicated that this city fared worst among all Indian cities followed by Kitakyushu in Japan, Indonesian capital Jakarta and Chinese

[6] See CPCB Parivesh Newsletter 2(1), June 1995.

[7] See SANDEE Working Paper – 17-06.

[8] Environmental Management Plan, 2000

city of Xiangshan. The growing population in Kanpur was one of the main reasons of worsening air quality.

"Eco Friends 2002" reported that in last one decade, there had been very high incidence of asthma and bronchial asthma in Kanpur. The burgeoning traffic increased the levels of carbon monoxide, hydrocarbons, benzene, nitrogen oxides, sulphur dioxide and lead in the air. The dust-ridden city of Kanpur, which was dubbed earlier as the 'Capital of TB' where even monkeys had been afflicted with the deadly disease, has now fast turned into a hotspot of asthma. A Medical College in Kanpur reported, "In any city, the asthma patients were between two to five per cent of the total population. However, in Kanpur, the number of asthma patients exceeded 10 per cent of the total population…" Experts predicted that every fourth person in the city would be a victim of asthma if the air quality of Kanpur kept plummeting at the current rate. There were also apprehensions that it could reach epidemic proportions very soon. Also, if the recent survey of Central Pollution Control Board (CPCB) is any indication, Kanpur is sitting on an environmental time bomb, which is ticking away and can explode any time.

3. Data Sources and Survey Design

The pollution parameters considered in the study are PM_{10}, NO_X and SO_2 for exploring an association between air pollution and health . Data relating to these pollutants were collected from the publications of Central Pollution Control Board (CPCB) and Uttar Pradesh Pollution Control Board (UPPCB) during the year 2004. There were four monitoring stations in Kanpur at the time of our survey. Vikas Nagar (VN), Deputy Ka Parao (DKP) and Kidwai Nagar (KN) are located in the residential areas and Fazal Ganj (FG) is located in an industrial area which is surrounded by a large residential area.

The Sampling procedure used for household survey was based on two-stage stratification -- air pollution monitoring stations and the type of dwellings. For the first stage of stratification an area of one-kilometer radius was marked around each monitoring station and a sample of almost equal number of households was drawn from each monitoring station area. The second stage of stratification followed Kanpur Development Authority's (KDA) classification of households residing in different "types of dwellings". These dwellings broadly reflected households' economic status and variability in their living standards and income levels. According to KDA, 67 percent of the total population lives in Kaccha houses, single rooms or a portion thereof, 21 percent in two - room dwellings and 12 percent in three or more rooms' houses. Our final sample consisted of 222 and 163 households residing respectively in one-room and kaccha houses representing the poorest section of the society; 116 households lived in two rooms' dwellings, representing the lower middle class category; 57 and 47 households resided in three and more than three rooms' houses respectively and were considered to be economically better off belonging to higher middle and high income levels.

Primary data were collected through household survey by administering a questionnaire through a face-to-face interview with the head or any other working member of the household. The survey questionnaire had four main sections with detailed subsections to facilitate the collection of relevant data on key variables. Sections 1 and 2 covered various aspects of socio-economic and demographic features such as religion, family background, sex and age of household members, level of their education, marital status, occupation and the size of the accommodation/house. Section 3 and its subsections contained information on individuals' past health stock (chronic diseases), their habits and the general awareness of households about air pollution induced illnesses. To collect data on gross annual income, different income brackets were offered to the respondents to select their respective range of income in Section 4. Data on an alternative measure of wealth of households/individuals in the form of average annual expenditure and inventory of durable consumer items were also collected to cross check the income levels.

A unique feature of this study is Weekly Health Diary. The health diary was maintained for eighteen weeks (six weeks in each season; summer, winter and monsoon seasons) to capture the impact of seasonal variations on health. Trained enumerators visited all the households, every week, in each season, to record the information on mitigating expenses, days of medicine taken, wages and workdays lost due to air pollution induced sickness. The seasonal phases to which the diary data belong were the first phase covering winter season (Jan. '04—Feb.'04); the second phase relating to summer season (May'04-June'04) and the third phase covering the monsoon season (July'04—Sept'04).

With the 18 weeks' health diary, and a total of 3122 household members (consisting of both children and adults), the existing data set resulted in a panel, containing 56,196 observations (3122 x 18). We have considered 2098 working and non working members from this sample in the age group of 15 years and above. The minimum permissible age to work is 15 years in India according to Indian labor law.

Weather Data relating to temperature, relative humidity and wind speed were collected from the Department of Meteorology (Chandra Shekhar Azad University of Agriculture, Kanpur) for analyzing the impact of weather variation and seasonality on health.

4. Methodology

Many variants of household health production model (HHPM) as originally found in *Grossman* (1972) have been formulated to explore health impacts of air pollution. The present study uses Freeman's model (1993)[9] to estimate economic benefits from reduced morbidity due to reduction of air pollution in Kanpur city. The household health production function and the demand function for mitigating activities that are implicit in the utility maximizing behavior of an individual are derived as follows:

An individual's utility function may be defined as

$$U = U(X, L, H, Q) \tag{1}$$

where, X is the consumption of marketed good, L denotes leisure time available per period to an individual, H represents air pollution induced sick days per week and Q shows level of ambient air pollution. Individuals derive utility from the consumption of X and L whereas H and Q result in disutility.

[9] *Murty et.al*, 2003 estimated this model for measuring welfare gains of reduced air pollution and morbidity in Indian cities Delhi and Kolkata.

An individual produces good health by combining mitigating activities[10] with the given level of air pollution (Q), health status and other socio-economic characteristics.

The household health production function can be written as

$$H = H(M, Q, Z) \quad (2)$$

where, H: health status, M: mitigating activities Q: level of ambient air pollution

Z: a vector of other parameters.

The individual's health status is also a function of M, Q and Z. Mitigating activities (M) include the individual's demand for medicines, hospitalization, pathological tests, doctor's consultation etc. The other health characteristics (Z) of an individual are the history of chronic illness, habits etc. The model assumes that individuals could maintain a given health status even with higher ambient air pollution through the choice of mitigating activities in the market. It means that there are substitution possibilities between mitigating activities and the ambient air quality.

Individual chooses X, L and M so as to maximize utility subject to the budget constraint:

$$I = Y + w(T - L - H) = X + P_M M \quad (3)$$

where, Y is non-wage income; w is wage rate; (T-L-H) is time spent at work (T is total time and L is leisure time); P_M is the price per unit of mitigating activity.

Given the pollution level (Q), prices of mitigating activities (P_M), wage rate (w), income (I) and other exogenous variables, individuals maximize utility with respect to X, M and L given the budget constraint. The maximizing function is given as

$$MaxG = U(X, L, H, Q) + \lambda[Y + w(T - L - H) - X - P_M M] \quad (4)$$

[10] The estimated model does not include averting activities because the survey data reveals that people in Kanpur do not adopt averting activities (such as a.c. car, staying indoors, using heater, mask, diverting to cleaner route, etc.,) to avoid exposure to air pollution.

where λ is the Lagrange multiplier that can be interpreted in terms of marginal utility of income. Solving the maximizing function, we obtain an individuals' demand function for mitigating activities (M) and the marginal willingness to pay function for air quality improvement (MWTP) as:

$$M = M(I, P_m, Q, Z) \quad (5)$$

$$MWTP = w.dH/dQ + P_M.\delta M/\delta Q + (\delta u/\delta H).dH/dQ/\lambda \quad (6)$$

Expression (6) shows that MWTP for health benefits from the reduction in pollution is the sum of observable reductions in the cost of sick time, cost of mitigating activities and the monetary equivalent of disutility of illness. To obtain MWTP the health production function and the demand function for mitigating activities may be estimated simultaneously, or alternatively, a reduced form "damage function" (dose-response function) with health as a function of pollution parameters and other variables can be estimated. This can be combined with the estimated demand for mitigating behavior[11]. Since our estimates of WTP are based on first two components and do not take into consideration the monetary equivalent of disutility of illness, these are lower bounds of WTP.

5. Estimating Household Health Production Function Model

5.1. Household Health Production Function

Since pollution parameters (PM_{10}, SO_2, NO_x etc) are monitored twice a week in Kanpur, we have taken one week as a recall period to analyze the impact of air pollution on health. The primary data used in the present analysis have two salient features: (i) dependent variables are count of the total number of sick days in a given week during the three seasons and (ii) there are repeated observations for the same individuals constituting a panel data set.

In this case, using Poisson regression model for estimating the household health production function is more appropriate because it takes into consideration the preponderance of zeros and the discrete nature of the dependent variable whereas least square and linear models do not account for these characteristics. Poisson model is:

[11] The estimation of damage function in the health production function framework is obtained by substituting the demand function for mitigating activities, M, into the health production function (Freeman 1993).

$$prob\left(Y_{it} = y_{it} / x_{it} \right) = \frac{\mu_{it}^{\ y_{it}} e^{-\mu_{it}}}{y_{it}!} \qquad \mathrm{Y_{it}} = 0,1,2\ldots \qquad (7)$$

where, Y_{it} is the count of number of sick days due to air pollution induced illnesses occurring during week t to i th individual. $\mu_{it} = \exp(x_{it}\beta)$ is for both mean and the variance of illness. The x_{it} is a matrix of covariates of i th individual and β is a vector of regression coefficients. The predicted count of sick days during week t for i th individual is, therefore, $\hat{y}_{it} = \exp\ (x_{it}\beta)$ or $\ln\ \hat{y}_{it} = x_{it}\beta$. The marginal effect of change in x_{it} is computed as $\hat{y}_{it}\ \beta$. For estimation purposes the model specification is as follows:

$$\ln y_{it} = \alpha_i + \beta_i X_{1it} + \beta_2 X_{2it} + ... + \beta_s X_{sit} + \mathrm{u_i} \qquad (8)$$

Poisson model estimates have been obtained through the estimation of maximum likelihood method[12]. However, it is noted that in practice the Poisson regression model is restrictive in many ways. Firstly, it is based on the assumption that events occur independently over time. The independence assumption may break down, as there may be a form of dynamic dependence between the occurrences of successive events. For example, the prior occurrence of an event, such as sick day due to air pollution induced illnesses, may increase the probability of a subsequent occurrence of the same or similar event. Secondly, the assumption that the conditional mean and variance of y_i, given X_i are equal may also be too strong and hence fail to account for over dispersion (the variance exceeds the mean). This restriction may produce larger estimated standard errors of the estimated β. An alternative to obtain accurate estimates of the standard errors, after adjusting the problem of over dispersion, is to apply the negative binomial distribution model.

5.2. Demand for Mitigating Activity

The dependent variable M indicating the demand for mitigating activities is a censored variable i.e. the dependent variable is zero for corresponding known values of independent

[12] To correct the special serial correlation inherent in panel data, the generalized estimating equation (GEE) approach devised by Liang and Zeger (1986) can be used.

variables for part of the sample. To address this problem, we use Tobit model[13] for estimating the demand function for the mitigating activities. Thus,

$$M_{it} = \alpha + \beta x_{it} + u_i \text{ if RHS} > 0 \quad (9)$$
$$= 0 \text{ otherwise}$$

where, M_{it} refers to the probability of the *ith* household incurring positive mitigating expenditure at time t, and X_{it} denotes a vector of individual characteristics, such as income, age and education, pollution parameters, weather conditions, etc.

5.3. Empirical Specification

Econometric estimation includes the following reduced form equations consisting of the household health production function and the demand function for mitigating activities. The estimated coefficients were used to compute the marginal effect of pollution on H (sick days) and M (mitigating activities). We use the random effects panel data regression model to estimate both of these equations.[14] The pollution parameter SO_2 could not be included in the analysis since its coefficient did not yield an appropriate sign, it may be due to its low concentration level in the ambient air.

$$\begin{aligned} H &= \alpha_i + \beta_1 pm_{10} + \beta_2 dtemp + \beta_3 t\max + \beta_4 NO_x + \beta_5 wind + \beta_6 age + \beta_7 bcj \\ &+ \beta_8 asthma + \beta_9 BP + \beta_{10} TB + \beta_{11} heart + \upsilon \end{aligned} \quad (10)$$

$$\begin{aligned} M &= \gamma_i + \delta_1 pm_{10} + \delta_2 dtemp + \delta_3 t\max + \delta_4 NO_x + \delta_5 wind + \delta_6 age + \delta_7 bcj \\ &+ \delta_8 asthma + \delta_9 BP + \delta_{10} TB + \delta_{11} heart + \varpi \end{aligned} \quad (11)$$

The dependent variables used in the equations are:

Dependent Variables:

Days of Sickness (H): H shows number of days of sickness, in a recall period of one week, due to air pollution induced diseases/symptoms. It also represents the health status of individuals.

[13] Amemiya (1984), "Tobit Models: A Survey". While OLS parameter estimates for a Tobit model are biased and inconsistent, maximum-likelihood estimates are unbiased and consistent (Maddala 1983).

[14] The Hausman test for choosing between the fixed and random effects models is in favor of the random effects model in the estimation of Poisson regression model.

Mitigating Activities (M): Mitigating activities (M) include expenses on medicines, doctor's fees, diagnostic tests, hospitalization, travel to doctor's clinic etc.

Independent Variables:

PM_{10}: It is measured for two days in a week in Kanpur. The time weighted average concentration of pollutants is recorded on each day for 24 hours at equal intervals of 8 hours. We have taken the average of maximum values of days' observations. It is measured in $\mu g/m^3$. PM_{10} remains in the atmosphere for longer periods because of its low settling velocity. It can penetrate deeply into the respiratory tract and cause respiratory illnesses in humans.

Nitrogen Oxides (NO_x): Average of maximum twice-weekly values of NO_x is measured in $\mu g/m^3$. NO and NO_2 are the main components of NOx. It is produced by natural phenomena such as lightning, volcanic eruptions and bacterial action in the soil and by anthropogenic sources such as combustion of fuels in internal combustion engines, thermal power plants, industrial and heating facilities and incinerators. Exposure to NO_x is linked with increased susceptibility of respiratory infection; asthma attacks, and decreased pulmonary function. Short-term exposure is associated with lower respiratory illnesses like cough, sore throat and runny nose etc.

Variation in Temperature (DTEMP): It is the weekly average values of the difference of daily maximum and minimum temperatures.

Maximum Ambient Temperature (TMAX): It is weekly average of daily maximum ambient temperature.

Wind: Weekly average of wind speed is measured in meter/second. Wind moves air pollutants from one location to another. The extent of dilution of air pollutants depends on wind speed and its direction.

Age: Years of age of an individual. With ageing the health stock deteriorates and therefore proneness to illness and mitigating activities increase.

Chronic Illnesses: Chronic illnesses such as Asthma, BP, TB and Heart Disease are taken as dummy variables. It takes value 1 if an individual is having a particular disease otherwise it takes value 0. These are control variables, which account for the health stock. An individual who is having a chronic illness is more susceptible to air pollution exposure and is likely to have higher medical expenses and number of sick days.

BCJ: This variable stands for the blue-collar job. It takes value 1 if a person is having blue-collar job otherwise it takes the value 0[15]. It also represents the work place environment.

Table 1 provides details of descriptive statistics of the variables used in the estimation of household health production function. The statistics relate to full longitudinal data set comprising individuals both in working and non-working categories with 37500 observations. The average numbers of sick days (H) are 0.188/week/person. The average medical expenditure incurred on air pollution induced sickness is Rs 3.35/week/person. Average age of people in Kanpur is 34.3 years. A dummy variable blue-collar job (BCJ) represents work place environment. It takes value one if workplace environment is affected by the high level of air pollution. BCJ include people who are employed as blue-collar factory workers, rickshaw pullers, hawkers, auto-rickshaw drivers, roadside shopkeepers etc. In Kanpur 26 percent people are exposed to high level of air pollution at their respective workplaces. Over 8 percent people in Kanpur have chronic diseases namely Asthma, TB, BP and Heart. Average level of NO_X concentration is $23.5\left(\mu g/m^3\right)$. It is well within the permissible limits of NAAQS standards whereas the level of PM_{10} exceeds the limit by 275 percent.

6. Results

6.1. Estimates of Equations

Tables 2 and 3 present the results of estimated Poisson and Tobit models respectively. The coefficients of pollution parameters, viz., PM_{10} and NO_X are positive and significant at one percent level of statistical significance. Considering the marginal effects of reducing the levels of PM_{10} concentration in the ambient air by one $\mu g/m^3$ the number of sick days for a representative person in Kanpur is estimated to lower by 0.00015 days/week. If the pollution level is reduced to the safe levels of NAAQS standards, the number of sick days would reduce by 0.0249 days/week, or by 1.3 days/annum for an average person..

[15] In the present study blue-collar workers are rikshaw-pullars, vegetable vendors, rag pickers, factory workers working outside the factory building and if inside the building they are exposed with indoor smoke, fumes and dust.

The coefficients of WIND and DTEMP are negative and significant at one percent level. The negative signs of coefficients of TMAX and DTEMP indicate a decrease in the number sick days during clear and warm days. AGE and individuals' health history of having ASTHMA, TB and BP have positive and statistically significant coefficients. The coefficient of workplace environment BCJ is positive and significant at 5 percent level indicating that the people with polluted work environment are likely to have higher number of sick days.

Table *3* presents estimate of the demand function for mitigating activities (medical expenditure). The coefficients of pollutants PM_{10} and NO_x are positive depicting a reduction in mitigating expenses with a fall in the concentration levels of PM_{10} and NO_X in the ambient air. The coefficients of PM_{10} and NO_X are statistically significant at five percent and one percent respectively. Although the level of concentration of NO_X does not exceed the NAAQS limits in Kanpur, but even at the lower levels it has significant adverse effects on health as is reflected by positive sign of the coefficient. The marginal effect of PM_{10} on the demand for mitigating activities of an average person is Rs 0.0042/week which translates to Rs. 0.684/week reduction if the pollution level is improved to the NAAQS standards.

The significant and negative coefficient of DTEMP indicates a reduction in mitigating expenses on sunny days. The coefficient of AGE is positive and significant indicating deteriorating health stock with age. All chronic diseases ASTHMA, BP, TB, and HEART have positive coefficients and are significant at one percent level, meaning thereby that people with these conditions have significantly higher medical expenditures. The coefficient of blue-collar jobs is positive and significant at one percent level, suggesting a higher medical expenditure by blue-collar workers as they are exposed to higher levels of air pollution at their respective work places. We have also reported the results of pooled Tobit to check for autocorrelation in the panel level error term. Since rho is nearly "zero" the panel estimator is not different from the pooled estimator, thus ruling out the possibility of autocorrelation in panel error term.

6.2. Welfare Gains from Reduced Sick Days (H)

Using the results of estimated equations (Tables 2 and 3) we measure welfare gains to the population of Kanpur city from the reductions in air pollution to the safe level. The present study attempts to value the total numbers of sick days in monetary terms by taking into account the workdays lost (absent days) and the low efficiency days (the restricted activity days) both for working and non-working individuals to arrive at welfare gains. Figure 1 comprehends these concepts as under:

The amount of daily wages lost due to absence from work may be taken as the cost of workdays lost due to air pollution induced sickness for working individuals. However, to compute the cost of illness of non-working individuals we need to know the imputed cost of their non-cash labor. This study proposes to take per day minimum average wage rate of Rs 83.51 fixed by the Government of India for the State of Uttar Pradesh as the imputed per day labor cost of non-working individuals for estimating the amount of wages lost per day due to sickness. To value the performance of low efficiency days (restricted activity days) [16] in monetary terms, the study suggests to considering a loss of one third amount of the daily wages. In case of US medical sector, Ostro (1992) valued 80 percent of Restricted Activity Day (RAD) at one-third of the average wage rate while remaining 20 percent of RAD resulted in lost workdays and was valued at a loss of a day's wage rate.

Welfare Gains to Working Individuals

Our survey data show that employed individuals would save 14 percent[17] workdays of the total sick days per week if air pollution were reduced to the safe level. An improvement in air quality is expected to lower morbidity and therefore a reduction in the loss of work days (WLD) and an improvement in efficiency (RAD). Valuing the reductions in WLD at the daily wage rate of Rs 207, a representative individual is estimated to gain Rs 38 per annum. Whereas estimating at one third of the daily wage rate the monetary value of an

[16] Low efficiency days (restricted activity days) can be the days when work is not completely lost but routine is inefficiently performed due to sickness.

[17] Computed as the ratio of workdays lost to the total days of sick days and normalized it at working population.

improvement in restricted activity days would be Rs 77 per annum. Thus, total economic gain to an individual is estimated as Rs 115 per annum if air pollution were reduced to the safe level. Extrapolating these gains to the entire working population of Kanpur the total gains are estimated as Rs. 97 million per annum which are due to the savings in WLD (Rs 32 million/annum) and improved RAD (Rs 65 million/annum).

Gains to Non-working Individuals

Following the same procedure, the gain in workdays due to the reductions in air pollution has been estimated using daily average minimum wage rate of Rs 83.51. Thus, the annual gains to a non-working representative individual are estimated as Rs.15 and Rs 31due to the reduced sick days and improved efficiency respectively. By extrapolating this gain to the entire non-working population of Kanpur, the annual gains from reduced sick days are estimated as Rs 103 million. Adding together (gains to working and non working individuals) the total economic gains from improved air quality and reduced sick days are estimated as Rs 200 million per annum. This accounts for 13.2 percent reduction in the number of sick days.

6.3. Welfare Gains from Reduced Mitigating Activities (M)

Gain to a representative person from the reduced medical expenditures due to the improved air quality is estimated as Rs 36 per annum which accounts for the reduction of 20.4 percent in mitigating expenditure. By extrapolating this gain to the total population of Kanpur, the annual gain from the reduced mitigating activities (M**)** is estimated as Rs.110 million. The total welfare gain due to reduction in sick days and mitigating activities turns out to be Rs 310 million per annum in Kanpur.

7. Conclusion

The analysis undertaken in this paper presents estimates of health benefits of improved air quality in Kanpur. The estimated household health production function model consists of two functions: health production function and the demand function for mitigating activities. For estimating this model individual’s health diary data have been collected which is considered to be more appropriate for producing reliable estimates of health benefits of reduced air pollution. There are already a few studies abroad using the household health diary data for estimating the household health production model (Alberini and Krupnick 1997). However, this study is first of its kind in India that has used panel data of household health diaries for estimating welfare gains. Many more such studies are required for other urban areas in India to provide useful inputs for designing the policy to control urban air pollution. The results show a total gain of Rs 310 million per annum to the population of the city of Kanpur from the reduced morbidity due to an improvement in air quality.

Comparing the results of the present study with that of Ostro (1983) we observe that one percent reduction in the level of pollution concentration may result in a saving of 0.18 percent in the number of sick days in Kanpur whereas it is 0.45 percent in the number of reduced activity days (RAD) and 0.31 percent in the number of work lost days (WLD) in the USA. Murty et. al (2003) estimated annual gain to an individual in Indian urban cities-Kolkata and Delhi-as Rs 295.10 and Rs 544.94 respectively whereas in Kanpur it is Rs 101 per annum.

However, estimates presented in this study are lower bound because these do not include expenditures on averting activities and the opportunity cost of time associated with medical care (the time spent on traveling and waiting at doctor's clinic and the time of the attendant or accompanying person, etc.). Also the estimated household health production function model in this study does not take into consideration losses that are incurred due to the discomfort caused by illness. Economic gains could be higher if the benefits of improved visibility; recreation opportunities and reduction in material damages etc are taken into account.

In the year 1997-98 the Central Pollution Control Board (CPCB)[18] developed an Environmental Management Plan (EMP) for Kanpur with a strong focus on air pollution reduction. The plan recommended a wide range of measures requiring fuel changes, relocating air-polluting industries, improving road network and increasing public transport

[18] See CPCB Environmental Management Plan (2000).

facility. However, the progress so far is very slow and the city needs to implement the EMP on high priority basis. There are significant costs involved to improve air quality. This would be the case if CNG is introduced for vehicular transportation or if the mode of transport is changed from road to metro rail or if any relocation of polluting industries occurs. The estimates of welfare gains from air pollution reduction obtained in this paper should help justify these costs.

Household health diary data and the data about air pollution and weather conditions in the city used in the estimation of the model could comprehensively explain the direct and synergetic effects of pollution and weather on the health of people in Kanpur. Controlling for all other factors, air pollution is found to be an important determinant of health of people in the city.

The analysis attempted in this chapter also highlights the importance of choice of appropriate econometric models in the environmental valuation depending upon the specific characteristics of data used. The characteristics of data collected are such that the Poisson and Tobit regression models are found to be suitable for estimating health production function and the demand function for mitigating expenditures respectively.

Table 1: Descriptive statistics

Estimated Variables	Mean	S.D	Minimum	Maximum
PM_{10} (µg/m^3)	224.44	69.55	42.5	462.5
NOx (µg/m^3)	23.49	4.97	10.5	39.0
Wind (m / sec)	7.39	2.72	3.54	14.66
Dtemp (^{0} C)	9.87	3.21	5.2	15.27
Tmax (^{0} C)	30.50	8.59	15.5	42.9
Age (years)	34.34	15.36	15	100
BCJ	0.26	0.44	0	1
Asthma	0.020	0.14	0	1
Bp	0.033	0.18	0	1
Tb	0.015	0.12	0	1
Heart	0.017	0.13	0	1
Medical expenditure (M) (Rs)	3.35	24.95	0	1200
Sick days (H)	0.188	0.99	0	7
Ratio of absence days to sick days	0.1424			
Population 15+ years age (%)	38.7			
Number of observations	37500			

Table 2: Number of sick days (H): Poisson Estimates

Independent Variables	**Coefficients (re)**	**Coefficients (fe)**
PM_{10} (+)	0 .0008034 (3.84)***	0.0008024 (3.84)***
NO_x (+)	0.0306 (11.90)***	0.0307 (11.90)***
WIND (-)	-0.0422 (6.57)***	-0.0421 (6.57)***
DTEMP	-0.0501 (10.69)***	-0.0502 (10.70)***
TMAX	-0.0002 (0.09)	-0.0001 (0.06)
AGE	0.0066 (1.68)*	
BCJ	0.276 (2.05)**	
ASTHMA	0.933 (2.26)**	
BP	0.548 (1.69)*	
TB	0.982 (2.08)**	
HEART	0.654 (1.45)	
Constant	-2.320 (11.48)***	
Log likelihood	-18811	-14946
Wald chi2 (14)	332.5 (0.000)	301.4
Number of observations	37500	13062
Number of groups	2098	729

Note: Location dummies are used in the estimation.
****Significant at 1% level; **Significant at 5% level; *Significant at 10% level. Hausman test does not reject the random effects.*

Table 3: Tobit Equations of Mitigating Activities (M) Left Censored (0)

Independent Variables	RE	Pooled Tobit
PM_{10} (+)	0.1032 (2.36)**	0.1035 (2.35)**
NO_x (+)	2.883 (5.14)***	2.891 (5.14)***
WIND	- 4.216 (3.12)***	- 4.229 (3.12)***
DTEMP	- 4.773 (4.79)***	- 4.786 (4.79)***
TMAX	- 0.0375 (0.10)	0.0374 (0.09)
AGE	0.5516 (3.25)***	0.5525 (3.25)***
BCJ	24.41 (4.30)***	24.48 (4.30)***
ASTHMA	79.89 (5.50)***	80.07 (5.51)***
BP	59.80 (4.89)***	59.98 (4.89)***
TB	91.74 (5.83)***	91.99 (5.84)***
HEART	66.54 (4.15)***	66.70 (4.16)***
Constant	- 445.65 (18.66)***	- 447.12 (18.66)***
Log Likelihood	- 14422	-14425
Wald chi^2 (14):	259.45 (0.000)	LR Chi^2 288.8 (0.000)
Rho	0.00064	-
Uncensored Obs: 1511 Number of groups: 2098	Left censored Obs: 35989	

*Note: Location dummies were also used in the estimation. ***Significant at 1% level; **Significant at 5% level; *Significant at 10% level.*

Figure 1: Monetary Valuation of Air pollution – Sick Days

	Working Individuals	Non working Individuals
Workdays lost (WLD) due to sickness	Loss in daily wages (w/day)	Loss in daily minimum average wage
Sick but not absent from work (Restricted Activity Days-RAD)	One third of the daily wage is lost (w/3)	One third of the daily minimum average wage (min w/3)

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