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VALUATION OF HEALTH IMPACTS OF AIR POLLUTION IN INDIA

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ABSTRACT

This paper surveys the studies measuring the economic impacts of air pollution on health in India. Air pollution has potentially large impacts on the health and well-being of households, especially the poor families. The literature shows that the distribution of the impacts of air pollution is not uniform across the cross sections of societies. It notes that though there are some case studies on the valuation of health impacts of outdoor air pollution, there is rarely any study on the valuation of health outcomes of indoor air pollution which uses consumer choice or behavior models. It identifies that studies should focus on both individual specific characteristics as well as the neighborhood specifications and these studies should be dynamic as the static studies fails to capture the effects of change in socio-economic features on health outcomes.

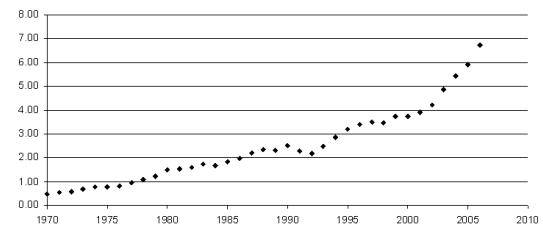
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■ Q25 ■ I12 ■ D12 ■ AIR POLLUTION ■ HEALTH ■ VALUATION ■ SOCIO-ECONOMIC FACTORS

INTRODUCTION

In last two decades India witnessed an unprecedented economic growth. Real gross national product has grown at an average rate of more than seven percent in the last decade. This economic growth was fueled by processes of industrialization and urbanization, and was not achieved without sacrifices. Air pollution problem must be counted among those sacrifices, and the levels of air pollution in urban areas often exceed national air quality standards for several pollutants. World Bank provides figure for countries for genuine savings - saving adjusted for the depreciation and degradation of environment and natural resources. The estimates of genuine savings include the saving foregone due to particulate matters based on various estimates of willingness to pay. Figure 1 shows the magnitude of growing burden of the impact of local air pollution measured in terms of particulate matters. In 2006, the magnitude of the impacts of particulate matters was about US$ 7 billions.

Figure 1: Damages due to particulate matters (bln. USD in 2000 prices), Adjusted Net Savings, World Development Indicator.



Source: World Bank (2008)

India's growth story is not inclusive; it has remained more confined to urban areas. The share of urban economy in the national income is about 60 percent and outdoor air pollution is generally considered a problem of urban areas.[1] However note that more than 72 percent of all households and 90 percent of poor rural households use traditional solid fuels such as crop residue, cow-dung and firewood for cooking (Census of India 2001). Burning of solid fuels in indoor kitchens through traditional stoves exposes these rural households especially women and children to toxic pollutants which cause many respiratory and cardiovascular disease along with lung cancer (WHO, 2002).

The chapter is organized as follows: The next section discusses the health impact of outdoor and indoor air pollution in India. Section 3 describes the various valuation methods used in the empirical studies to assess the economic burden of health impacts caused by air pollution. Section 4 presents a snap shot of empirical valuation studies. Section 5 discusses the various socio-economic variables that determine the impact of air pollution on health. The ways of reducing the health impacts of air pollution, that is, possible policy recommendation are dealt in Section 6. The last section concludes the chapter.

2. Air Pollution Exposure and Health Impacts

2.1 Outdoor air pollution exposure and health impacts

Epidemiological studies show that the concentration of air pollution is responsible for increased adverse health impacts (Ostro et al. 1995). Air pollution contributes to the respiratory diseases like eye irritation, bronchitis, emphysema, asthma etc which not only increases individuals' diseases mitigation expense but also affect their productivity at work.

An increase in the air pollution level raises public mortality and morbidity (Krupnick et al, 1990; Cropper et al, 1997; Chhabra et al, 2001). Cropper et al. report the results of a study relating levels of particulate matter to daily deaths in Delhi between 1991 and 1994. The focus is on Delhi because it is one of the world's most polluted cities. This study finds a positive, significant relationship between particulate pollution and daily non-traumatic deaths, as well as deaths from certain causes (respiratory and cardiovascular problems) and for certain age groups. This study concludes that the impact of particulate matter on total non-trauma deaths in Delhi is smaller than effects found in the United States, and the impacts of air pollution on deaths by age group may be very different in developing countries than in the United States, where peak effects occur among people aged sixty-five and older. In Delhi, peak effects occur between the ages of fifteen and forty-four, implying that a death associated with air pollution causes more life-years to be lost. Such differences in the magnitude of impacts of pollution would question the validity of the transfer of dose – response procedure when such relationships as found for

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[1] Recently, especially in northern India, there is a problem of air pollution caused by agricultural residue burning also. Though health consequences from burning of agricultural residue are not fully understood, relative short exposure may be more of a nuisance rather than a real health hazard, many of the components of agricultural smoke cause health problem under certain conditions (Long and Manfreda, 1998).

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the industrialized countries are applied to the cities of the developing countries (Sengupta and Mandal 2007). However, this study of Cropper et al. has no specific reference to the problem of apportioning the damage caused by pollution to its different sources and that of ascertaining the responsibility of automotive emission for the health damage as have occurred in Delhi. Chhabra et al. find evidence of elevated rates of respiratory morbidity amongst those dwelling in highly polluted areas of Delhi, after adjusting for several confounders. Daily counts of emergency room visits for acute asthma, acute exacerbation of chronic obstructive airway disease (COAD) and acute coronary events are related to daily levels of pollutants, particularly total suspended particulate (TSP) recorded a day earlier using time series approach.

Sharma et al (2004) conducted a panel study was conducted in the town of Kanpur, India In the Kanpur city the level of air particulates known as PM_{10} ranged from about 100-500 $\mu g/m^3$. It was found that the level of PM_{10} has been associated with reduced Peak Flow on high pollution days. Kumar et al. (2004) studied the respiratory health of adult inhabitants of two small towns in northern India with different pollution levels (PM_{10} 113 versus 76 $\mu g/m^3$). In the more polluted town there has a steel factory but in the other town which is less polluted has a sugar care facility. They found a positive association between pollution level and morbidity. Bronchitis, wheeze and shortness of breath were observed higher among the inhabitants of more polluted town.

2.2 Indoor air pollution exposure and health impacts

In India a large chunk of population burns solid fuels through traditional stoves to meet their cooking needs. Various studies find a positive association between indoor air pollution from the burning of biomass fuels serious health treats, particularly to women and young children who spend a considerable amount of time near the cooking stove. The burning of solid biomass fuels generates various pollutants, including particulate matter (PM) and carbon monoxide (CO) that have been shown to be highly toxic and associated with increased rates of infant mortality (Chay and Greenstone 2003a and 2003b, Duflo et al 2008).

In the developing countries like India, the emissions rates of pollutants from the use of traditional stove burning solid fuels are extremely high. Numerous studies have found positive associations between indoor air pollution and acute lower respiratory infection (Smith et al, 2000), chronic obstructive pulmonary disease (Bruce et al, 2000; WHO, 2002) and lung cancer in the case of coal smoke (Mumford, 1987, Smith, 1993). Smith (2000) finds that in India the mean 24-hour PM_{10} concentration from solid-fuel-using households sometimes exceeds 2000 $\mu g/m^3$, against the United States (US) Environmental Protection Agency's (EPA) standard for an acceptable annual 24-hour average of PM_{10} 50 $\mu g/m^3$ (EPA 2006). To estimate the annual burden indoor air pollution Smith (2000) uses morbidity/mortality attributable to indoor air pollution. He finds that, in terms of sick days, the annual health burden from indoor air pollution is 1.6-2.0 billion days of work lost.

There is emerging evidence that indoor air pollution increases the risk of other child and adult health problems, including low birth-weight, prenatal mortality, asthma, otitis media (or middle ear infection), tuberculosis, nasopharyngeal cancer, cataracts, blindness, and cardiovascular disease (WHO 2002). The World Health Organization finds that indoor air pollution is responsible for 2.7% of the loss of disability adjusted life years (DALYs) worldwide and 3.7% in high-mortality developing countries.

Table 1 provides the estimates of child mortality under-5 due to the use of solid biomass fuels in India.

Table 1: Estimated annual child mortality due to not using clean fuels in India

Ages	Urban	Rural	All India	YLL*	DALY**
7 days to <1 year	10000	385000	395000	13.2 million	13.6 million
1 year to <5 years	4000	172000	176000	6.2 million	6.4 million
Total (7 days to <5 years)	14000	557000	571000	19.4 million	20 million

* Using Years of Life Lost

** Using the ratio of DALY/YLL for ALRI in Indian children under five (1.03)

Source: Smith and Mehta (2003)

Note that all these studies measuring the health impacts of indoor and/or outdoor air pollution use dose-response functions. Pearce and Crowards (1996) points out certain problems with respect to dose-response function. The main critical factors appear to be are threshold levels, biological pathways, confounding factors and long term effects, among others.

The first question is, is there a threshold or other non-linearities in the concentration-response relationship? Schwartz (1994) finds no evidence is seen for a threshold. In general, the linear and exponential functional forms adopted by most researches don't suggest a strong attenuation of effects at low levels (Desvousges *et at* 1993). WHO standards also don't provide any reasonable approximation to a threshold. Since Ostro (1995) points out that the absence of an observed threshold may be the result of study design or of the fact that there is no threshold, but that the few studies that test for low level effects suggest effects continue to very low concentration.

Similarly, the biological pathway by which particulate matter affects human health appears to be uncertain. Utell and Samet (1993) review the various epidemiological studies and argue that the biological mechanism is unknown. Ostro (1995) reviews the evidence and suggests that pollution exposure is an additional burden of inflammation that may make worse the conditions of those already affected by respiratory infections.

One potentially significant issue is the extent to which the dose-response function adequately controls for all variables affecting health status. It is usual to control for factors such as smoking and diet, but Pearce and Crowards (1996) suggest that 'social status' may be an important factor in determining illness. One possibility then, is that exposure to PM_{10} is corrected with social status and with illness. This needs careful testing with panel data that include income, other measure of social status, and indoor and outdoor pollution concentrations. Ostro (1995) notes that time series studies avoid such confounding factors since the population characteristics are fairly constant over time. This issue is further discussed in Section 5.

Most of the studies use cross section data and neglect long term chronic effects, especially permanent impairment of long function and development of disease such as asthma and chronic obstructive pulmonary disease. Studies based on essentially 'acute' data will probably not capture long term health risks. This point suggests that the procedure used may actually understand the health damage from air pollution.

3. Valuation Methods

The governments increasingly need information about the costs and benefits associated with reduced levels of

pollution to assists them in pollution control measures. Air quality affects the utility of individuals and an economic value exists. There are several ways to capture this economic value, viz., dose-response, revealed preferences and contingent valuation methods. The dose-response method assumes a relationship between air quality and morbidity (and/or mortality). It puts a price tag on air quality without retrieving people's preferences for the good. The revealed preference methods assume that the consumers are aware of the costs/benefits of air quality, and are able to adjust their locations to reveal their preferences. Markets should be functioning perfectly and consumers should be well informed (Freeman 1993). In developing countries like India, markets neither are functioning perfectly nor are consumers well informed. Moreover, dose-response and revealed preferences methods do not consider the non-use values that form a substantial portion of total economic value of environmental resources. Therefore, in conducting demand assessment studies in a developing country context (including India), the contingent valuation method (CVM) continues to be extensively used by researchers (Whittington and Swarna, 1994; Griffin et al., 1995; Choe et al., 1996; Bateman and Willis, 1999; Ready et al., 2002; Ahmad et al., 2002)

The indirect valuation approach is usually applied to environmental problems. That is, if there is some damage and it is linked to a cause, the relationship between that cause and its effect is a dose response linkage. Once a dose response relationship is established, the indirect approach then utilizes valuations that are applied to the 'responses'. For example, consider the linkage between air pollution and health. If the health effects are established, a value of life and for illness is applied, but such type of mechanical relationship of the dose response function does not take into account consumer behavior. In the absence of stated preferences, it becomes necessary to have estimates of WTP or willingness to accept (WTA) on the basis of a consumer choice model aimed at measuring the strength of association between health effects and septic air pollutants.

In case of public goods like air quality, individuals face a quantity rather than a price constraint. Public goods have much higher income elasticity than marketed goods. This may be particularly true in a developing country where air quality is considered a luxury good which is afforded only when adequate food, clothing and shelter has been acquired. Hence, the income effect due to a change in air quality provision undermines the consumer surplus of welfare change. Hicksian compensating surplus (CS) (i.e. WTP to ensure that the change occurs) and equivalent surplus (ES) (i.e. willingness to accept (WTA) if gain does not occur), could be used to measure change in the level of welfare in quantity constrained utility functions.

Measurement of consumers' preferences for air quality improvement initiatives allows one to quantify the individuals' WTP. Consumers' preferences can be elicited either using revealed or stated preference data. The main differences between the two methods lay in the data origin and collection procedures. Revealed preference data are obtained from the past behavior of consumers. In CVM, the economic value placed by an individual for improved air quality is contingent upon a hypothetical scenario that is presented to the respondent for valuing. By means of an appropriately designed questionnaire, a hypothetical market is described where the good or service in question can be traded. The contingent market defines the good itself, the context in which it is provided and the way it is financed. Respondents then express their maximum willingness to pay for the good/service.

4. Valuation Case Studies

There have been relatively very few comprehensive studies on the health damage cost of air pollution in the Indian context. A tentative estimate of health costs of urban air pollution in India was estimated to be US $1.4 billion (Brandon and Homman, 1995). The data provided by the World Bank's World Development Indicators indicate that India loses about US$ 7 billion annually due to particulate matters (Figure 1).

There are many studies in developed countries that estimate the value of adverse health effects of air pollution (Gerking and Stanley 1986, Dockery et al. 1993, Schwartz, 1993, Pope et al. 1995 etc). Similar evidence is available from India and other developing countries (e.g., Cropper et al. 1997, Kumar and Rao 2001, Murty et al. 2003, Gupta 2008, Chestnut et al. 1997, Alberini and Krupnick 2000). These studies used either household health production model or damage function or cost of illness approaches to estimate the monetary value of health damages caused due to ambient air pollution. Note that theses studies are restricted to measure the monetary value of reducing urban air pollution to the safe level since air pollution has been considered mainly the problem of urban areas.

Cropper et al (1997) using dose-response model find that a 100-μg/m^3 increase in total suspended particulate matter (TSPM) leads to a 2.3% increase in trauma deaths in Delhi. Kumar and Rao (2001) estimated the household health production function using data of working individuals of the residential complex of Panipat Thermal Power Station in Haryana, India and find that individual willingness to pay varies between Rs 12-53 per month for improving the air quality to WHO standards. The model used by Kumar and Rao is described as follows:

Individuals derive utility (*U*) from the consumption of two classes of goods: their own stock of health capital (*H*), and representative consumption good (*X*) that yields direct satisfaction, but does not affect health.

Hence we write

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

The stock of health capital is determined by the production function.

$$H = (M; \alpha, \delta) \tag{2}$$

Where

$$H_M > 0, H_\alpha > 0, H_\delta >=< 0$$

Where, *M* denotes medical care (from which the individuals derive no direct utility), *α* denotes air quality, *δ* denotes a set of other exogenous variables, such as education, that affect *H*, and subscripts denote derivatives.

Utility is maximized subject to Equation (2) and the full income budget constraint shown in Equation (3)

$$Xq_x + Mq_M + WT_L = WT + A \tag{3}$$

Where $q_i = (P_i + WT_i)$, $i = X, M$; Pi is the money price of commodity *i, W* is the wage rate, *Ti* is the time required to consume one unit of commodity *i, TL* is the time lost from market and non-market activities due to illness, *T* is the total time available to the consumer, and *A* is an exogenously determined amount of asset income. *TL* is related to health stock according to

$$T_L = G(H) \tag{4}$$

Where $G_H < 0$.

This model can be manipulated in order to derive a compensating variation (CV) type expression for the

marginal WTP for improved air quality. Totally differentiating the utility function and setting *dU =0*,

$$dU = 0 = U_x dX + U_H H_M dM + U_H H_\alpha d\alpha + U_H H_\delta d\delta \quad (5)$$

Then, totally differentiate the full income budget constraint, holding $dq_i = dW = dT = 0$ *for i = X, M.*

$$d(WT) = 0 = q_x dX + (q_M + WG_H H_M) dM - dA + WG_H H_\alpha d\alpha + WG_H H_\delta d\delta \quad (6)$$

The Lagrangian of the objective function is

$$L = U[X, H(M; \delta, \alpha)] + \lambda[WT + A - Xq_x - Mq_M - WG(H)] \quad (7)$$

and the first order conditions for the model are

$$\partial L/\partial X = U_X - \lambda q_x = 0 \text{ or } U_x/q_x = \lambda$$
$$\partial L/\partial H = U_H H_M - \lambda (q_M + WG_H H_M) = 0 \text{ or,} \quad (8)$$
$$(U_H H_M)/(q_M + WG_H H_M) = \lambda$$

from equations (8) and (9)

$$U_x/q_x = U_H H_M/(q_M + WG_H H_M) = \lambda \quad (9)$$

Equations (6), (8) and (9) yield

$$\partial A/\partial \alpha = -H_\alpha q_M/H_M \quad (10)$$

This equation indicates that the individual is willing to pay more for a given air quality improvement, the greater the associated improvement in health. Also, that bid is higher, the lower the productivity of medical services and higher their costs. Therefore, if medical services are as expensive, but are an ineffective means of improving health, the individual is willing to pay more for improved air quality. Moreover, this equation is relatively straightforward to implement empirically, since utility terms have been eliminated.

As shown in equation (10) magnitude of the WTP term hinges critically on the estimation of the health production function. In estimating the health production function, H is treated as a multidimensional, rather than a uni-dimensional variable. The basic equation to be estimated is

$$MED = MED(PM_{10}\ Chro,\ Length,\ Age,\ School,\ F/B,\ Income,\ Envknow) \quad (11)$$

Where,

MED = a discrete variable, whether a doctor has been consulted during the last one month,

PM_{10} = the ambient concentration of particulates, i.e. particles measuring less than 10 microns in diameter, measured in μg/m^3.

Chro = dummy variable indicating whether the illness is chronic (1) or not (0),

Length = length of illness in days,

Age = age of the respondent in years,

School = years of schooling of the respondent,

F/B = family background of the respondent whether rural or urban,

Income = monthly income of the respondent in Rupees, and

Envknow = awareness about environmental problems, a dummy variable 1–4.

In Equation (11), the aerometric variable *PM10* is pollution rather than air quality. Hence, the expected sign on the coefficient of this variable is positive, implying that it must be multiplied by minus one in computing $\partial A/\partial \alpha$. Moreover, the expected signs of chro and length should be positive, since increase in the magnitude of these variables is associated with increase in the use of medical care.

The expected signs of the five socio-economic and demographic variables should be as follows: The coefficient of age should be positive if the aging process reduces the efficiency with which the health stock is produced. The coefficient of school should be negative if years of schooling increase the efficiency with which health is produced. The coefficient of family background (*F/B*) should be positive if rural areas tend to have lower health stock. The coefficient of income and environmental knowledge (subjectively reported) should be negative since these variables increase the health stock.

Equation (11) was specified as a restricted Cobb-Douglas function. Additionally, because of the discrete nature of the dependent variable MED, Logit and Probit models were used for estimation purposes. As is commonly done in such analysis, for each observation ten observations are taken, one for each PM10 level, since the data is available for ten months on PM10. The other explanatory variables have the same value in all ten observations. The discrete dependent variable takes value one if the MED is yes, and zero otherwise. Model estimates are presented in Table 2.

With respect to the air pollution variable PM10, the coefficient is positive, but not significantly different from zero at the 10% level. The coefficient of length and chro are, as expected, at a significance level of 1% in both the models. For socioeconomic demographic variables, the signs are according to expectations and are significantly different from zero, at either the 5 or 10% level.

With caution, the results from Table 2 can be used to illustrate willingness to pay (WTP) estimates for a reduction in PM10 levels. These benefit estimates are offered advisedly because of the caveats enumerated concerning the model, as well as the above outlined data problems. Since the sign of the PM10 is expected but insignificant, this is used in making the benefit calculation.

Table 2: Estimates of the medical care function

	Logit model		Probit model	
Variable	coefficient	t-value	coefficient	t-value
Constant	0.514	0.178	0.356	0.23
Y1/(length of disease)	0.0002	3.20	0.0001	3.261
Y2/(chronic)	0.830	4.614	0.458	4.546
Y3/(schooling)	0.039	1.231	0.026	1.486
ln Y4 (age)	0.783	1.698	0.458	1.814
Y5 (family B/G)	0.295	1.846	0.162	1.844
ln Y6 (PM10)	0.121	0.545	0.070	0.567
ln Y7 (income)	-0.758	-2.497	-0.45	-2.756
Y8 (knowledge)	-0.261	-2.497	-0.45	-2.756
Loglikelihood	-624.206		-622.454	
RMSE	0.456		0.456	
M_α	0.097		0.056	

Source: Kumar and Rao (2001)

Because PTPS colony experiences a large number of days each year when the average PM10 level substantially exceeds both national and World Health Organization (WHO) standards, large reductions in ambient concentrations are necessary in order to meet the standard. Therefore, a reduction in PM10 level of 67% of the mean has been used to calculate benefits (mean level for PTPS colony is 248.6 μg/m3 and WHO standard is 75μg/m3).

Illustrative willingness to pay (WTP) estimates are calculated based on Logit and Probit models, respectively. For a sixty seven percent reduction in ambient mean PM10 level concentrations, the monthly WTP ranges from Rs. 21 to Rs. 52.5 for the Logit model and Rs. 12.15 to Rs. 30.45 for the Probit model in 1996. The WTP estimates reported are computed using the means of the independent variable. These estimates appear to be small. This may be because the production function method is able to capture only the short-term illness effects of air quality improvements. The reduction in mean levels of PM10 allows us to calculate the WTP for each microgram/m3. That is a WTP of Rs. 21/173.6 per month per microgram (lower bound for the Logit model), which amounts to Rs. 1.45 per person per year. These estimates account only for the effects of the improvements in air quality on illness. A total estimate might also account for reduced materials damage, minor symptomatic discomforts and improve visibility.

Using a similar model, Murty et al (2003) observe that a representative household gains about Rs 2086 and Rs 950 per annum due to reduced morbidity from reduction of air pollution to the safe level in Delhi and Kolkata respectively. Similarly, Gupta (2008) estimates aggregate benefits of the magnitude of Rs 224.55 millions per year reducing air pollution to the safe level for the city of Kanpur, India.

Murty et al (2003) uses a health production function approach for the estimation of the benefit of saving of health damage due to urban air pollution in terms of the willingness to pay which has been derived from the econometric estimation of a simultaneous equation model. They use a reduced form structural household behaviorist model of utility maximization subject to the full time budget constraint and health production function. This study which has estimated the benefit of abatement of urban air pollution for Delhi and Calcutta, however, refers only to the health damage effect of air pollution without any serious source wise reference of the problem.

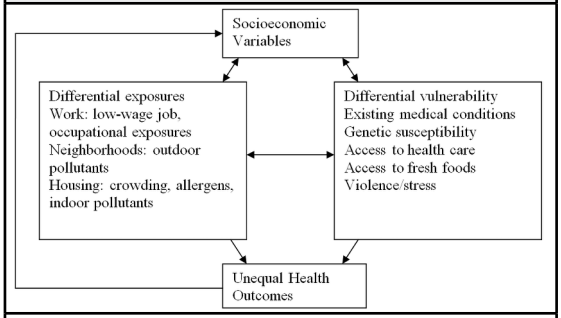
Gupta (2008) uses a model similar to Marty et al. (2003) to get the monetary estimates of reduced air pollution level to the safe level for the rural Punjab. Kumar and Kumar (2010) use the household health production function (HHPF) model to estimate the health benefits from reduced particulate matter from the burning of agricultural residues to the safe level for the rural Punjab. They find the total annual welfare loss in terms of health damages due to air pollution caused by the burning of rice straw in rural Punjab amounts to Rs 105 millions.

Sengupta and Mandal (2007) imputes the health damage cost to the source of emissions from vehicular exhausts for the Indian cities. No other study on the damage cost of air pollution in the Indian cities has, however, attempted to work out the health cost effect of urban transport. They used benefit transfer method for finding out the impact of air quality improvements on health costs from the studies on US cities and use some of the crucial health cost parameters from the study of Delucchi (2000). The latter studies use broadly a household health production function approach and they monetize the health damage by using the estimates of cost of illness due to loss of income for working days lost, cost of treatment, etc. The question of appropriateness of benefit transfer across countries would nevertheless remain important due to the inevitable culture dependence of methodologies and health cost estimates which cannot all be neutralized by any adjustments.

5. Socio-economic factors and health impacts of air pollution

Sections 2 and 3 establish that both indoor and outdoor pollution leads to health damages and these damages can be monetized using various methods. Section 4 reveals that the same level of air pollution leads to different levels of damages at different locations and the damages also differs among the cross sections of same populations, i.e., the level of damages due to air pollution is not only dependent on the levels of pollution, but depends on the level of exposure and various socio-economic factors that determine the level of exposure and vulnerability of a person to the air pollution. The determinants include both, individual specific socio-economic factors and neighborhood characteristics.

Figure 2: Potential pathways for SEP to increase susceptibility and exposure



Source: Adapted from O'Neill et al. (2003)

In paper, O'Neill et al (2003) hypothesize that people with lower socio-economic status get exposed higher to air pollution; the people with lower socio-economic status are experiencing compromised health status due to economic deprivation and psychological stress, therefore these people are more vulnerable to the health effects of air pollution; and as these are the people which are exposed more to the air pollution and are more vulnerable, they face higher health effects due to air pollution exposure. These potential pathways can be understood through Figure 2. This figure shows that the socio-economic status of an individual determine his/her level of exposure to the air pollution and the degree of vulnerability which in turn determine the outcome in terms of health effects. That is, those who are in a better position in terms of socio-economic status are less exposed to air pollution and are less vulnerable in comparison to the people who enjoy lower level of socio-economic status.

Air pollution caused due to industry-led production that is oriented towards satisfying urban consumer preferences is inherently inequitable considering that the poor are forced to bear a disproportionately greater burden of the pollution that such consumption and production activities generate. It is the 'poorest of the poor' who are most exposed to hazards in their environment due to the lack of clean and fresh water, and adequate food, shelter, fuel and air. Poverty impacts health because it determines how much resources poor people have and defines the amount of environmental risks they will be exposed to in their immediate environment. A particularly revealing example in this context relates to the problem of lead pollution in most large cities in the developing world. Motor vehicles, a prime symbol of urban consumption, account for up to 90 percent of all airborne lead contamination in urban areas where leaded gasoline is still widely used[2]. Although lead from air pollution causes relatively few deaths, it causes many and different types of disabilities[3], particularly among children.

[2] According to the Global Lead Network, 47 countries has completed phase-out of leaded gasoline in January 2002. However, many other countries and regions still use gasoline with high lead content, including Eastern Europe, the Middle East, and Africa.

[3] The World Health Organization estimates the effect of lead poisoning to be

Three environmental problems (contaminated drinking water, untreated human excrement, and air pollution) account for 7.7 million deaths annually or 15 percent of the global death toll of 52 million. One in five children in the poorest regions of the world will not live to see their fifth birthday, mainly because of environment-related diseases, i.e., mostly due to malaria, acute respiratory infections or diarrhea - all of which are largely preventable. This amounts to 11 million childhood deaths a year worldwide (Roberts, 1998). More than one billion people in developing countries live without adequate shelter or in unacceptable housing and more than 2.9 billion people have no access to adequate sanitation and all of these are necessary for good health (Parikh, 1998). Lack of sanitary conditions contributes each year to approximately 2 billion diarrhea infections and 4 million deaths, mostly among infants and young children in developing countries, and an estimated one-sixth of the world's population (1.1 billion people) remains without access to improved sources of water. More than 1.4 billion people lack access to safe water. Dirty water is the worlds "deadliest" pollutant (Lean, 2001).

The environment health burden as a percentage of the total disease burden is highest in regions that house most of the world's poor (27 % in Africa and 18 % in Asia) and lowest in industrial countries. Within individual countries, the poor suffer disproportionately from unsafe environmental conditions at the household and community levels.

Note that the health effects of air pollution or environmental degradation don't remain confined to the poor only, though the poor at the higher risks of premature mortality and morbidity effects. Generally the relationship between air pollution and health effects is a graded one, i.e., as the status of one goes on higher hierarchy of socio-economic status the health effects of environmental degradation or air pollution lower down (O'Neill et al., 2003). This graded relationship between air pollution and health effects or unequal health outcomes of air pollution that the studies measuring the health outcomes of air pollution should be done at both the individual level and area level. The conceptualization of these studies should also include time dimension as well, as the socio-economic status of individuals rarely remains static across the life course. Since the static studies cannot capture the dynamic and cumulative effects of socio-economic variables on health outcomes.

6. Policy Recommendations

From the preceding discussion it is clear that there is a positive association between air pollution and mortality and morbidity; air pollution either outdoor or indoor affects the human health adversely. Outdoor air pollution occurs due to urbanization, industrialization and growth of transport activities whereas the cause of indoor pollution is largely the burning of biomass for cooking needs. The effects of outdoor pollution are generally considered a problem of urban areas, though rural areas also suffer from the problem of outdoor pollution, especially the pollution caused by the agricultural residue burning in agricultural fields after the harvest times. The effects of indoor pollution are largely confined in the poor population in general and rural population in particular.

Outdoor air pollution is basically the problem of environmental externality and it can be controlled or internalized by the public policy interventions. To measure the extent of these externalities the regulating authorities measure the levels of air pollution at different locations both ambient and stack emissions. To control outdoor air pollution these authorities specify source specific standards for point and non-point sources. The various sources of pollution comply with these standards, the regulators specifies various measures which includes both carrot and sticks. In developing countries, like India, the policy prescription is largely a regime which is popularly know in the area of environmental economics as command and control (CAC) mechanism. Though in the developed countries like US or European Union countries now governments are using incentive based market instruments such as 'cap and trade' and emission taxation for controlling air pollution, the developing countries have yet to fully utilize the benefits of these improved measures which are cost effective in comparison to conventional command and control measures. Developing countries also try to harvest the benefits of these measures as these measures are less information demanding and compliance to some extent in these measures is in-built.

As stated above the problem of indoor air pollution is largely confined to rural and poor population and it is caused due to burning of solid biomass burning which happens in a most inefficient manner. Note also that the problem of indoor air pollution is, unlike outdoor pollution, not a problem of externality, but it is the problem of poverty. Due to poverty and non-availability of clean fuels, these people use solid biomass for meeting their cooking needs. Dufflo et al (2008b) suggest three measures for reducing indoor air pollution and thereby reducing the health effects. The first solution is to make available clean fuels such as kerosene, LPG and electricity at affordable prices to these people. That is, the clean fuels are required to be subsidized so that poor people can afford for these clean fuels. Subsidy programs tend to be quite expensive, in an age when governments are trying to trim already overstretched budgets. Moreover, Kerosene and LPG/Gas are often too expensive for poor households, and they may have the additional difficulty of being difficult to transfer to rural areas that often lack roads. Similarly, electric stoves are not practical in areas with low electricity levels, and the access of the poor to electricity varies greatly across countries. In India, about 40 percent people don't have access to electricity.

The second solution could be the improvement in the burning efficiency of conventional fuels themselves. At present poor households use conventional fuels using the conventional stoves which are very inefficient. Improved cooking stoves attempt to use traditional fuels in a more efficient manner and, therefore, do not impose a large cost on poor households. The improved cooking stove has become a particularly popular policy prescription. India has distributed over 12 million improved stoves in the first seven years of a national program to develop and subsidize improved stoves that has now been ongoing for more than 20 years. However research is required on whether or not distributing the improved cooking stoves actually is a cost-effective method to both reduce indoor air pollution and improve health. The third measure that Dufflo et al has suggested is to increase the ventilation within the household. However, if smoke exposure is the greatest threat in the immediate vicinity of the stove, it is unclear whether improving ventilation in the kitchen as a whole will reduce the smoke exposure for the primary cook in the household.

7. Conclusions

Air pollution has potentially large impacts on the health and well-being of households, especially the poor families. The literature indicates ambient air pollution levels and personal exposure are dramatically high in developing countries especially to indoor air pollution. The uncontrolled outdoor

about 1 to 3 points of IQ lost for each 10 ug/dl lead level. At higher levels, the effect may be larger. Lead affects almost every organ and system in the body-including the kidneys and the reproductive system. Recent studies supported by NIEHS suggest that a young person's lead burden is not only linked to lower IQ and lower high school graduation rates but to increased delinquency.

air pollution is the problem of urbanization, industrialization and growing transport facilities, whereas the indoor air pollution is largely the problem caused due to poverty. From both of the sources the country has been loosing a lot as the increased levels of pollution either indoor or outdoor leads to higher levels of mortality and morbidity risks and lower down the productivity of the labour force. The literature has also shown the distribution of the impacts of air pollution is not uniform across the cross sections of societies. The poor are more exposed to air pollution and are more vulnerable to the effects of air pollution due to their lower socio-economic status which is reflected in terms of material deprivation and psychological stress, and as a result there are unequal health outcomes among the different groups of society. The developing countries like India need urgent attention towards the problem of air pollution which is caused both by the development and poverty. Informed policy decision requires research inputs. Though there are some case studies on the relationships between air pollution (indoor or outdoor) and health outcomes, but much more studies are required to understand the relationship between health outcomes and exposure to the levels of air pollution especially indoor air pollution. Note also that though there are some case studies on the valuation of health impacts outdoor air pollution, but to our knowledge there is rarely any study on the valuation of health outcomes of indoor air pollution which uses consumer choice or behavior models. The studies should focus on both individual specific characteristics as well as the neighborhood specifications and these studies should be dynamic as the static studies fails to capture the effects of change in socio-economic features on health outcomes.

References

Ahmad, J. K., B. N. Goldar, M. Jakariya, and S. Misra (2002), 'Willingness to pay for arsenic free, safe drinking water in rural Bangladesh—Methodology and results', report, Water and Sanitation Programme–South Asia, Dhaka, Bangladesh, Dec.

Alberini A, Krupnick A (2000) 'Cost of illness and willingness to pay estimates of the benefits of improved air quality: evidence from Taiwan', Land Economics Bateman, I., and K. G. Willis (Eds.) (1999) Valuing Environmental Preferences: Theory and Practice of the Contingent Valuation Method in the US, EU, and Developing Countries, Oxford Univ. Press, New York

Brandon, C. and K. Hommann (1995) The Cost of Inaction: Valuing the Economy-wide Cost of Environmental Degradation in India. Asia Environmental Division, World Bank

Bruce N., R. Perez-Padilla, and R. Albalak (2000) 'Indoor Air Pollution in Developing Countries: A Major Environmental and Public Health Challenge' Bulletin of the World Health Organization 78(9): 1078-92.

Census of India 2001, Office of the Registrar General (2003)

Chay, Kenneth and Michael Greenstone (2003a) 'The Impact of Air Pollution on Infant Mortality: Evidence from Geographic Variation in Pollution Shocks Induced by a Recession', Quarterly Journal of Economics, 118(3), 1121-67.

Chay, Kenneth and Michael Greenstone (2003b) 'Air Quality, Infant Mortality, and the Clean Air Act of 1970', NBER Working Paper No 10053.

Chesnut LG, Ostro BD, Vichit-Vadakan N (1997) 'Transferability of air pollution control health benefits estimates from the United States to developing countries: evidence from the Bangkok study' American Journal of Agricultural Economics 79:1630–1635

Chhabra, S. K., J. N. Pande, T. K. Joshi and P. Kumar (2001) 'Air Quality and Health' Paper presented at the workshop on Land Use, Transportation and the Environment, Pune, India, December 3-4, retreived: http://www.deas.harvard.edu/TransportAsia/workshop_papers/ChhabraetalFinal2.pdf

Choe, K., D. Whittington, and D. T. Luria (1996) 'The Economic Benefits of Surface Water Quality Improvements in Developing Countries: A Case Study of Dauao Philippines'. Land Economics 72, 519-537.

Cropper Maureen, Simon NB, Alberini A, Seema A, Sharma PK (1997) 'The health benefits of air pollution control in Delhi' American Journal of Agricultural Economics 79(5), 1625–1629

Delucchi Mark A. 2000. 'Environmental Externalities of Motor Vehicles Use in the U.S.' Journal of Transport Economics and Policy, 34(2), 135-168.

Desvausges, W. et al. (1993) 'Review of health effects resulting from exposure to air pollution', working paper 1 (revised) Research Triangle Institute, Task force on Externality Costing

Dockery, D. W. et al. (1993) 'An Association between Air Pollution and Mortality in Six U.S. Cities' The New England Journal of Medicine, 329(24): 1753-1759.

Duflo, E., Michael Greenstone, Rema Hanna (2008a) Cooking Stoves, Indoor Air Pollution and Respiratory Health in Rural Orissa, , Economic & Political Weekly, Vol. 43, No. 32, pp. 71-76, Special Issue, August 09 - August 15.

Duflo, E., Michael Greenstone, Rema Hanna (2008b) Indoor air pollution, Health and Economic Well-being, Working Paper, Department of Economics, Massachusetts Institute of Technology and J-PAL

Freeman, A.M. (1993) The Measurement of Environmental and Resource Value: Theory and Methods, Washington DC: Resources for the Future.

Gerking S, Linda RS (1986) 'An economic analysis of air pollution and health: the case of St Louis', Review of Economics and Statistics 68:115–121

Griffin, C. C., J. Briscoe, B. Singh, R. Ramasubban, and R. Bhatia (1995), 'Contingent valuation and actual behavior: Predicting connections to new water systems in the state of Kerala, India', World Bank Economic. Review, 9(1), 373–395.

Gupta, U. (2008) 'Valuation of Urban Air Pollution: A Case Study of Kanpur City in India', Environmental and Resource Economics 41:315–326

Krupnick, A., W. Harrington and B. Ostro (1990) 'Ambient Ozone and Acute Health Effects: Evidence from Daily Data'. Journal of Environmental Economics and Management 18(1), 1-18.

Kumar R, Sharma M, Srivastva A, Thakur JS, Jindal SK, Parwana HK (2004) Association of outdoor air pollution with chronic respiratory morbidity in an industrial town in northern India, Arch Environ Health, 59(9):471-77

Kumar, Surender and D. N. Rao (2001) 'Valuing the Benefits of Air Pollution abatement Using Health Production Function' Environmental and Resource Economics vol. 20, reprinted in Surender Kumar and Shunsuke Managi, Economics of Sustainable Development: Case of India, New York: Springer (2009)

Kumar, Surender and Parmod Kumar (2010) Valuing the Health Effects of Air Pollution from Agricultural Residue Burning

Lean, G., "At A Glance," Our Planet Vol. 12, No. 2 (2001): 16.

Long, W. Tate, RB; Neuman, M.; Manfreda, J.; Becker, AB and Anthonisen, NR (1998) 'Respiratory Symptoms in a Susceptible Population Due to Burning of Agricultural Residue', Chest; 113; 351-357

Mumford J.L. et al.(1987) "Lung cancer and indoor air pollution in Xian Wei, China," Science, 235(4785): 217-220.

Murty MN, Gulati SC, Banerjee A (2003) 'Health benefits from urban air pollution abatement in the Indian subcontinent', Discussion Paper no. 62/2003, Institute of Economic Growth, Delhi, IEG Website

O'Neill, M. S., M Jerrett, I Kawachi, J I. Levy, A. J. Cohen, N. Gouvei, P. Wilkinson, T. Fletcher, L. Cifuentes, and J. Schwartz (2003) 'Health, wealth, and air pollution: advancing theory and methods', Environmental Health Perspectives, 111:1861-1870.

Ostro B, Sanchez, J., Aranda, C., Eskeland, GS (1995) 'Air pollution and mortality: results from Santiago, Chile', Policy Research Department, Working Paper 1453, World Bank, Washington, DC

Parikh, K. S. (1998) "Poverty and Environment Turning the Poor into Agents of Environmental Regeneration" (Working Paper Series), United Nations Development Programme Poverty Related Publications. See http:www.undp.org/poverty/publications/wkpaper/wp1

Pearce, D. and Crowards, T. (1996) 'Particulate matter and human health in the United Kingdom, Energy Policy, 24, pp. 609-619

Pope IIICA, Thun MJ, Namboodiri MM, Dockery DW, Evans JS, Spieizer FE, Health CW (1995) 'Particulate air pollution as a predictor of mortality in a perspective study of US adults', American Journal of Respiratory and Critical Care Medicine 151(3):669–674

Ready, R. C., J. Malzubris, and S. Senkane (2002), 'The relationship between environmental values and income in a transition economy: Surface water quality in Latvia', Environment and Development Economics, 7(1), 147–156.

Roberts, L., World Resources 1998-1999. London: Oxford University Press, 1998.

Schwartz (1993) 'Particulate air pollution and chronic respiratory diseases', Environmental Research 62:7–13

Schwartz, J. 1994. "Air pollution and daily mortality: a review and meta analysis." Environmental Research 64: 36-52.

Sengupta and Mandal (2007) Health Damage Cost of Automotive Air Pollution: Cost Benefit Analysis of Fuel Quality Upgradation for Indian Cities, Working Paper, National Institute of Public Finance and Policy, New Delhi.

Sharma M, Kumar VN, Katiyar SK, Sharma R, Shukla BP, Sengupta B. Effects of particulate air pollution on the respiratory health of subjects who live in three areas in Kanpur, India. Arch Environ Health. 2004 Jul; 59 (7):348-58.

Smith, K R (2000): 'National Burden of Disease in India from Indoor Air Pollution', Proceedings of the National Academy of Sciences of the United States of America, 97(24): 13286-293.

Smith, K. R. and Sumi Mehta (2003) 'The burden of disease from indoor air pollution in developing countries: comparison of estimates' International Journal of Hygiene, Environment and Health, 206: 279-289.

Smith, V.K. (1993) 'Non-Market Valuation of Environmental Resources: An Interpretive Appraisal'. Land Economics 69, 1-26.

Utell, S. and Samet, J. (1993) 'Particulate air pollution and health: new evidence of an old problem', American Review of Respiratory Disease, 147, pp. 1334-1335.

Whittington, D., and V. Swarna (1994), 'The economic benefits of potable water supply projects to households in developing countries', Economics Staff Papers 53, Asian Development Bank, Manila

World Bank, Adjusted Net Savings, World Development Indicators, Retreived from http://siteresources.worldbank.org/EXTEEI/Resources/ANS_time_series_by_country_1970to2008.xls Accessed on 30 July 2008

WHO (2002): 'Addressing the Links between Indoor Air Pollution, Household Energy and Human Health', based on the WHO-USAID Global Consultation on the Health Impact of Indoor Air Pollution and Household Energy in Developing Countries (meeting report), Washington DC, May 3-4, 2000.