Health Damage Cost of Automotive Air Pollution : Cost Benefit Analysis of Fuel Quality Upgradation for Indian Cities•

Ramprasad Sengupta[1]
and
Subrata Mandal[2] **

The paper has analysed the economic implication of judicial activism of the apex court of India in the regulation of automotive air pollution. It estimates the health damage cost of urban air pollution for 35 major urban agglomerations of India arising from automotive emissions and the savings that can be achieved by the regulation of fuel quality so as to conform to the *Euro* norms. It has used the results of some US based study and has applied the transfer of benefit method from the US to the Indian situation for the purpose. The paper finally makes a benefit cost analysis of refinery upgradation for such improvement of fuel quality.

Key words: Urban air pollution, health damage cost, benefit – cost comparison.

• The paper is based on a study on the subject carried out by the authors for the National Institute of Public Finance and Policy. The authors are indebted to Ashok Lahiri and Govinda Rao for their support, comments, and suggestions.

1. Professor of Economics, Jawaharlal Nehru University, New Delhi.
2. Senior Economist, National Institute of Public Finance and Policy, New Delhi. Email: subrata@nipfp.org.in.

** Communicating Author

Health Damage Cost of Automotive Air Pollution : Cost Benefit Analysis of Fuel Quality Upgradation for Indian Cities

Ramprasad Sengupta
and
Subrata Mandal

Introduction

With urban growth and industrialisation, an urban ecosystem has begun to draw substantially upon the resources of nature directly and indirectly and generate growing amounts of wastes in solid, liquid-effluent and gaseous forms, which either the local ecosystem or the peripheries have to receive, irrespective of their ability to absorb. Of the various kinds of pollution, the air pollution has attracted high priority in respect of environmental regulation since the environmental damage due to such pollution mostly affects human well-being directly by way of adverse health effects on the population exposed to it. Again, among the different sources of urban air pollution the share of vehicular exhaust has been perceived to be rising over time and is at present the largest for many of the Indian cities because of rising income and vehicular population. The significance of motor vehicles in contributing to the total damage value that a society suffers due to air pollution, has increased substantively particularly after the realisation based on the findings of environmental researches that particulates are the most damaging pollutant while ozone and other air pollutants have smaller impacts. Very fine particulates like PM_{10} or $PM_{2.5}$ being more dangerous than larger particulates, the combustion of fuel like high speed diesel (HSD) has become a greater danger for human health than apparently more visible source of road dust (Dockery *et.al.* 1993; Marrack 1995; Pope *et. al.,* 1995). The studies of Small and Kazini (1995), Krupnick *et. al.* (1997) and Delucchi and McCubbin (1999) point to the relative importance of automotive pollution in determining urban air quality and their health cost implications. Since diesel is the prime fuel of automotive transport in developing countries like

India, the environmental air policy is increasingly focusing on regulation of both vehicular engine design and fuel quality specifications.

As any policy specification needs to weigh the benefits against the costs of the measures involved in policy implementation, the issue of valuation of health damage due to automotive air pollution has become one of growing importance in the Indian context. The present paper is based on a study carried out by the authors (Sengupta and Mandal, 2002) for the National Institute of Public Finance and Policy, New Delhi which addresses the problem of estimation of health damage cost due to urban automotive transport emissions for 36 urban agglomerations of India. The historical backdrop of this study has been the directions of the Supreme Court of India on the quality of automotive fuel and vehicular emission regulations in India in recent years which stipulated the conformity of engine design and fuel quality to *Euro* norms within a certain time frame. As any such regulation for upgrading fuel quality and reducing pollutants emission from exhaust would involve costs both for refineries and automobile industry, internal debate arose on the question whether the benefit of saving of health cost (which had not yet been assessed) would be commensurate with the costs involved.

The purpose of this paper has, therefore, been two fold. First, we have estimated the health damage cost of urban air pollution for major urban agglomerations of India due to automotive pollution and its saving as would be ensured by the regulation of fuel quality and vehicle design so as to approximately conform to *Euro*-norms in a certain time frame. Secondly, the paper makes a cost-benefit analysis of refinery upgradation for the improvement of fuel quality for the different urban agglomerates of the country.

II. The Methodological Issues

The estimation of health damage cost due to automotive air pollution for any city involves the following steps:

(a) Estimation of emissions inventories of various pollutants from any given inventory of motor vehicles.

(b) Estimation of the relationship between emission rates of pollutants from exhausts and the air qualities as given by the ambient concentration of pollutants at the receptors' locations where these are being monitored by the regulatory authority.
(c) Assessment of the physical impact of the exposure of the different pollutants on human health in terms of morbidity and mortality.
(d) Monetisation of health damage as assessed in (c).

Any effect of variation in the emissions of pollutants from automobile exhausts from a baseline scenario has to be ideally traced down to changes in health damage cost along this line of stepwise estimation.

The emissions for a given inventory of vehicles for their respective distances traveled can be derived for each type and model of vehicles, once this emission rates for the different models and engine designs are given per kilometre of distance travelled. The estimates of exposures to air pollutants caused by such emissions as indicated in the second step again requires the use of models of emissions, dispersion, and atmospheric chemistry along the lines developed by, for example, Delucchi and McCubbin (1996) which adopts micro-environment estimation approach. The epidemiological literature, on the other hand, suggests that air pollution causes a variety of effects including eye irritation, headaches, acute and chronic respiratory illness, and death. Exposure – response functions of logistics or *Poisson* type are often fitted to find out the changes in health effects due to changes in the exposure as given by the variation in the concentration level of a variety of criteria pollutants. Particulate matters are found to be the most significant among the air pollutants, the smaller ones having greater damaging effects as per such epidemiological studies of dose-response relations. (Delucchi 2000; Dockery *et.al.,* 1993; Marrack 1995; Pope *et.al.,* 1995).

The literature on health impacts of pollution, both technical and economic, is largely dependent on researches carried out in the United States. The lack of interdisciplinary research initiatives by health research institutions in India, has particularly caused the absence of epidemiological studies which could provide reliable estimates of health damages for variation in pollution emissions in the Indian situation. European studies for estimating the health effect of environmental quality are also heavily dependent on US research. (Holland, Berry, and Forste, Extern E Project, 1999). As a result we have often had to rely on the studies of other countries, specially US, and examine the transferability of the benefit of pollution abatement in terms of savings in health damage cost from the US to the Indian situation in order to arrive at some estimates of health benefits for variations in the automotive pollution in Indian urban situation.

While using the transfer method of results of the US research work to other countries' situation, it is of course important to look at the cultural dependence of the estimates and methodologies adopted (Holland, Berry and Foster, 1999, Extern E Project of European Commission 1998). There have been attempts of estimates of cost of illness and/or willingness to pay for benefits due to improvement in air qualities for the situations of Taiwan, Thailand and other developing countries by mostly transferring the parametric estimates of physical impacts or of monetisation of physical impacts from US situation (Alberini and Krupnick 1997; 2000; Chestnut, Ostro and Vichit – Vadakan 1997; Pearce 1996).

For monetising the value of health damage, economists use the method of value of statistical life for monetising the mortality part of the health damage of pollution. Such statistical value of life essentially represents the loss of value due to the shortening of life. There has emerged, on the other hand, two alternative approaches for valuing the morbidity (Cropper and Freeman, 1991):

(a) **Observed market approach**: This includes techniques that rely on demand and cost functions, market prices, and observed behaviour and choices. Household production functions and cost of illness studies illustrate this approach (Moore and Viscusi, 1988; Viscusi, 1991; Krupnick and Cropper 1992). As per this approach the cost of illness studies considers the wage or earning loss due to the loss of working days and the cost of treatment to monetise morbidity.

(b) **Constructed market approach**: This method consists of directly asking the people about their willingness to pay or accept compensation for certain assumed change in the level of pollution or risk of morbidity. The contingent valuation method (CVM) has been an example of this second approach.

While the observed market valuation is based on actual behaviour, it does not capture the valuation of those aspects of morbidity like suffering or pain for which there is no market signal. The observed market often values a part of the totality which we wish to value. For example, the cost of illness studies cannot capture the cost of suffering and pain due to illness which cannot be observed in the market. The constructed market approach as illustrated by the CVM can avoid this problem only if the questionnaire is precise and focused on all the relevant issues and also if the respondents reveal their true preferences and be realistic while structuring their preferences. As a consequence of all these difficulties, the valuation of health damage cost has often been found to be unreliable and uncertain as arrived at in either approach. It is, in fact, difficult to give a point estimate of the damage cost with reliability. It is therefore often a range of interval estimates of such valuation that are given assuming different scenarios of values for the uncertain factors relating to the environmental parameters of exposure or ambient concentration effect or to the ones relating to the epidemiological impact or to the monetisation of damage. (Krupnick and Kopp 1988; Delucchi and McCubbin, 1999).

III. Studies on Health Damage Costs in the Indian Context

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 study on physical health impacts of urban air pollution in Delhi by Cropper *et. al.* (1997), reveals that particulate air pollution has less overall impact on non-traumatic deaths in Delhi than in the US. However, according to their findings, it is also true that deaths occur earlier in life in Delhi than in US because the age distribution of impacts is different between these two countries. 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 the industrialised countries are applied to the cities of the developing countries. 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 occured in Delhi.

There has also been a recent study by Murty, Gulati, and Banerjee, (2003), on 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. The latter is in its turn the reduced form of a structural household behaviouristic model of utility maximisation 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.

As our present study refers specifically to the imputation of health damage cost to the source of emissions from vehicular exhausts for the Indian cities, such analysis has to take account of the problem of impact of emissions from vehicular exhausts on the ambient air-quality to which any given city population is exposed. None of the other notable studies on the damage cost of air pollution in the Indian cities has, however, attempted to work out the health cost effect of urban transport. There is in fact no counterpart study or data in India of the ones as given by the studies of auto oil programme of Europe or of those of emissions, dispersion, and ambient concentration of pollutants. Nor has there been any epidemiological study of finding the health effects of pollution exposures as has been carried out in the United States. As a result, we have had to depend on the transfer of benefit 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 monetise the health damage by using the estimates of cost of illness due to loss of income for working days lost, cost of treatment, etc. which have in turn been based on the judgmental values based in large part on the works of Krupnick (1988), Krupnick and Kopp (1988), Krupnick and Cropper (1992), and Delucchi and McCubbin (1996). As these works are mostly based on the observed behaviour of the local environment and the household's choices in respect of labour supply, income and health related expenses, Delucchi's work from which our present study draws upon for the transfer of environmental benefits for air pollution abatement is not based on any scheme of contingent valuation survey.

Unlike in the case of water, there is in fact no market for clean air which may provide price signal and can be used as a benchmark reference by one who is to respond to the queries of contingent valuation survey. This gives the rationale for relying on the observed market approach for the valuation of health damage due to air pollution. In the application of health benefit parameters for air quality improvement as estimated for the US cities by Delucchi to the Indian urban situation, we have, however, made adjustments of the concerned parameters estimated for the US cities for differences in demographic, income and currency purchasing power, etc. between the two countries. The question of appropriateness of such benefit transfer across countries would nevertheless remain important due to the inevitable culture dependence of methodologies and health cost estimates which cannot all be neutralised by such adjustments.

IV. Upgradation of Refinery Fuel Quality Norms in India

Judicial activism has played an important role in environmental regulation in India. Being concerned with the growing vehicular population and automotive pollution in urban agglomerations in India, particularly in the National Capital Region, the Supreme Court directed in May 1999 that *Euro-II* norms should be made effective for all newly registered private non-commercial motor vehicles with effect from April 1, 2000, for the National Capital Region (NCR). Following the Supreme Court directives, India 2000 norms were formulated in the year 2000. These norms are significantly tighter than the earlier standards and are at least *Euro-I* equivalent for all four-wheelers, *Euro-II* equivalent for non-commercial four-wheelers in the NCR (also referred to as *Bharat Stage II*) and are the tightest norms in the world for two-wheelers.

As per the directions of the Supreme Court in 1999, the government intervened to upgrade the fuel quality standard in India and specified that the sulphur content of commercial fuel for meeting the emission standards both in gasoline and diesel engines shall be up to a maximum weight of 0.05 percent, and the benzene content up to a maximum volume of 1 percent for the supply of motor spirit (MS) in the NCR by April, 2001. The notifications of the government in these respects essentially meant that only fuel quality of *Euro-IV* specifications with respect to benzene and sulphur could be sold in the NCR. The regulation of fuel quality in India is now being effected through the introduction of the norms of *Bharat Stage II* for the entire country by April, 2005 and *Bharat Stage III* for the severely affected cities from April, 2005.

Given the regulators' trend of the other parameters of fuel quality like RON AKI, aromatic and olefin contents in motor spirit (MS), and cetane number, distillation temperature and polycyclic aromatics in high speed diesel (HSD), these norms for sulphur and benzene require the fuel quality parameters for oil to lie in the range between *Euro-III* and *Euro-IV* which are targeted to be achieved within the time frame of 2005 in major metro cities of India. The public sector refinery industry in India accordingly targetted to upgrade their refineries so that motor spirit and high speed diesel could match these ultimate quality requirements. The comparative estimates of *Euro* norms and such target quality norms as followed in such refineries in India are presented in table 1 and table 2. We find out in this paper both the benefit of health cost saving and the cost of refinery upgradation from pre-*Euro* norms of fuel i.e. Bureau of Indian Standards (BIS) 2000 to various *Euro* norms in an attempt to assess the economic justifiability of the directives of India's apex court.

Table 1: *Euro* Norms and Target Quality for MS in Indian Refineries

S.N	Attributes	Max/ min	BIS 2000	Euro-II	Euro-III	Euro-IV	Target quality for MS
1.	Ron AKI	Min. Min.	88 84	91 82.5	95	95	91 86
2.	Sulphur content Ppm wt.	Max.	1000	200	150	50	50
3.	Benzene vol. %	Max.	5*	5	1	1	1
4.	Aromatic content vol.%	Max.	-	-	42	35	35
5.	Olefin content vol.%	Max.	-	-	18	18	18

* As per CPCB 3% by vol. max for metro cities with effect from 2000.
Source: Government of India, Central Pollution Control Board (2000).

Table 2: *Euro* Norms and Target Quality for HSD in Indian Refineries

S.N	Attributes	Max./ Min	BIS 2000	Euro- II	Euro-III	Euro-IV	Target Spec. for upgraded HSD
1.	Cetane no	min.	48	49	51	53	51
2.	Sulphur content, Ppmv	Max.	2500	500	350	50	350
3.	Distillation	Max					
	85% vol.	^{o}C	350	-	-	-	-
	95% vol.		370	-	360	340	360
4.	Polycyclic aromatics	% wt. Max.	-	-	11	11	11

Source: Government of India, Central Pollution Control Board (2000).

V. Automotive Emission of Pollutants in the Indian Urban Situation

We have considered 4 main pollutants – PM_{10} (among particulate matters), NOX, CO and HC (Hydro Carbons) in our study of health damage costs in 35 urban agglomerations of India with population exceeding 1 million mark. The baseline scenario has been defined to be a hypothetical one in which the assumption is that all the vehicles of various modes as well as the fuel used are of pre-*Euro* specification, whereas the *Euro-II, Euro-III* and *Euro-IV* scenarios are generated on the assumption that both the fuel used and the engine designs for all the vehicles of all the modes conform to the respective specifications of these norms. The study has considered the modal mix of Indian cities to comprise 2-wheelers, 3-wheelers, cars, jeeps, taxis, buses, trucks and light commercial vehicles (LCVs) and the vehicular population size to be as existing or as estimated for 2002 (*see* Table 3). The vehicular population given for each mode in table 3 gives the estimate of the number of vehicles of that mode as on road in the concerned city and this has

Table 3: Vehicular Population and Composition in 35 Major Urban Agglomerates as on 1st April 2002

Cities	2-wheelers	3-wheelers	Cars	Jeeps	Taxis	Buses	Trucks	L.C.V.s	All vehicles
Agra	80466	2910	5387	1219	210	389	73	9	90663
Ahmedabad	607276	35349	92929	8188	5432	5511	10021	8783	773489
Allahabad	437262	2557	28161	6370	1100	1259	5843	707	483258
Amritsar	106429	2785	11685	4182	1106	212	3883	n.a.	130281
Asansol	2090	150	2414	0	51	186	690	n.a.	5582
Bangalore	669206	35300	124406	5641	5366	4241	16619	8306	869086
Bhopal	133157	6063	5392	5566	386	1167	1452	648	153830
Chennai	866507	38656	186525	7680	346	1596	16492	2630	1120432
Coimbatore	47643	2480	3543	146	7	558	798	127	55302
Delhi	1565540	52870	702289	0	14938	31606	98488	n.a.	2465730
Dhanbad	45290	1501	6634	3653	875	772	2558	1841	63125
Faridabad	47248	5007	8521	3050	807	626	25244	n.a.	90501
Hyderabad	761141	45401	68294	37607	9006	6849	9891	7118	945306
Indore	223583	3577	11725	12103	840	6772	7991	3565	270155
Jabalpur	122553	859	1843	1903	132	1648	2405	1073	132416
Jaipur	178789	2872	15167	5428	1435	3964	14855	n.a.	222510
Jamshedpur	24673	818	5830	240	11	421	2067	330	34389
Kanpur	163768	397	19147	4331	748	190	1043	126	189750
Kochi	100014	9930	16308	5836	1543	3707	14423	n.a.	151762
Kolkata	307200	22035	178521	0	23822	27348	101413	n.a.	660339
Lucknow	232689	3685	31198	7057	1218	1098	3034	367	280347
Ludhiana	205447	5376	22556	8073	2135	409	6318	n.a.	250314
Madurai	53609	2791	3987	164	7	628	898	143	62228

Table 3: Vehicular Population and Composition in 35 Major Urban Agglomerates as on 1st April 2002

Cities	2-wheelers	3-wheelers	Cars	Jeeps	Taxis	Buses	Trucks	L.C.V.s	All vehicles
Meerut	89118	521	5740	158	1365	257	1191	144	98494
Mumbai	620189	180511	245920	19024	46094	9840	32319	45559	1199456
Nagpur	206936	6713	12024	4097	1225	1351	4879	2783	240008
Nasik	54119	4566	6394	563	374	133	3462	1544	71155
Patna	59253	1963	8079	4055	927	1010	5643	112	81043
Pune	367716	29851	42610	8976	3115	3834	13288	4410	473801
Rajkot	104323	1581	6816	601	398	343	4257	3731	122049
Surat	347733	17965	33115	2918	1936	662	8863	7767	420958
Vadodara	99449	7103	12796	1128	748	59	1676	1469	124427
Varanasi	91556	535	5897	1334	230	264	1223	148	101188
Vijayawada	32453	1647	1970	1085	260	17	546	393	38371
Vishakhapatnam	56102	2846	3427	1887	452	29	1117	803	66664

Source: Data obtained from Government of India, Ministry of Petroleum and Natural Gas, Petroleum Planning Analysis Cell on Enquiry.

been taken to be the difference between the total stock of registered vehicles in a city in the concerned year and that of it fifteen years earlier, assuming 15 years as the average effective life of such vehicles for full scale use. We have also estimated the total vehicle distance travelled by each mode from the actual data regarding the daily lead distances of travel for each mode in the different cities. The norms of emission coefficients for the different modes and for the different pre-*Euro* and *Euro*-specifications for fuel and engine design as obtained from the Central Pollution Control Board (CPCB) of the Government of India as per their assessment have been as given in table 4. Since there are no *Euro*-norms available for 2-wheelers and 3-wheelers, the norms as shown against pre-control, 1996 norms, 2000 norms and 2005 norms would correspond to the pre-*Euro*, *Euro-II, Euro-III* and *Euro-IV* environmental standards. The application of these norms to daily vehicular travel of distance would yield the total daily flows of emissions of the various pollutants in the different cities which would determine the exposure level causing the physical health damage for the baseline and the different *Euro* norm scenarios.

Table 4: Emission Coefficients

(Kg./Km.)

Vehicle		CO	HC	NOX	PM
2 wheeler	Pre control	0.0065	0.0039	0.0003	0.0023
	1996 norms	0.004	0.0033	0.00006	0.0001
	2000 norms	0.0022	0.00213	0.00007	0.00005
	2005 norms	0.0014	0.00132	0.00008	0.00005
3 wheeler	Pre control	0.014	0.0083	0.00005	0.00035
	1996 norms	0.0086	0.007	0.00009	0.00015
	2000 norms	0.0043	0.00205	0.00011	0.00008
	2005 norms	0.00245	0.00075	0.00012	0.00008
Car	Pre Euro	0.0039	0.0008	0.0011	0.00005
	Euro II	0.00198	0.00025	0.0002	0.00003
	Euro III	0.00139	0.00015	0.00012	0.00002
	Euro IV	0.001	0.000125	0.000127	0.000016
Jeep	Pre Euro	0.0012	0.00037	0.00069	0.00042
	Euro II	0.0009	0.00013	0.0005	0.00007
	Euro III	0.00058	0.00005	0.0005	0.00005
	Euro IV	0.0005	0.00025	0.00045	0.000025
Taxi	Pre Euro	0.0039	0.0008	0.0011	0.00005
	Euro II	0.00198	0.00025	0.0002	0.00003
	Euro III	0.00139	0.00015	0.00012	0.00002
	Euro IV	0.001	0.000125	0.000127	0.000016
Bus	Pre Euro	0.0045	0.00121	0.0168	0.0016
	Euro II	0.0032	0.00087	0.011	0.00024
	Euro III	0.0025	0.00077	0.01	0.00024
	Euro IV	0.0014	0.00039	0.0049	0.00022
Truck	Pre Euro	0.0045	0.00121	0.0084	0.0008
	Euro II	0.0032	0.00097	0.0055	0.00012
	Euro III	0.0028	0.00077	0.005	0.0001
	Euro IV	0.0014	0.00039	0.00245	0.00006
L.C.V.	Pre Euro	0.0069	0.00028	0.00249	0.0005
	Euro II	0.00072	0.000063	0.00059	0.00007
	Euro III	0.00064	0.000058	0.0005	0.00005
	Euro IV	0.0005	0.00003	0.000025	0.000025

Source: Based on the data on revised norms provided by the Central Pollution Control Board, Government of India.

VI. Transfer of Health Damage Cost from the US to the Indian Situation

In order to arrive at the health damage cost for the selected 35 Indian urban agglomerates, Delucchi's estimates of health damage costs in US $ cost at 1991 prices per (kg.) unit of emission of each of the four pollutants of our consideration for the US urban situation have been applied in the Indian situation after adjustments to take into account the differences in temporal and cross country situations between US and India.

Health costs are, in fact, thought of as consisting of two components, namely income loss and treatment cost due to the pollution-related sickness. For any two countries, both these components are sensitive to the relative purchasing powers of the currencies and the relative average incomes in comparable purchasing power terms. Similarly, in any country over time, both the components are sensitive to inflation. Thus, to derive the estimates for the Indian cities, Delucchi's estimates of damage cost per unit of emission of the pollutants for the low cost and high cost scenarios as presented in table 5 have been adjusted by correcting for the following

Table 5: Estimates of Health Cost Pollutants
(in US cities)

Unit $/kg of pollutant
(1991 US prices)

Pollutants	Low Cost Scenario	High Cost Scenario
CO	0.01	0.10
HC	0.13	1.45
NOX	1.59	23.34
PM_{10}	13.74	187.48

Source: Delucchi (2000)

variations: (i) difference in purchasing power of currencies of the two economies; (ii) variation in the income level in PPP terms between the two countries; (iii) difference in population density; and (iv) inflationary adjustment to convert the damage cost in 2000-01 Indian prices. These adjustments have been as follows:

(i) First, the US dollar costs of emission per kilogram of different pollutants in 1997 US prices are obtained from the corresponding cost estimates at 1991 prices (Delucchi, 2000) by using the inflation in US GDP deflator between 1991 and 1997 and then convert it into Indian rupee by using the US dollar exchange rate into Indian rupees for 1997.

(ii) Second, the ratio of Indian GDP in US dollars to the same in PPP (purchasing power parity) dollar – that is, the PPP dollar-rupee exchange rate – is used for adjusting the cost estimates of step (i) for the difference between the purchasing power of the US dollar and the Indian rupee in 1997.

(iii) Third, to adjust for the variation in per capita real income between the US and the Indian cities, the ratio of per capita income for the selected Indian cities to the US per capita income in PPP dollar in 1997 is used to adjust the costs obtained in step (ii). The variation in urban and rural per capita income in the US is not considered in view of more than three-quarters of the population of the country living in urban areas and the non availability of data on urban – rural income distribution for that country for our use. This rural-urban variation in the US income is in any case likely to be of second order of importance.

(iv) Fourth, the values obtained in step (iii) are adjusted for the variation in the size of the exposed population to the pollutants by using the ratio of density of the population in the concerned Indian city to the average population density of the nine US cities of relevance for an inter-country adjustment as per the demographic data for the year 2001.

(v) Fifth, the estimated cost in Indian rupee for 1997 as obtained using the PPP exchange rate between the two countries is then converted into Indian rupees of 2000-01 by using the inflation index in terms of the GDP deflator between 1997 and 2000-01.

We used the data from the sources of the Government of India (GoI), Central Pollution Control Board (2000), GoI, Census of India (2001), GoI, Ministry of Finance (2000, 2001), International Monetary Fund (1999) and World Bank (1993) for such adjustments. As the per capita income as well as the adjusted health damage cost per unit of pollutants has been obtained to be different across these cities, the urban agglomeration wise and pollutant-wise low and high estimates of health damage costs have been given in tables 6 and 7.

Table 6: Health Cost of Pollutants
(Low Cost Estimate)

Rs/kg.

Cities	CO	HC	NOX	PM
Agra	0.01	0.09	1.13	9.73
Ahmedabad	0.02	0.29	3.49	30.16
Allahabad	0.01	0.12	1.48	12.77
Amritsar	0.01	0.19	2.32	20.08
Asansol	0.00	0.05	0.63	5.43
Bangalore	0.015	0.19	2.33	20.12
Bhopal	0.00	0.06	0.69	5.95
Chennai	0.01	0.17	2.04	17.67
Coimbatore	0.01	0.08	0.98	8.51
Delhi	0.05	0.60	7.37	63.73
Dhanbad	0.00	0.03	0.36	3.09
Faridabad	0.01	0.12	1.51	13.05
Hyderabad	0.03	0.37	4.53	39.11
Indore	0.01	0.11	1.33	11.51
Jabalpur	0.00	0.05	0.67	5.80
Jaipur	0.01	0.14	1.68	14.52
Jamshedpur	0.00	0.04	0.53	4.60
Kanpur	0.007	0.09	1.08	9.35
Kochi	0.01	0.07	0.87	7.54
Kolkata	0.01	0.17	2.11	18.20
Lucknow	0.01	0.07	0.81	6.98
Ludhiana	0.02	0.23	2.80	24.23
Madurai	0.01	0.17	2.12	18.30
Meerut	0.00	0.06	0.79	6.83
Mumbai	0.03	0.40	4.87	42.05
Nagpur	0.02	0.21	2.57	22.17
Nasik	0.01	0.08	1.02	8.80
Patna	0.01	0.08	0.96	8.28
Pune	0.02	0.20	2.40	20.70
Rajkot	0.01	0.18	2.19	18.89
Surat	0.04	0.50	6.11	52.84
Vadodara	0.01	0.16	1.92	16.63
Varanasi	0.01	0.09	1.14	9.85
Vijayawada	0.01	0.16	1.99	17.21
Vishakhapatnam	0.01	0.09	1.12	9.67

Table 7: Health Cost of Pollutants
(High Cost Estimate)

Rs/kg

Cities	CO	HC	NOX	PM
Agra	0.07	1.03	16.53	132.79
Ahmedabad	0.22	3.18	51.23	411.49
Allahabad	0.09	1.35	21.69	174.20
Amritsar	0.15	2.12	34.10	273.94
Asansol	0.04	0.57	9.23	74.12
Bangalore	0.146	2.12	34.18	274.58
Bhopal	0.04	0.63	10.10	81.14
Chennai	0.13	1.86	30.02	241.13
Coimbatore	0.06	0.90	14.45	116.08
Delhi	0.46	6.73	108.26	869.57
Dhanbad	0.02	0.33	5.24	42.10
Faridabad	0.09	1.38	22.17	178.09
Hyderabad	0.28	4.13	66.44	533.67
Indore	0.08	1.21	19.56	157.09
Jabalpur	0.04	0.61	9.85	79.09
Jaipur	0.11	1.53	24.66	198.09
Jamshedpur	0.03	0.48	7.81	62.70
Kanpur	0.068	0.99	15.88	127.52
Kochi	0.05	0.80	12.80	102.82
Kolkata	0.13	1.92	30.92	248.36
Lucknow	0.05	0.74	11.85	95.18
Ludhiana	0.18	2.56	41.15	330.55
Madurai	0.13	1.93	31.09	249.77
Meerut	0.05	0.72	11.60	93.16
Mumbai	0.31	4.44	71.43	573.78
Nagpur	0.16	2.34	37.66	302.47
Nasik	0.06	0.93	14.95	120.07
Patna	0.06	0.87	14.07	113.03
Pune	0.15	2.18	35.17	282.49
Rajkot	0.14	1.99	32.08	257.70
Surat	0.38	5.58	89.75	720.96
Vadodara	0.12	1.76	28.25	226.95
Varanasi	0.07	1.04	16.74	134.45
Vijayawada	0.13	1.82	29.23	234.80
Vishakhapatnam	0.07	1.02	16.43	132.00

The health damage costs per unit of emission flows of the different pollutants as derived from Delucchi's study and indicated in tables 6 and 7 have been applied to the annual emission flows of the respective pollutants from automotive transport of the different urban agglomerations to obtain the total estimates of health costs in the different urban agglomerations and at the aggregate all-India level, for the baseline and the different Euro norms and for the low cost and the high cost scenarios. (*See* Table 8 and Table 9). The comparison of the health damage costs for the different *Euro*-norms scenarios would yield the benefit of savings of health cost for the different Indian cities due to the upgradation of the fuel quality for these scenarios. We highlight some of these results in the following section.

Table 8: Annual Health Cost Across Cities in India
(Low Cost Estimates)

(In Rs. million)

Cities	Pre Euro	Euro II	Euro III	Euro IV
Agra	19.6	2.1	1.5	1.1
Ahmedabad	509.3	69.7	50.5	33.7
Allahabad	125.8	8.6	5.1	4.4
Amritsar	52.0	4.9	3.3	2.4
Asansol	1.6	0.7	0.6	0.3
Bangalore	435.3	45.9	30.6	22.6
Bhopal	19.8	2.1	1.4	1.0
Chennai	553.6	50.8	31.8	25.0
Coimbatore	11.8	1.8	1.4	0.9
Delhi	2699.2	333.8	236.7	163.4
Dhanbad	4.0	0.6	0.4	0.3
Faridabad	17.9	2.7	1.9	1.3
Hyderabad	788.2	95.0	67.1	46.5
Indore	58.4	4.0	2.4	2.1
Jabalpur	16.0	1.1	0.7	0.6
Jaipur	59.2	4.2	2.5	2.2
Jamshedpur	3.6	0.6	0.5	0.3
Kanpur	37.5	3.6	2.5	1.8
Kochi	20.3	2.6	1.8	1.3
Kolkata	119.6	29.2	24.5	14.0
Lucknow	38.8	3.4	2.2	1.7
Ludhiana	113.7	8.2	4.8	4.1
Madurai	25.5	3.0	2.2	1.5
Meerut	15.0	1.5	1.1	0.7
Mumbai	719.8	132.3	89.8	60.7
Nagpur	109.1	9.6	6.2	4.8
Nasik	11.7	1.2	0.7	0.6
Patna	11.7	1.0	0.6	0.5
Pune	213.8	29.7	21.7	14.5
Rajkot	47.3	4.3	2.9	2.1
Surat	432.0	36.8	21.4	18.0
Vadodara	39.6	3.6	2.1	1.8
Varanasi	20.5	1.4	0.9	0.7
Vijayawada	15.5	2.1	1.6	1.0
Vishakhapatnam	13.0	1.2	0.7	0.6
Total	7379.8	903.3	626.0	438.4

Table 9 : Annual Health Cost Across Cities in India
(High Cost Estimates)

(In Rs.million)

Cities	Pre Euro	Euro II	Euro III	Euro IV
Agra	268.1	29.4	21.3	14.7
Ahmedabad	6961.4	958.4	706.4	468.4
Allahabad	1710.6	113.2	68.2	58.6
Amritsar	708.6	66.1	45.1	33.3
Asansol	22.9	9.4	8.5	4.5
Bangalore	5930.4	620.7	420.8	310.2
Bhopal	269.7	28.0	19.3	13.9
Chennai	7532.5	678.5	431.1	340.6
Coimbatore	161.5	24.8	19.1	12.1
Delhi	36890.2	4575.1	3299.7	2265.0
Dhanbad	55.2	8.1	6.3	4.0
Faridabad	243.8	36.5	26.5	17.7
Hyderabad	10757.7	1298.0	932.5	643.5
Indore	793.3	53.3	31.7	27.7
Jabalpur	218.1	14.7	9.1	7.6
Jaipur	804.4	56.1	33.5	28.9
Jamshedpur	49.1	8.6	6.9	4.2
Kanpur	511.0	48.9	34.6	24.4
Kochi	277.2	35.6	24.4	17.4
Kolkata	1659.7	414.6	350.2	199.2
Lucknow	528.6	46.1	30.6	23.3
Ludhiana	1544.8	107.8	63.3	55.6
Madurai	348.0	40.9	30.0	20.2
Meerut	205.4	20.6	14.9	10.3
Mumbai	9820.3	1800.4	1252.7	843.1
Nagpur	1485.1	128.6	83.9	64.8
Nasik	159.2	15.7	9.9	7.8
Patna	159.4	13.6	8.5	6.9
Pune	2922.9	409.0	303.4	202.2
Rajkot	645.0	58.3	40.0	29.3
Surat	5866.9	485.3	286.4	242.8
Vadodara	537.9	48.0	28.1	23.9
Varanasi	278.5	19.2	11.8	9.9
Vijayawada	212.2	29.3	22.2	14.4
Vishakhapatnam	176.3	15.4	9.8	7.8
Total	100715.9	12316.2	8690.5	6058.3

VII. Health Damage Cost Estimates: Analyses of Results

As per the norms and assumptions regarding the emission of different pollutants in the pre-*Euro* situation the total annual health cost for the 35 urban agglomerates of India together works out to be Rs.737.97 crore in the low cost scenario and Rs.10071.5 crore in the high cost scenario. These estimates are based on the population of 2001, vehicle population of 2002, real income of 1997-98 and prices of 2000-01. The health cost estimates for the same set of urban agglomerates as per the low cost scenario comes down to Rs.90.33 crore for *Euro-II*, Rs.62.80 crore for *Euro-III* and Rs.43.84 crore for *Euro-IV*. The corresponding high cost estimates for health damage are Rs. 10071.5 crore for pre-*Euro*, Rs.1231.6 crore for *Euro-II*, Rs.869.05 for *Euro-III* and Rs.605.83 crore for *Euro-IV* norms.

If we refer to the table 3, Delhi is found to have a dominant share of the urban vehicular population in India. It may be noted that under the low cost scenario the annual health damage cost for Delhi worked out at Rs. 269 crore at 2000-01 prices for pre-*Euro* norms with 2001 population and 1997-98 income. The corresponding estimate under high cost scenario is Rs.3689 crore. As per the low cost scenario, Delhi is followed by Hyderabad (78.82 crore) Mumbai (Rs.71.98 crore), Chennai (Rs.55.36 crore), Ahmedabad (Rs.50.93 crore), Bangalore (43.52 crore) and Kolkata (Rs.11.95 crore). The cities with the lowest health damage cost are Asansol and Jamshedpur. Table 8 gives the similar cost estimates for all the 35 urban agglomerates for low cost scenario for pre-*Euro*, *Euro-II, Euro-III* and *Euro-IV* emission norms. The results for the high cost scenario are given in table 9.

The percentage of savings in health-cost for a shift to *Euro-II* from the Pre-Euro emission levels is thus found to be above 60 percent for every city as per the results given in the above mentioned tables, the overall savings being about 88 percent of the pre-*Euro* level. The additional saving by moving to the *Euro-IV* is only 7 percent more at an average. For a shift to the *Euro-III* from the *Euro-II* emission level, the saving is 30.07 percent of the *Euro-II* level damage. Again a shift to the *Euro-IV* from the *Euro-III* emission levels would contribute to the saving of 29.97 percent of the *Euro-III* level damage. Thus, the percentage savings in health cost is much higher for the shift from the pre-*Euro* to the *Euro-II* level of emission than for the shifts from the *Euro-II* to the *Euro-III* and from the *Euro-III* to the *Euro-IV* levels of emission for the same vehicular traffic as of 2002 as per the low cost scenario. The high cost scenario results also show very similar results regarding the proportion of cost savings for the upgradation of fuel quality in the high cost scenario.

According to an interim report of the Expert Committee on the *Auto Fuel Policy* in India constituted by the Government of India (GoI), an investment of Rs.60,000 on capital equipment in refineries and vehicle manufacturing units was supposed to be required for shifting to the *Euro-III* regime from the pre-*Euro* regime in 2001-02 prices. Our estimates of savings for the health damage cost for 35 urban agglomerates in India for 2000-01 as given in table 7 for the low cost scenario implies a payback period of 88 years and the corresponding rate of return works out to 1.12 percent. For the high cost scenario the counterpart estimates for the upgradation of fuel quality from the pre-*Euro* to the *Euro-III* work out to be 6.5 years of pay back period and 15.33 percent rate of return.

VIII. Cost of Fuel Upgradation

In order to compare the benefit with the cost of upgradation of fuel, we have worked out the costs of upgradation of motor spirit and High Speed Diesel (HSD) for a sample of public sector refineries. As these refineries are located at different places of India, having different vintages of technology and productive efficiency, the upgradation to the target norms of fuel quality involved varying costs per unit of the fuel upgraded across the refineries. Based on the data of the various feasibility reports of the fuel quality upgradation for various refineries, the upgradation cost was derived from the difference between the cost of fuel per litre with and without upgradation respectively from the pre-*Euro* to a standard between *Euro-III* and *Euro-IV*. The summary of these results is presented in table 10 for the crude oil price $ 35 per bbl and 15 percent discount rate as normative rate of return of capital. Although, as of today in 2005, the crude oil price is much higher, the benefit cost ratio is mainly determined by the ratio of health cost savings and increase in the conversion cost of crude oil into petroleum products in the refineries which would not be expected to be affected much with the variation in oil prices.

Table 10 : Comparative Costs of Upgradation of MS and HSD from Pre-*Euro* to *Euro-III* for Selected Refineries

(Rs./Tonne) Discount rate 15%

Crude Price Scenario	MS			HSD		
	Min.	Max.	Un-weighted mean	Min.	Max.	Unweighted mean
US $35 per bbl	1.92	2.44	2.210	0.47	3.27	1.580

IX. Cost-Benefit Analysis of Upgradation of fuel quality to Euro-III/Euro-IV

In the preceding section, the benefit from upgradation of fuel quality in terms of savings in the health cost due to the reduction in vehicular emission in the most populous urban regions has been estimated in monetary unit on the basis of the health cost per unit of the pollutants emitted. The cost estimates of fuel upgradation have been, on the other hand, obtained per unit (litre) of the fuel used. To make the cost and benefit estimates comparable, the benefits in terms of health cost saved per litre of MS/HSD uses have been derived as presented in table 11. These estimates of benefits of the improvement of quality of the MS or HSD have been derived from the estimates of health cost savings by using the estimated share of each vehicular mode in the total consumption of the concerned fuel in a city and assuming a fixed proportionality between a given fuel use and the emission arisings of the concerned pollutants in a given mode.

In comparing the costs of fuel upgradation with the benefits, we have taken the average cost of upgradation to be the unweighted mean cost of upgradation across the refineries of our sample in the absence of refineries – city distribution linkage data. These have been Rs.2.21 per litre for motor spirit and Rs.1.58 per litre for high speed diesel, assuming crude oil price at $ 35 per barrel and 15 percent rate of discount which we consider to be the most viable in the long run. The following are the summary observations on the results of such benefit-cost comparison.

Table 11: Savings In Health Cost per Litre of MS/HSD From pre-*Euro* to *Euro-III* Norm

Rs./litre

Cities	Low Cost Estimate		High Cost Estimate	
	MS	HSD	MS	HSD
Agra	0.96	0.06	3.91	2.59
Ahmedabad	2.12	0.18	10.98	7.94
Allahabad	1.37	0.07	5.20	2.76
Amritsar	1.80	0.12	7.67	4.67
Asansol	0.13	0.03	1.44	1.43
Bangalore	1.40	0.14	7.14	5.87
Bhopal	0.58	0.04	2.45	1.41
Chennai	1.18	0.12	6.13	4.88
Coimbatore	0.73	0.05	3.34	2.23
Delhi	3.02	0.46	19.46	18.91
Dhanbad	0.24	0.02	1.13	0.75
Faridabad	0.79	0.08	4.66	3.18
Hyderabad	3.28	0.25	15.14	10.16
Indore	1.25	0.07	4.76	1.66
Jabalpur	0.74	0.04	2.57	1.49
Jaipur	1.41	0.08	5.72	2.93
Jamshedpur	0.30	0.03	1.57	1.20
Kanpur	0.87	0.05	3.55	2.15
Kochi	0.48	0.04	2.72	1.78
Kolkata	0.71	0.14	5.38	5.77
Lucknow	0.59	0.04	2.60	1.63
Ludhiana	2.18	0.13	9.25	4.14
Madurai	1.70	0.11	7.26	4.79
Meerut	0.73	0.04	2.78	1.77
Mumbai	1.57	0.24	13.78	10.17
Nagpur	2.20	0.13	9.00	5.33
Nasik	0.65	0.06	3.30	2.55
Patna	0.66	0.05	3.07	1.70
Pune	1.55	0.14	7.78	6.06
Rajkot	1.95	0.11	7.65	4.85
Surat	4.30	0.30	20.31	12.62
Vadodara	1.18	0.10	6.18	4.42
Varanasi	1.05	0.06	4.01	2.54
Vijayawada	1.59	0.10	6.91	4.34
Vishakhapatnam	0.90	0.06	3.88	2.44
Total	1.32	0.11	6.36	4.37

a) The benefit (i.e. savings in health cost) from a litre of upgraded motor spirit exceeds the average cost of upgradation for only 3 urban agglomerates by the low health cost scenario.
b) The benefit from a litre of upgraded HSD is lower than the average cost of upgradation for all the urban agglomerates by the low health cost scenario. However, in the case of Delhi, the benefit is the same as the cost of upgradation of HSD of the nearby refinery in the sample.
c) The benefit from a litre of upgraded motor spirit exceeds the average cost of upgradation for all but three urban agglomerates in the high health cost scenario.
d) The benefit from a litre of upgraded HSD exceeds the average cost of upgradation for all but five urban agglomerates in the high cost scenario.
e) The benefit from a litre of upgraded MS/HSD is higher for some of the urban agglomerates with high population density and high vehicular density per unit of its area. These agglomerates are not often metropolitan cities or state capitals. On the other hand, some state capitals or even metropolitan cities have much less benefit in terms of savings in health cost from a litre of MS / HSD. This aspect urges rethinking on the policy of introducing upgraded MS / HSD in the metropolitan cities and state capitals earlier than the rest of the cities in India.

X. Concluding Remarks

The estimated savings of health cost due to the upgradation of automotive fuels as presented in the preceding sections should, however, factor in the following three additional considerations.

(a) The savings in health cost due to upgradation of environmental norms will accrue over a period of time from the introduction of new standards. For example, if *Euro-II* is introduced from 2003, it is likely that a transition period will be allowed to phase out the older vehicles with pre-*Euro* standards. A progressively larger proportion of savings will accrue as more and more older vehicles with pre-*Euro* specifications get phased out. The full savings will accrue only when all the vehicles with pre-*Euro* specification are fully off the road and all fuel is upgraded.

(b) The vehicular population in urban India is likely to grow over time. Thus the absolute savings on health cost benchmarked with the 2002 vehicle population is an underestimate of the true absolute savings that would accrue relative to what would happen without the upgraded specifications. The savings in percentage terms, of course, is impervious to the vehicle population. It is, however, the absolute levels of stress on the ecosystem and human health damage which are important for the environmental sustainability of our urban development process.

(c) The absolute savings in health cost are likely to vary directly with the size of the vehicle population, provided the composition of the vehicle population in terms of 2-wheelers, 3-wheelers, passenger cars, goods carriages and buses remain constant. Thus, a doubling of the vehicle population with the relative composition remaining unchanged will lead to a doubling of absolute savings. But, if the composition of the vehicle population tilts in favour of less polluting vehicles, then the absolute savings in health cost will increase more than proportionately relative to the vehicle population, and *vice versa*.

It may be clarified here that fuel upgradation is only one of the alternatives of reducing vehicular pollution. Reduction in vehicular pollution actually requires an integrated approach where the problems of road conditions, traffic congestion, maintenance of vehicles and engine design are also addressed and solved. Poor road conditions as well as congested roads invariably reduce the efficiency of the vehicle and fuel use. This leads to higher consumption of fuel and therefore higher emission of pollutants for the same distances being travelled. Proper maintenance of vehicle is extremely important for deriving the optimal mileage a vehicle is capable of achieving from a litre of fuel. An optimal mix of engine oil and fuel is the effective means of achieving fuel economy and lower emission. Aspects of engine design like multi point fuel injection are important ways to ensure complete combustion of fuel and thereby to allow for higher fuel efficiency and less emissions. In this study of cost-benefit analysis the focus is mainly on fuel upgradation, its cost and benefit. This in no way implies that fuel upgradation is the most effective way to reduce vehicular pollution. In the absence of any useable information regarding the other aspects of infrastructural conditions, we make a cost benefit analysis for refinery upgradation for improved fuel quality with the implicit assumption that the engine design of vehicles, road condition, and maintenance of vehicles should satisfy the appropriate requirement of complementarities so that the full benefit of the better fuel is realised.

Finally, the results of our cost benefit analysis of fuel upgradation have not given very conclusive policy directions, particularly because of the wide range of variation between the low cost and the high cost scenarios of health damage as based on Delucchi's basic cost parameters obtained using the health production function approach due to the underlying factors of uncertainty. Although for the low health damage cost scenario, the benefits of health cost savings would not be commensurate with costs for many cities, it should be noted that the estimates of such cost savings are likely to grow over time due to population growth, increasing urbanisation and growth of urban vehicular traffic over time. The estimates as given in this paper are likely to be substantively underestimates of the true situation even as of today. However, it is also to be further noted that we have considered the cost of refinery upgradation only for deriving the benefit of health cost saving. As we have emphasised the complementarity of vehicular engine design, vehicle maintenance, and improvement of road quality etc., some additional investments would be involved on these counts for the full realisation of the potential of savings of health cost. However, the present study is a preliminary exercise to formulate a broad idea about the dimension of the health cost damage due to automotive fuel pollution in urban India and to draw a broad comparison of the saving of health cost with the benefit of such pollution abatement by way of fuel quality upgradation.

References

1. Alberini, A. and Alan Krupnick, 1997. "Air Pollution and Acute Respiratory Illness: Evidence from Taiwan and Los Angeles," *American Journal of Agricultural Economics*, Vol 79.

2. Alberini, A. and Alan Krupnick, 2000. "Cost of Illness and WTP Estimates of the Benefits of Improved Air Quality: Evidence from Taiwan," *Land Economics*, 76(1); 37-53.

3. Brandon, C. and K. Hommann, 1995. "The Cost of Inaction: Valuing the Economy-wide Cost of Environmental Degradation in India," Presented at the ***Modelling Global Sustainability*** conference at the United Nations University, Tokyo, Japan.

4. Chestnut L., B.D. Ostro, and N. Vichit-Vadakan, 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* Vol. 79;1630-1635.

5. Cropper Maureen *et. al.,* 1997. "The Health Benefits of Air Pollution Control in Delhi," *American Journal of Agricultural Economics*, Vol 79;1625-1629.

6. Cropper M.L. and A.M. Freeman, 1991. "Environmental Health Effects" in J.B. Braden and C.D. Kolstad (*ed.*) *Measuring the Demand for Environmental Quality.* Amsterdam: Elsevier Science Publications.

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

8. Delucchi M.A. and D. McCubbin, 1999. "The Health Cost of Motor-Vehicle – Related Air Pollution," *Journal of Transport Economics and Policy*, 33(3).

9. Delucchi, M.A. and D. McCubbin, 1996. "The Contribution of Motor Vehicles and Other Sources to Ambient Air Pollution," Report No.16 in the series, The Annualised Social Cost of Motor Vehicle Use in the United States, August 1996.

10. Dockery D.W. *et. al.,* 1993. "Association Between Air Pollution and Mortality in Six US Cities," *New England Journal of Medicine*, Vol 329;1753-1759.

11. Government of India, Central Pollution Control Board (CPCB), 2000. *Transport Fuel Quality for Year 2005*. New Delhi: CPCB.

12. Government of India, 2001. Census of India, *Provisional Population Totals, India, Part 1*.

13. Government of India, 2000, 2001. Ministry of Finance (MoF), *Economic Survey 2000, 2001*. New Delhi: MoF.

14. Government of India, 2001. *Town and Urban Agglomerations 1991, Census of India 2001, Series I, Part II-A(ii)-A Series*.

15. Holland M, J. Berry and D Forster, (*eds*.), 1999. *Extern E 1999: Externalities of Energy* Vol 7: *Methodology 1998 Update.* Luxembourg: Office for Official Publications of the European Communities.

16. International Monetary Fund (IMF), 1999. *International Financial Statistics 1999.* Washington D.C: IMF.

17. Krupnick, Alan 1988. A Health Benefit Analysis of Reductions in Photochemical Oxidants in the North Eastern United States, US Environmental Protection Agency (EPA).

18. Krupnick Alan and R.J. Kopp, 1988. "The Health and Agricultural Benefits of Reductions in Ambient Ozone in the United States," US Congress: Office of Technology Assessment.

19. Krupnick Alan and Maureen Cropper, 1992. "The Effects of Information on Health Risk Valuation," *Journal of Risk and Uncertainty,* Vol 5;29-48.

20. Krupnick Alan *et. al* 1997. "Valuing Health Effects of Air Pollution in Developing Countries: The Case of Taiwan," *Journal of Environmental Economics and Management,* 34(2); 107-126.

21. Marrack D., 1995. "Public Health and Toxic Particles: Danger in the Air: Toxic Air Pollution in Houston – Galveston Corridor;" Report by the Galveston – Houston Association for Smog Prevention, (GHASP); 72-78.

22. Moore M.J., and W.K. Viscusi, 1988. "The Quality – Adjusted Value of Life," *Economic Inquiry*, 26(3); 369-388.

23. Murty, M.N., S.C. Gulati, and A. Banerji, 2003. Health Benefits from Urban Air Pollution Abatement in the Indian Subcontinent, Working Paper Series No. E/236/2003, Institute of Economic Growth, New Delhi.

24. Pearce D., 1996. "Economic Valuation and Health Damage from Air Pollution in the Developing World," *Energy Policy,* 24(7); 627-630.

25. Pope C.A., *et. al* 1995. "Particulate Air Pollution as a Predictor of Mortality in a Prospective Study of U.S. Adults", *American Journal Respiratory Critical Care Medicine*, Vol 51; 669-674.

26. Small K., and C. Kazini, 1995. "On the Costs of Air Pollution from Motor Vehicles," *Journal of Transport Economics and Policy*, January 1995.

27. Sengupta Ramprasad and Subrata Mandal, 2002. Refinery Upgradation, Environmental Sustainability and Cost Sharing, National Institute of Public Finance and Policy (mimeo).

28. Viscusi W.K., 1991. "Product and Occupational Liability," *Journal of Economic Perspectives*, 5(3); 71-91.

29. World Bank, 1993. *World Development Report, 1993*, Washington D.C.