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Economic policy instruments for controlling vehicular air pollution

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ABSTRACT. When continuous monitoring of individual emissions is not feasible, policy makers need to investigate what other options are available and how best to provide appropriate incentives for pollution reduction. This paper offers an analysis of some such options with a view to identifying and suggesting appropriate policy measures for emission control from automobiles in Delhi.

1. Introduction

Policies for controlling environmental pollution are commonly divided into economic approaches and command and control (CAC) strategies. In India, so far, there has been an overwhelming reliance on CAC measures for pollution control. The critical state of air pollution in Indian cities is a clear indication that policies currently in use have failed to make the desired impact and it is imperative to look for alternative instruments for prevention and control of air pollution (Pandey, 1998). The use of economic instruments has long been endorsed by environmental economists (Bohm and Russell, 1985; Baumol and Oates, 1988; and Montgomery, 1972) as they are seen to be more cost effective *vis-à-vis* CAC measures and also have a greater chance of successfully internalising the social costs of pollution to the polluters. This paper examines economic policy options for controlling vehicular air pollution in Delhi.

2. Vehicular emission control: a theoretical perspective

Air pollution from transport is a typical case of negative externality. A vehicle can be seen as a production unit whose output is passenger kilometres and the by-product is pollutants released in the atmosphere (a free common property resource). In the absence of any intervention to correct the failure of the existing system, motorists may have no incentive to take these external costs into account in making decisions regarding vehicle

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ownership, its maintenance and use. The text book solution to this problem would be to impose a tax on emissions from vehicles. Since imposing a tax on this mobile source of emissions – very large in number – is not feasible, the regulator needs to look for alternative instruments/programmes aimed at achieving the least cost solution to the externality.

Reduction in emissions from motor vehicles can be achieved in two ways. One is by making the polluting activity cleaner by either switching to cleaner vehicles or by technical modifications to in-use cars – whether in the form of tune-ups or retrofitting of existing equipments or in the form of new configurations of machinery (for example catalytic converters), fuels etc. A second is by reducing the scale of emission by reduced vehicle trips. Under an emission tax, the vehicle owner will choose the socially optimum mix of these two methods of reducing emissions such that emission reductions, at the margin, cost the same for each method.

Existing analyses of the effectiveness of strategies and instruments for vehicular pollution control can be classified into (1) simple statistical methods; (2) econometric methods, and (3) modelling techniques.

The literature in this field (Repetto *et al.*, 1992; World Bank, 1997; Hahn, 1995; Xie, *et al.*, 1998; Kim and Hanley, 1996; Sevigny, 1998; and Eskeland, 1994) considers various instruments to account for the characteristics of the local vehicular fleet and the level of development in vehicular and fuel technology.

Eskeland (1994) has developed a theoretical model for the optimal tax on gasoline. The study first considers the maximization problem of the representative consumer, which is characterized by the equation given below

$$U^j = u^j\left(y^j, x^j \sum_i e^i(x^i, a^i)\right) \quad i = 1\text{–}n \tag{1}$$

subject to the following budget constraints

$$Y^j + (p_x + t_x)x^j + p_a a^j - \left(I^j + \frac{1}{n} t_x \sum_i x^i\right)$$

where individual j'_s emissions, e^j, of pollutants depends on his consumption of the polluting good, x^j, the abatement measures the person applies, a^j. His utility, u^j, depends on quantities consumed, y^j, x^j of non-polluting and polluting goods respectively, as well as the total amount of emissions from all n individuals. In the budget constraint, (p_x and t_x) and p_a are the consumer prices of the polluting good and of abatement respectively, whereas p_x and p_a are the producer prices. The non-polluting good is untaxed, and its price is normalized to 1. Further, the budget constraint reflects the assumption that tax revenues are redistributed to consumers as transfers. The individual's optimal consumption and abatement is characterized by

$$u_x/u_y = p_x + t_x \quad \text{and} \quad a^j = \bar{a}^j \tag{2}$$

where p_x is the producer price and t_x is the tax on the polluting good. The $a^j = \bar{a}^j$ denotes that the consumer will adjust the level of abatement

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to the lowest possible level. The optimization problem of the planner is characterized by

$$\mathrm{Max}_{tx} \quad W = u(y(a, t_x), x(a, t_x), n^* e(x(a, t_x), a)) \tag{3}$$

The difference between the individual's objective function and the planner's objective function is that the individual does not take into account his effect on emissions, since only a negligible amount affects him, while the planner has to take into account the effect of emissions on all individuals.

Optimal allocation is characterized by

$$(u_x/u_y) + nu_e(e_x/u_y) = p_x \tag{4}$$

$$(nu_e/u_y) = p_a/e_a \tag{5}$$

Assuming that the marginal rate of substitution in consumption will equal consumer prices and eliminating nu_e, we have

$$t_x/e_x = p_a/e_a \tag{6}$$

where t_x is the tax levied on fuel, e_x is emissions (gm/lt), p_a is cost of technological change, e_a is emission reduction through technological change; that is, the optimal tax rate on polluting good should be equal to the direct marginal cost of abatement per unit of achieved emission reductions. The study then uses comparative statistics to characterize a cost-effective programme and shows that, for a programme to be cost-effective, the above equality must hold. In this setting, the marginal cost of using tax rate changes to reduce emissions does not depend on the elasticity of demand for polluting goods. In other words, the marginal welfare cost, per unit of obtained emission reductions, is independent of the demand elasticity. This is not to say that the amount of emission benefits offered by a given tax change is independent of the demand elasticity. As an example, if the elasticity were small, emission reductions would be small, but so would be the costs from sacrificed consumption, that is because changes in consumption would be small. Eskeland (1994) has shown that, in the absence of continuous monitoring of emissions, a cost-effective programme aimed at controlling vehicular pollution would seek emission reductions from a combination of these instruments. Such a cost-effective programme is characterized by the equilibrium where marginal costs of technological changes and the tax on fuel are equalized (equation (6)).

The left side of equation (6) is the marginal cost measure for the tax on polluting goods, and the right side is the direct incremental costs of abatement divided by the increment in emission reduction, $-\ p_a/e_a$. The analysis of technical control options assumes that the abatement requirements do not affect demand, and that the cost of abatement, $-\ p_a/e_a$, is unaffected by the tax on fuel. Demand for fuel is however sensitive to changes in its price through taxation; that is, emission reductions which would result from a given tax would depend on the price elasticity of fuel.

The main argument of the paper is as follows. If the pollution control programme does not tax fuel and pursues policies to stimulate adoption of the only technical modifications needed to achieve a given level of pollution reduction, motorists may be faced with technical modification requirements which are quite costly at the margin compared with the cost of foregoing some less essential trips. Similarly, in the absence of technical changes as a policy instrument, motorists may be burdened with a very high cost at the margin owing to many essential trips sacrificed, compared with the cost of technical changes in vehicle.

What combination of instruments will be used depends on the elasticity of demand for the polluting good and the relative costs of options. In the context of motor transport, a reduction in emissions is likely to be provided mostly by technical changes if the vehicle fleet is old and poorly maintained and fuel quality is inferior. These circumstances provide scope for switching to environmentally superior fuel, and retrofitment of vehicles with emission reducing technology, rather than use of a fuel tax. Conversely, if the vehicle fleet is relatively modern and fuel is of better quality, fuel taxes are likely to have a relatively greater role in effecting vehicular emission reduction. Following this framework, section 4 examines various instruments that would induce adoption of cleaner vehicles and fuel, and reduction in vehicular trips.

3. Vehicular air pollution issues in Delhi

Motor vehicles are a major source of air pollution in Delhi. What is more alarming is the rapid growth in the share of emissions from the transport sector from 23 per cent in 1970–71 to 72 per cent in 2000.[1] This is due both to rapid growth in number of vehicles, implying growth in vehicle density causing road congestion, increased fuel consumption and pollutant emissions. An analysis of environmental characteristics of vehicles in Delhi reveals that about 68 per cent of the total vehicles in Delhi are of the most polluting kind in terms of emissions of hydrocarbons (HC), that is, two-stroke engine two- and three-wheelers. Over 70 per cent of total vehicles (including the two-stroke engine vehicles) are the most polluting kind in terms of carbon monoxide (CO) emissions. However, if we look at the total emissions per vehicle, we find that buses and taxis are the biggest polluters followed by diesel trucks and three-wheelers (Pandey, 1998). This is attributed mainly to old vehicle technology, inferior fuel quality and poor maintenance of vehicles.

4. Fuel tax and technical options for Delhi

Table 1 presents a ranking of the proposed interventions to make vehicles and fuels cleaner based on cost per ton abated, together with the rates of tax on fuel that would optimally match these (equation (6)).

[1] Source of this data is Central Pollution Control Board (CPCB) in India which monitors ambient air quality under the National Ambient Air Quality Monitoring (NAAQM) programme. Equal weights have been used by CPCB in aggregating various regulated and monitored pollutants from automobiles. Use of equal weights by CPCB in analysing relative contribution of transport sector to the air pollution problem in Delhi seems appropriate. However, in the analysis of policies for addressing air pollution problems prioritization of pollutants would be extremely important.

Vehicular emissions include a number of pollutants with varying health and other impacts. A prioritization of pollutants is necessary in any programme to control vehicular air pollution. Prioritization of pollutants can be done in two ways. One reflects the health and other impacts of pollutants. The other reflects the desirability to reduce pollutants in a city/airshed so as to achieve the legislated ambient air quality standards for that city. Because of a paucity of reliable data on the health impacts of pollutants (considered in this study) and the fact that the relationship between threshold concentrations of pollutants in the atmosphere and their health effect is taken into account in setting the ambient air quality standards, the latter approach has been used in assigning weights to various pollutants. The following weights have been applied: NO_x 0.9/gm; CO 1.56/gm; HC 4/gm; and PM_{10} 3.33/gm.

Costs in the first column in table 1 are the net costs per weighted ton of emissions. Data used for the calculation of costs have been obtained from various sources. Negative signs imply a net benefit due to technical changes (please see section 4.2). Assumptions employed and sources of data are outlined in the notes to the table for each technical option. Cumulative emission reductions are computed using estimates in column 1 and the information on the scale at which a given option would be implemented. Cost estimates and resultant emission reduction that can be obtained from implementation of these technical controls can be compared since assumptions used in computation of net costs are the same across options. However, since data on emission factors and reduction in emissions due to application of a given technical control have been obtained from various studies, it may be only broadly comparable on account of variation in sample size, and methods employed in measuring emissions by different studies. Such data limitations are extremely difficult to overcome especially in a developing country context where research on such issues is still evolving.

4.1. Fuel tax

The rates of fuel tax (Rs. Per litre) corresponding to various technical options are calculated using equation (6). In equation (6) while P_a and e_a are known, P_a and e_a are measured in Rs per weighted tons of emissions and emissions reductions per weighted tons respectively (table 1), e_x is average emission rate per litre for the vehicular fleet resulting from adoption of a given technical measure. The fuel tax would thus be equal to the value of P_a/e_a multiplied by the value of e_x. For example, if technical changes 1–8 were applied in a programme with a cost of Rs. 1.2 thousand per weighted ton of abatement then Rs. 0.6 per litre is the rate of fuel tax[2] which should be levied to affect the demand for vehicular trips. An estimate of fuel demand is needed to estimate the emission reductions resulting from the tax on

[2] It would be seen that the tax rate per litre of fuel in table 1 increases less than proportionally with the costs of technical measures. This is due to the fact that as successive technical control measures are taken, the vehicles become cleaner so the base (e_x) for fuel tax declines.

Table 1. *Technical options, costs and emission reduction*

S.No.	*Technical options*	*Cost: thousand Rs. per weighted ton of abatement*[ii]	*Cumulative emission reduction (weighted tons)*	*Cumulative emissions reduced as % of total vehicular emissions*	*Fuel tax (Rs./lt.)*
1.	Convert taxis to CNG vehicles[iii]	−27.7	27,348.4	2.5	−13.8
2.	Convert cars to CNG vehicles[iv]	−22.3	148,356.0	13.6	−12.2
3.	Convert buses to CNG vehicles (50% of the fleet)[v]	−20.3	163,699.0	15.0	−10.9
4.	Convert 3-wheelers to CNG vehicle (40% of 3-wheelers fleet)[vi]	−20.1	212,828.6	19.5	−10.4
5.	Modern carburator (20% of 3-wheeler fleet)[vii]	−10.6	215,360.3	19.7	−5.5
6.	Fuel/oil premix (10% of 3-wheeler fleet)[viii]	−6.5	216,638.8	19.8	−3.3
7.	Electronic ignition (10% of 3-wheelers fleet)[ix]	−2.5	219,642.9	20.1	−1.3
8.	Periodic I & M (10% of 3-wheeler fleet)[x]	1.2	224,363.0	20.5	0.6
9.	Catalytic converter (10% of 3-wheeler fleet)[xi]	5.9	231,862.6	21.2	2.9
10.	Catalytic converter retrofitment (10% of 2-wheeler fleet)[xii]	9.6	246,517.4	22.5	4.7
11.	CRT retrofitment in buses (50% of fleet)[xiii]	32.3	281,834.8	25.7	15.0
12.	4-stroke 2-wheelers (30% of fleet)[xiv]	55.2	327,804.8	29.9	24.2

Notes and Sources:

(i) Computations are based on vehicular population as on 31 December 1998.

(ii) The cost of technical changes is paid up-front. It is also assumed that this is financed by a loan obtained at 10 per cent interest to be repaid in equal instalments over a period of five years.

(iii) Reduction in emissions of CO and HC is 98 and 82 per cent respectively from the base line emissions from a petrol driven Ambassador car. Cost of CNG conversion is taken to be Rs. 30,000. *Source*: Gas Authority of India Limited (GAIL, 1999).

(iv) Emission reduction of CO and HC is 97 and 11 per cent from the base line emissions from a Maruti 800 model car. *Source*: GAIL, 1999.

(v) Reduction in emissions of CO, HC, nitrogen oxide (NO_x), and particulate matter (PM_{10}) is 19, 17, 42, and 83 per cent respectively. *Source*: GAIL, 1999. The operating cost is taken to be Rs. 3.37/km, on CNG and Rs. 5.08/km on diesel mode. *Source*: Sharma, 1999. The cost difference between a new CNG bus or CNG retrofitment in a diesel bus and diesel bus is Rs. 3.5 lakh. *Source*: Chima, 1999.

(vi) Emission reduction of CO, HC, NO_x, and PM_{10} is 71, 63, 20, and 80 per cent respectively. *Source*: GAIL, 1999 and Xie *et al.*, 1998. The cost of conversion to CNG fuel is taken to be Rs. 18,000. *Source*: AIAM, 1998a.

(vii)–(xi) *Source*: Xie, *et al.*, 1998.

(xii) Emission reduction of CO and HC is 45 and 40 per cent respectively. Cost of CAT retrofitment is taken to be Rs. 1,000 and refuel cost of catalyst is Rs. 500 once in two years. *Source*: AIAM, 1998b.

(xiii) Emission reduction of CO, HC, NO_x, and PM_{10} is 76, 96, 34, and 90 per cent respectively from the base line emissions from a diesel bus. The cost of CRT is taken to be Rs. 2.5 lakh and it requires ultra low sulphur diesel (50 parts per million). *Source*: Adie, 1999.

(xiv) Emission reduction of PM_{10} and HC is 86 and 76 per cent respectively. Emissions of CO and NO_x increased by 18 and 100 per cent respectively. *Source*: ARAI, 1998. The cost of a four-stroke two-wheeler is taken to be higher by Rs. 8,000 than a two-stroke two-wheeler. Four-stroke engine is 40 per cent more fuel efficient *vis-à-vis* a two-stroke two-wheeler. The average resale value of an in-use two-stroke two-wheeler is taken to be Rs. 12,000. *Source*: Personal interaction with AIAM officials.

fuel. In this study, a price elasticity of −0.52 has been employed (Imran and Quan, 1992).

The rates of fuel tax in the last column of table 1 represent optimal discouragement of fuel use, given the burden placed on fuel users to make their use clean. Negative signs in the fuel tax column imply that technical measures to convert vehciles to CNG can be combined with a subsidy on petrol for a desired level of emission reduction. For example, if technical changes 1–6 were applied in a programme at a net benefit of Rs 6.5, a subsidy of Rs 3.3 per litre of petrol would be desirable to achieve a 19.8 per cent cumulative reduction in emissions. Any combination of technical controls with a lower tax than suggested implies that, keeping total emissions unchanged, consumers would be better off spending less on abatement and cutting more trips. In table 1 technical control options are ranked according to incremental costs per unit of weighted emission reductions. It can be seen from the table that the fuel tax is an option only after technical controls 1–8 have been applied at a cost of ≤ Rs 1.2 thousand per weighted ton of emissions.

It can be noted from table 1 that there is a lot of scope for using technical measures to effect emission control from the existing fleet of vehicles in Delhi. This is mainly because of the low cost of improving technology and of maintaining the vehicular fleet. However, once cheaper technical options are exhausted, further reductions in emissions through technological change can be achieved only at high cost. That is where a tax on fuel begins to play a role.

4.2. Technical options

A number of technological options have been evaluated for controlling air pollution in Delhi. These options include conversion of petrol and diesel driven vehicles to compressed natural gas (CNG) or switching to new CNG vehicles; switching to four stroke two- and three-wheeler vehicles retrofitting (electronic ignition system, leaner carburettor, continuously regenerating trap (CRT) and catalytic converter (CAT), and periodic inspection and maintenance. We analyse these technological options quantitatively according to their effectiveness in emission reduction and annual costs and savings. Net costs (savings) of each option per weighted ton of abatement of various pollutants are listed in column 1 of table 1. The net cost is: annual fixed cost of technical changes minus the difference between the operating cost of vehicle before and after the technical changes. Possible changes in pollution emissions of these options are listed in column 2. The change that each option could bring about in the local air quality is presented in column 3.

It can be seen from table 1 that out of 12 options listed as many as seven could be win–win solutions as these result in negative costs (or net profits), due primarily to fuel savings and also lower price of CNG.[3] These measures are estimated to achieve a cumulative weighted emission reduction of more

[3] One may argue that if switching to these options means net profits why the vehicle owners do not go for these. Explanation for this behaviour can be found in mainly one or more of these three factors; lack of information on the options

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Table 2. *Proposed rates of annual emission charge*

S. No.	*Vehicle type**	*Rate of emission charge (Rs.)***
1.	Cars	
	(i) with CAT	200
	(ii) without CAT	400
2.	Taxies	
	(i) petrol	1,700
	(ii) diesel	2,200
3.	Three Wheelers	
	(i) petrol	1,500
	(ii) diesel	1,800
4.	Two-stroke two-wheelers	
	(i) with CAT	–
	(ii) without CAT	200
5.	Buses	2,200

Notes: * Cars, taxies, buses and three-wheelers running on CNG to be exempt from the annual emission charge.
** Rates of emission charge are based on the costs which emissions from these vehicles impose on people (see section 5 and Pandey and Bhardwaj, 2000).

than 20 per cent[4] of total weighted vehicular emissions. For buses, three wheelers, taxis and cars the most cost-effective way of achieving this level of emission reduction in Delhi is conversion to CNG. As conversion to CNG leads to positive gains (negative net costs), owners of these vehicles are expected to self select for conversion. However to induce faster conversion the following are being considered: (i) an annual charge on non-CNG cars, taxies, buses and three wheelers; and (ii) a subsidy to school buses, as CNG conversion is a costly option for them owing to the low utilization rate of school buses (table 2). Further, two options are considered for buses. CNG retrofitment and CRT retrofitment. The estimates in table 1 show that, while the former is less costly than the latter, emission reduction with the former option is only about 44 per cent of what could be achieved with the latter option. However, the costs per weighted ton of emission reduction in the latter option is 52 times higher than the cost in the former. In view of the fact that the CRT device can be very effective in reducing particulate matter from all types of vehicles including trucks (goods vehicles) – in which CNG retrofitment does not seem feasible until CNG is made available across the country – there is a strong case for encouraging further research with full government funding on this technology in making it commercially viable (see section 5). In the interim, however, the CNG option is most viable.

So far as emission control from two-wheelers is concerned, there are two technical options: (i) retrofitment of catalytic converter in existing

available, inadequate number of CNG stations, and lack of incentive to do it now rather than later. The situation is changing. Number of CNG stations is increasing. Motorist awareness campaigns are on the rise. Adoption of policies to induce faster switching to cost effective less polluting options is under discussion.

[4] Considering the most cost-effective measure for three-wheelers.

two-stroke vehicles; and (ii) substitution of two-stroke vehicles with four-stroke vehicles. The former option is significantly less costly than the latter and can bring about a 13.4 per cent reduction in total vehicular emissions, which is marginally lower (0.6 per cent) than what can be achieved with the latter option. Therefore there appears to be a strong justification in favour of catalytic retrofitment in in-use two-stroke vehicles until emission standards for two-wheelers are tightened further. Thus only very old two-stroke two-wheelers, ten years old and above, should be phased out. To encourage CAT retrofitment, an annual emission charge on two-wheelers which are without CAT may be levied.

5. Petrol vs. diesel cars

Statistics on passenger vehicles show that in recent years new models of diesel cars have been introduced in the market and that there is a significant rise in the growth of sale of diesel cars. This trend is attributed to the significant difference in petrol and diesel prices – a result of the governments fuel pricing policy – and has evoked considerable discussion on the desirability of diesel versions of passenger cars in India. The main concern is the greater pollution potential of diesel vehicles *vis-à-vis* petrol vehicles.

Emission rates of sulphur oxide (SO_x), nitrogen oxides (NO_x) and particulate matter (PM) are higher in diesel vehicles *vis-à-vis* petrol vehicles fitted with catalytic converters. Relatively lower emissions of CO and HC *vis-à-vis* petrol vehicles, fuel efficiency, longer engine life are some of the advantages of diesel vehicles. These are, however, not the main reasons for the spurt in supply and demand for diesel vehicles in India. The key factor responsible for this is the price difference between diesel and petrol. In other countries, where diesel does not enjoy a significant price advantage *vis-à-vis* petrol, growth in demand for diesel vehicles is mainly driven by two factors: (i) given the vehicular engine technology, diesel engines are less costly to adapt than petrol engines; (ii) diesel engines are more fuel efficient. Experts say that the problem of PM emissions has to a large extent been solved with the development of a device called CRT for diesel vehicles and there is a lot of scope for improvement in this technology to further reduce the harmful emissions of diesel vehicles.

It may not be prudent to ban non-commercial diesel vehicles. Instead, the government should end the price discrimination in favour of diesel and against petrol to discourage excessive use of diesel vehicles because of the artificial fuel price advantage. The dismantling of the administrative price mechanism in hydrocarbons by 2002 will remove part of the price distortion. If the artificial price difference between petrol and diesel is removed only in a phased manner, then to avoid the environmental damage due to diesel vehicles in the interim, the regulator should levy a tax on diesel vehicles that would induce motorists to consider alternative fuels. Such a tax should be based on the average cost that emissions from diesel vehicles inflict on the society. It may be noted, that petrol driven vehicles also emit pollutants into the atmosphere that impose a cost on the society. Since emissions from petrol vehicles are not currently taxed in India, the base for a tax on diesel

Table 3. *Costs of diesel and petrol versions of Tata Indica*

Items	*Standard petrol*	*Standard diesel*
Ex-showroom price	259,000	285,000
Piston displacement	1405cc	1405cc
Capacity	5	5
Weight (unladen)	980 Kg.	980 Kg.
Road tax	Rs. 3,815 (one time tax)	Rs. 3,815 (one time tax)
Excise duty	40%	40%
Sales tax	8%	8%
Mileage	12 km/lt	18 km/lt
Annual utilization (Km/yr)	10,000	10,000
Annual fuel use, lt.	834	556
Fuel price Rs./lt.	26	14.04
Annual fuel cost	Rs. 21,667	Rs. 7,800

vehicles should be the difference in average costs of emissions from diesel vehicles and petrol vehicles. Information on the cost of emissions is however not available for all the pollutants. In the context of India, some estimates of health costs of PM_{10} are available (World Bank, 1995). We thus take the emission of PM_{10} as the additional negative externality from diesel vehicle *vis-à-vis* a petrol driven vehicle.

Following the World Bank (1995), the present value of the cost of pollution (income loss and medical costs) due to emissions by a diesel car over a period of ten years[5] is estimated to be Rs. 10,648.[6] This works out to Rs. 1,109 per year. An annual 'emissions' tax of Rs. 752 (an average of lower and upper bound estimates of annual costs due to PM_{10}) should be levied on diesel cars. The proposed tax rate may, however, be lower than the tax rate that would be obtained at the intersection of the marginal abatement cost and marginal damage cost curves.

It must be noted that this measure would not have the desired impact as long as difference between diesel and petrol prices is significant. An analysis of estimates in table 3 highlights this point. Table 3 provides estimates of the present value of savings from diesel Tata Indica *vis-à-vis* petrol Tata Indica over a period of ten years. The present value of net savings from the diesel version of Tata Indica over a period of ten years is estimated to be Rs. 67,725, which is 23.76 per cent of the ex-showroom price of the diesel version of Indica. The tax on diesel vehicles should accordingly have two components. Given the existing pricing of petrol and diesel, an excise duty of an equivalent amount should be levied on diesel cars to neutralize the price advantage in favour of diesel. In addition to this, an annual 'emissions' tax of Rs. 752 may be levied on diesel cars.

[5] Life of car is assumed to be ten years.
[6] This is upper bound estimate. Lower bound estimate of present value is Rs. 3,797.3.

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6. Conclusion

The above analysis shows that there is a case for the adoption of economic instruments to reduce emissions from automobiles in order to improve the environmental quality in Delhi. This paper suggests the following measures based on a ranking of the cost of abatement under each measure.

Motorists should be encouraged to switch to CNG. An annual 'emissions' tax based on average damage due to emissions of different types of vehicles should be levied. Cars, taxis, three-wheelers and buses running on CNG fuel should be exempt from the annual 'emissions' tax. In other words, the 'emissions' tax would reflect the difference in damage costs due to emissions from petrol or diesel powered vehicles, and damage due to CNG powered vehicles. Owing to low utilization rate of school buses (buses owned by schools), CNG retrofitment does not appear to be a cost-effective option for them. For environmental reasons, a subsidy to induce conversion of school buses (diesel) to CNG fuel, seems justified. A loan up to 50 per cent of the CNG retrofitment cost might be provided at an interest rate of 10 per cent for a period of five years. Alternatively, a lump sum subsidy equivalent to the present value of the difference in market interest rate and concessional rate of 10 per cent might be granted. This would be Rs. 36,150 or 10.33 per cent of the cost of CNG retrofitment.

The substantial price differential in favour of diesel fuel *vis-à-vis* petrol in India has contributed to the growth of the market for diesel-powered passenger cars – a fiscally induced development having some clear disadvantages from the point of view of air pollution. Thus, excise duty on diesel cars should be increased by 24 per cent. In addition to this, an annual emission tax of Rs. 752 may be levied on diesel cars. Institutions should be identified and entrusted with the responsibility of further research on CRT device in making it commercially viable. Government funding should be provided for the same.

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