CHAPTER 1
INTRODUCTION

The economy and the natural environment are interlinked. These interlinkages between the economy and the environment are all-embracing; every economic action can have some effect on the environment and every environmental change can have an effect on the economy. This linkage is shown as follows:

The production sector in the economy extracts energy resources and material sources from the environment. These are then transformed into outputs; some useful and some, which are waste products. The environment's first role, then, is supplier of resources. Its second is sink or receptor of waste products. These waste products may originate either from the production process or from the consumption process. The third role of the environment is that it acts as a supplier of amenity—educational and spiritual. That is, in other words, the utility which a person derives in a society does not depend only on the consumption of goods and services produced in the production sector of the economy, but also on the aesthetic values or benefits one derives from the environmental assets like air quality or water quality. Since environment is a supplier of utility directly to an individual via the environmental assets and indirectly via its role in the production process of the economy, it is clear that increase in the output of the production process will result in decrease in the quantity or quality of environmental assets. That is, in other words, use of environment as a supplier of resources reduces its ability to provide us with other services like better air quality etc.

The environment is thus a scarce good, with many conflicting demands placed on it. It is important to realize that this scarcity is a relative one and not an absolute one. This scarcity is due to the economic growth. It is apparent that economics has a role to play,
since much of economics is concerned with allocating source resources to conflicting demands. Therefore, the economic system, primarily the market system can play a very effective role in addressing the problems arising out of environmental scarcity. It is at this backdrop this thesis will focus on one of many urban environmental problems, viz. deterioration of air quality due to vehicular pollution and suggest suitable policy measures to reduce it.

The chapter is organized as follows: Section 1.1 describes relevance of the study Section 1.2 gives motivation for the study and in Section 1.3 the scope of the study is described. Section 1.4 lists down major pollutants emitted by type of vehicles. Section 1.5 presents the objective of the thesis, Section 1.6 describes the plan of the thesis. A brief note on the technical formation of pollutants is given in the Appendix A-1.1

1.1 Relevance of the Study

Deterioration of air quality is a major environmental problem in many large urban centres in both the developed and the developing countries. Although urban air quality in industrial countries has been controlled to some extent during the past two decades, in many developing countries like India, it is worsening and becoming a major threat to the health and the welfare of the people and the environment. The main causes of the deteriorating air quality are urbanization and industrialization. These two factors have led to dramatic growth in vehicular population. The major pollutants due to vehicles are carbon monoxide, hydrocarbons, and lead from gasoline vehicles, oxides of nitrogen and suspended particulate matter from diesel vehicles.

The selected area for the analysis is a single metropolitan area, Chennai City, located in the southern part of India. The reason for choosing this area is the familiarity of the area to the researcher and lack of sufficient economic research in this field. The air quality of Chennai has been deteriorating over the last few years, despite the fact that SPM
is the only major pollutant in Chennai. Though, the other pollutants are below the standards, these pollutants will cross the acceptable standards in the near future if no actions are taken on this front. This is due to the rapidly increasing vehicular population rather than industrialization as Chennai is not a major industrial centre. The boom in vehicular population coincided with the economic reforms, one of which was the liberalization of the automobile industry in India. Since 1990-1991, the three-wheelers have grown at a compound rate of 13% per annum, the two-wheelers at 8.2% per annum and the cars at 6.2% per annum, while the public buses have risen at a rate of 0.6% per annum. This trend is expected to continue in the future, which means that suitable proactive steps are needed to control the menace of pollution posed by the increasing vehicular population.

1.2. Motivation for the Study

The reasons for rapid increase in the vehicular population during the last decade are: an increase in the purchasing power of the people and liberalization of the automobile industry. However, the increase in the number of vehicles alone is not responsible for the pollution. Other factor, which is equally responsible for pollution, is the physical characteristics of the vehicular fleet. Most of the vehicles plying on the road are old and high polluting vehicles, which form a major proportion of the vehicular fleet in the city. Road conditions further aggravate the problem. Therefore, it is important that suitable measures are taken, which would control the expected increase in pollution.

In the last decade or so, the development of methodology for application of economic instruments to find solution to environmental problems is copious. Until this, it was thought that the regulation was the best policy option to manage this problem. Now it is possible to apply market based principles, which would be least costly. This motivated
the researcher to search for appropriate market based instruments for the control of vehicular pollution.

1.3. Scope of the Study

The study focuses on the importance and the role of the indirect economic instruments in the control of vehicular pollution. The study attempts to fill the lacuna in the pollution control measures by the Government both at the Centre and the State, as these measures are purely of command and control type which are not supported by economic instruments. Therefore the existing measures are not cost effective. In order to find cost effective solutions it is important to first look at what are the various technical modifications available in each category of vehicle and by how much each type reduces pollution and then to find net cost of bringing in such changes in the vehicles. This study makes an attempt on these lines.

Net cost is computed to arrive at the suitable economic instrument to induce the owners to go for technical modifications. This includes instrument such as automobile tax on those who do not willingly opt for modifications. This thesis does not specify target reduction in pollution growth rate from the vehicles independently as given by the Board or other sources. Because these targets are often very unrealistic. Therefore this thesis uses as targets the reduction that could be achieved by adopting all the technical retrofitment and modifications which are more realistic and achievable. The major focus of the thesis is how to achieve this target in a cost-effective manner using combination of instruments. The part of the instruments package is also fuel tax which reduces demand for fuel and thereby reduces pollution.

It is to be noted that measures, which help in the control of vehicular pollution, which is a local phenomenon, might also affect the CO₂ emission, which is a global pollutant. As for global pollutant, we consider only CO₂. It is estimated that CO₂
emissions accounted for 66% of greenhouse effect between 1880 and 1980 and 49% of the greenhouse effect since 1980. Since the focus of study is local pollution, the study only looks at the effect of complementary measures controlling local emission on the emission of CO₂.

Another way of controlling pollution is through the enhancement of mass transport system. It is important that the mass transport system in the selected city must be restructured for meeting environmental objectives. This is necessary in view of the fact that despite a good bus system, the use personal vehicles has been on the increase. However, the restructuring of the public transport system in the selected city, Chennai has to be supported by other measures, which reduce the dependence on private vehicles. Therefore, this study suggests measures for restructuring of mass transport system, supplemented by measures that reduce dependence on private modes of transport, as this would help in controlling the pollution from vehicles to a considerable extent.

1.4. Sources of Different Vehicular Pollutants

For effective vehicular pollution control management, it is imperative to know the different vehicular sources of the pollutants. This would enable one to formulate effective policy measures, which targets the specific category of vehicles based on the vehicular fleet distribution and the vehicle characteristics in the city.

The major source of the pollutants are given in the table 1.1
TABLE 1.1: SOURCE OF VEHICULAR POLLUTANTS

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Major Source</th>
</tr>
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<tbody>
<tr>
<td>Carbon monoxide</td>
<td>All gasoline vehicles-more those without a catalytic converter</td>
</tr>
<tr>
<td>(Unburnt or Partially burnt) Hydrocarbons</td>
<td>Petrol vehicles without catalytic converter, two-stroke engines and pump stations (due to spillage).</td>
</tr>
<tr>
<td>(HC)</td>
<td></td>
</tr>
<tr>
<td>Nitrogen oxides (NO₅)</td>
<td>Diesel vehicles.</td>
</tr>
<tr>
<td>Particulate matter</td>
<td>Diesel fueled vehicles and oil burning in two stroke engines.</td>
</tr>
<tr>
<td>Lead</td>
<td>Petrol vehicles due to the lead in the petrol.</td>
</tr>
<tr>
<td>Sulphur –di-oxide (SO₂)</td>
<td>Both petrol and diesel vehicles, and this is mainly due to the sulphur level in the fuel.</td>
</tr>
<tr>
<td>Benzene</td>
<td>Mostly from the fuel directly. There is occasional formation in the combustion or conversion of aromatics.</td>
</tr>
<tr>
<td>Ozone</td>
<td>A global pollutant mainly due to HC and NO₅.</td>
</tr>
</tbody>
</table>

Source: The Hindu Survey of Environment 2000

From the above table, we can see that the diesel vehicles are the major source of nitrogen oxides, particulate matter and sulphur di oxide, while the petrol vehicles are the major contributors of lead, hydrocarbons and carbon monoxide.

1.5 Objectives

The objectives of the study are as follows:

a) to study the status of air pollution and the reasons for the deterioration in the air quality in Chennai;

b) to examine the vehicular pollution control measures, focussing on economic instruments introduced in other developed and developing countries and its relevance for India;
c) to compute the net cost of abatement achieved via various technological modifications and use these measures to arrive at various economic instruments to control vehicular pollution and finally suggest combination of instruments.

d) To analyse the scope for mass transport restructuring in the selected area that would substitute the personal vehicles in their uses.

1.6 Plan of the thesis

The remainder of the thesis is organized as follows:

*Chapter 2* briefly discusses the theories of environmental economics as propounded by experts and reviews the existing studies on vehicular pollution control based on methodology which are classified as: a) Simple statistical methods b) Econometric methods c) Modelling techniques.

*Chapter 3* discusses the worsening trend of the air quality in Chennai, the causes- the road network, the increasing vehicular population and the environmental characteristics of the vehicular fleet- of the increasing air pollution in Chennai and also provides a comparison of the status of air quality in the other major cities of India.

*Chapter 4* critically examines the measures taken by the Government so far, both at the Centre and the State to control the problem of vehicular pollution. The chapter also reviews the experiences of other developed and developing countries.

*Chapter 5* describes the database and the methodology used in the study and is divided into two sections. The chapter first describes the estimation of vehicular pollution load based on the projected vehicular population. Then, it describes the method used for calculating the net cost of the various technical modifications and also the method for estimating the gasoline elasticity to compute required gasoline tax.
Chapter 6 gives the results of the empirical analysis. The chapter estimates vehicular pollution load in the year 2007 based on the projected vehicular population. Net cost for each technical modification is worked out. Suitable technical options are suggested based on the net cost. Estimates of pollution reduction due to each of the technical option and also due to the combination of all are also given. Mixtures of policies are derived. Finally, the effect of the policy measures on CO₂ emissions is estimated.

Chapter 7 discusses the status of mass transport in Chennai, the reason for the increasing share of private modes of transport and suggests measures for the qualitative and quantitative enhancement of public transport.

Chapter 8 summarizes the result of the thesis.
APPENDIX A - 1.1

FORMATION OF POLLUTANTS

The following give details about formation of the main pollutants emitted by the vehicles, viz., Hydrocarbons, Carbon monoxide, Oxides of nitrogen and Particulate matter.

Hydrocarbons

Hydrocarbon exhaust emission may arise from three sources-wall quenching, incomplete combustion and exhaust scavenging.

Wall Quenching

Wall quenching is a combustion phenomenon, which arises when a flame tries to propagate in the vicinity of a wall. Normally the effect of the wall is a slowing down or stopping of a reaction. Because of the cooling there must be a cold zone next to cooled combustion chamber walls. This region is called the quench zone, and because of the low temperatures the fuel—air mixture remains unburnt. During the exhaust stroke, the first gas that exits is from near the valve and is relatively cool, the last part of the gas is what is scrapped off the cool cylinder walls and is also relatively cool. Therefore, during the exhaust stroke, an initial high HC concentration is expected followed by a lower concentration as the bulk gas exhaust and ending with a high concentration.

Incomplete combustion

Under engine operating conditions where mixtures are extremely lean or rich, where exhaust gas dilution is excessive, incomplete flame propagation may occur in cycles. Thus, incomplete flame propagation results from a high exhaust gas dilution arising from high vacuum operation such as idle or deceleration. However, during transient operation, especially warm up and acceleration, which are too rich or too lean to burn completely find their way to the cylinder resulting in very high hydrocarbon emissions.
Scavenging

In two stroke engine a third source of hydrocarbon emissions results from the scavenging of the cylinder with fuel air mixture, part of which blows through the cylinder directly into exhaust and escapes the combustion process completely. Hydrocarbon emissions from these engines may be several times more than those from naturally aspirated 4-stroke engines. Supercharged 4-stroke gasoline engines may have some HC emissions from this source.

Carbon monoxide

In an engine, fuel is burnt with air. Fuel (petrol or diesel) consists of hydrocarbons. Air mainly consists of oxygen only. Carbon Dioxide and water vapor coming out of engines cannot burn the fuel completely. Because of such incomplete combustion, Carbon monoxide is produced. Carbon monoxide remains in the exhaust if the oxidation of CO to CO$_2$ is not complete. This generally is due to lack of sufficient oxygen. The emission levels of CO from gasoline engines generally depend on the A/F ratio.

Oxides of Nitrogen

Nitric Oxide (NO), is formed within the combustion chamber at peak combustion temperature and persists during expansion and exhaust in non-equilibrium amounts. Upon exposure to additional oxygen in the atmosphere, nitrogen dioxide and other oxides of nitrogen may be formed. Though many oxides of nitrogen may also be formed in low concentrations like N$_2$O$_3$ (nitrogen trioxide), N$_2$O$_5$ (nitrogen pentoxide) etc, they are unstable compounds and would decompose to nitrogen dioxide at ambient conditions.

Particulate Matter

Diesel exhaust particulates are basically substances deposited on a Teflon-coated glass fiber exposed to Diesel exhaust mixed with air in a dilution tunnel. The particulates
are a conglomerate of a variety of components, viz., carbon, lube oil and sulphates. Carbon particulates are formed due to the low air-fuel ratio at low loads. Lube oil particulates are directly linked to the lube oil consumption. They are the result of oil leakage into the intake and exhaust systems of in-cylinder evaporative and partial burn process of the lube oil. The dominating lube oil particulate source is the lube oil from the cylinder wall. Sulphates on the other hand originate from fuel sulphur during the combustion process.