THE INCIDENCE OF HYPOTHETICAL AUTOMOBILE POLLUTION TAXES

Dissertation for the Degree of Ph. D.

MICHIGAN STATE UNIVERSITY

JAN WILLIAM ZUPNICK

1975

This is to certify that the

thesis entitled

THE INCIDENCE OF HYPOTHETICAL AUTOMOBILE
POLLUTION TAXES

presented by

Jan William Zupnick

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Economics

Warren J. Samuels
Major professor

Date November 6, 1975

O-7639

0495536

ABSTRACT

THE INCIDENCE OF HYPOTHETICAL AUTOMOBILE
POLLUTION TAXES

By

Jan William Zupnick

This study seeks to estimate the static incidence of various taxes which might be imposed on automobile emissions. Technical data as emissions by type (unburned hydrocarbons, carbon monoxide and oxides of nitrogen) by year of automobile manufacture were combined with data on the distribution of automobile ownership by income by year of manufacture to form a system of four dimensional tax base matrices: type of pollutant by income class by quantity of pollution by model year of automobile manufacture. Hypothetical emission taxes encompassing all likely tax structures and rates were imposed on owners of automobiles whose in-use emissions exceeded an arbitrarily chosen acceptability standard. The resulting tax liability was calculated by income class utilizing the process of matrix multiplication and the short run incidence of the various hypothetical taxes was estimated.

The short run patterns of incidence of all hypothetical taxes based on emission characteristics were shown to be regressive throughout all income categories regardless of whether incidence was measured per household or per car-owning household. The

pattern of incidence of all hypothetical taxes on annual emission output was found to be progressive through the lower-middle income classes (exclusive of the lowest income class) becoming increasingly regressive as incomes rose above $6,000 when calculations were on an all-household basis. Finally, calculations of the short run incidence of the annual emission output taxes on a per car-owning household basis once again revealed regressive incidence patterns.

These short run patterns of incidence were compared to the patterns of incidence of selected federal taxes and current methods of emission control. Results of the comparisons revealed similar distributions of the tax burden. Many of these patterns were strongly regressive in terms of "ability to pay," and inequitable. Only the patterns of incidence of the emission output taxes revealed ranges of progressivity. As such, the conclusion that, other things being equal, emission output taxes were more equitable than the other hypothesized taxes was drawn.

Potential behavioral responses to the imposition of the various taxes were then discussed and estimates of potential reductions in the total automobile pollution output were calculated where possible. Although a lack of adequate data prevented quantitative evaluation of the impact of the various taxes over time, a tentative conclusion was reached that the emission output taxes would be the most effective taxes since they impacted on more of the factors taken into consideration by consumers in their motoring decisions than the characteristic taxes.

THE INCIDENCE OF HYPOTHETICAL AUTOMOBILE POLLUTION TAXES

By

Jan William Zupnick

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Economics

1975

ACKNOWLEDGMENTS

I wish to acknowledge the assistance that I received from Dr. Warren Samuels, and express appreciation for the interest Dr. Samuels expressed throughout all stages of my graduate studies. His willingness to work with me on earlier drafts of this study and the time he spent suggesting corrections of initial errors deserve praise.

I also wish to thank Dr. Daniel Saks who initially suggested the dissertation topic and whose comments on earlier drafts of the study were extremely helpful.

I would like to thank Professors Bruce Allan and David Verway for their aid and suggestions.

The National Science Foundation must be acknowledged for the financial support given me during 1974 which permitted me to obtain a significant portion of my data.

I would like to express a special thanks to my loving wife Linda. For her understanding and continual support, both of which are reflected in this study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure		Page

CHAPTER I

INTRODUCTION

The purpose of the dissertation is to estimate the static incidence of various taxes which might be imposed on automobile emissions. Technical data on emissions by year of automobile manufacture will be combined with data on the distribution of automobile ownership by income by year of manufacture to form the data base for the estimate. As a part of the determination of the incidence of said taxes, likely behavioral responses by consumers of taxed services will be considered, though data are not available for estimating these impacts. Finally, the study will evaluate this approach to the resolution of the automobile pollution problem by discussing the empirical results within the context of equity and efficiency criteria and by reference to other, currently in-force taxes.

The economic environmental problem addressed by the thesis arises within the context of public concern for the preservation and potential enhancement of our environmental quality. Recent attention has focused on the gasoline powered automobile's contribution to air pollution through exhaust emissions which until recently were uncontrolled. Estimates of the severity of the automobile's contribution to this problem vary considerably depending upon whether they are presented on a crude weight basis or are presented after correcting for toxic effects. Table 1.1 estimates the relative contribution that transportation makes to nationwide air pollution.[1] The table is based upon the estimated number of millions of tons per year of pollutant emitted from ground sources.

As can be readily observed from Table 1.1, transportation pollution is a major contributor of carbon monoxide (77.3%), hydrocarbon (55.3%) and oxides of nitrogen (50.9%) pollution. These three pollutants accounted for nearly 70 percent of the total U.S. pollution by weight in 1971. Further, transportation pollution is responsible for nearly 50 percent of all pollution, when measured by source (EPA, 1973: 266).

TABLE 1.1.--Relative Pollutant Contribution by Source: 1971.

Source	Percent of Each Pollutant by Source				
	Carbon Monoxide	Particulate	Sulfur Dioxide	Hydrocarbon	Oxides of Nitrogen
Transportation	77.3	3.7	3.1	55.3	50.9
Fuel combustion	0.9	24.1	80.7	1.0	46.4
Industrial processes	11.4	50.4	15.6	21.1	0.9
Solid waste disposal	3.8	2.6	0.3	3.8	0.9
Other	6.5	19.2	0.3	18.8	0.9
Total	100.0	100.0	100.0	100.0	100.0

Source: Calculated from Environmental Protection Agency, Environmental Quality (Washington, D.C.: Government Printing Office, 1973), p. 266.

[1]The autmobile accounted for nearly 90 percent of all transportation pollution according to EPA estimates in the Economics of Clean Air, 1971.

Table 1.2 presents one of many[2] studies which correct emission measurements by weight in an attempt to account for the different thresholds of harm associated with each type of pollutant. For example, in terms of environmental harm, it is estimated that a given weight of oxides of nitrogen is nearly 80 times more harmful to the environment than the identical weight of carbon monoxide (Babcock, 1970: 653-657). This "Pindex" weighting technique presumes that the basis for determining environmental harm can be found in current ambient air quality standards--when the ambient level of a given pollutant exceeds the standards, a dangerous or unhealthy situation is said to exist. These standards are used to determine the air tolerance factors presented in Table 1.3. The weight tolerance factors ($\mu g/m^3$) are then used to reduce various unweighted pollutant concentrations to the Pindex levels which appear in Table 1.2.[3]

The use of tolerance factors and Pindexing reorders the United States' air pollution problem. Carbon monoxide, which accounted for 52.8% of the source distribution based on emission weights, becomes insignificant after Pindexing (2 percent contribution). Particulate matter becomes the most serious pollutant, sulfur oxides and nitrogen oxides following close behind.

---

[2]See, for example, L. S. Caretto and R. F. Sawher, "The Assignment of Responsibility for Air Pollution," Society of Automotive Engineers Annual Meeting, January 10-14, 1972; or E. G. Walther, "A Rating of Major Air Pollutants and Their Sources by Effect," Journal of the Air Pollution Control Association (Sept. 1972): 727.

[3]A sample calculation is provided in Appendix A.

TABLE 1.2--U.S. Air Pollution Source Distribution: 1969.

Source	Carbon Monoxide	Particu-lates	Sulfur Dioxide	Hydro-carbons	Oxides of Nitrogen	Total
Uncorrected (% Grand Total)						
Transportation	48.5	1.5	0.4	7.9	2.5	60.7
Industrial processes	1.5	4.9	7.1	3.0	1.3	17.7
Power plants	0.4	1.9	8.3	0.1	1.9	12.7
Space heating	1.5	0.97	2.8	0.4	0.7	6.3
Solid waste disposal	1.0	0.49	0.2	0.8	0.1	2.6
Total	52.8	9.7	18.7	12.2	6.5	100.0
Corrected (Pindex Levels)						
Transportation	2.0	6.0	1.0	3.0	7.0	19.0
Industrial processes	0.0	22.0	11.0	1.0	4.0	38.0
Power plants	0.0	11.0	2.0	0.0	6.0	29.0
Space heating	0.0	5.0	4.0	1.0	2.0	12.0
Solid waste disposal	0.0	2.0	0.0	0.0	0.0	2.0
Total	2.0	46.0	28.0	5.0	19.0	100.0

Source: Calculated from L. R. Babcock, "A Combined Pollution Index for Measurement of Total Air Pollution," Journal of the Air Pollution Control Association 20 (Oct. 1970): 653-657.

TABLE 1.3.--Derivation of Tolerance Factors.

	Proposed California Standards	Tolerance Factors (ppm)	Tolerance Factors ($\mu g/m^3$)
Oxidant	0.1 ppm for 1 hr	0.10	214
Particulate matter	Visibility below 7.5 miles for 12 hr, below 3 miles for 1 hr	--	375
Nitrogen oxides	0.25 ppm for 1 hr (for nitrogen dioxide)	0.25	514
Sulfur oxides	0.1 ppm for 24 hr 0.5 ppm for 1 hr (for sulfur dioxide)	0.50	1,430
Hydrocarbons	--	--	19,300
Carbon monoxide	20 ppm for 8 hr	32.0	40,000

Source: Calculations by L. R. Babcock in "A Combined Pollution Index for Measurement of Total Air Pollution," Journal of the Air Pollution Control Association 20 (Oct. 1970): 653-657.

Hydrocarbons assume a low Pindex value despite their essential contribution to photochemical oxidant synthesis. Among the sources of pollution, transportation remains a significant contributor (19 percent), but Pindex lowered its rank from first to third behind industry (38 percent) and power plants (29 percent).

Regardless of the method of data presentation and the resulting importance one attaches to the particular source of air pollution, the serious environmental problem is that any amount of pollution which even nears the levels for which transportation is responsible poses a serious threat to the ecosystem. This is particularly evident when one realizes that all urban areas in the U.S. with population levels of a million or more have serious air pollution problems, problems which are exaggerated because of the unequal incidence of air pollution. Table 1.4 presents the results of a study of air samples collected over a two-year period by the Environmental Protection Agency in a representative urban area. The study showed that air pollution generally hangs more heavily over the urban area than the surrounding non-urban areas with average concentrations of pollutants declining with distance from the central city. Since automobile emissions account for an estimated 92 percent of all urban pollution (Macinko, 1971), one serious problem is that of controlling concentrations of automobile emissions due to societal congestion. Since, however, the externality and public bad characteristics of air pollution prevent individuals from reaching agreement to voluntarily reduce pollution output, some method designed to discourage the use of environmental resources

TABLE 1.4.--Selected Particulate Constituents: Chicago 1966-67 (g/mi.).

Constituent	Urban	Non-Urban		
		Proximate	Intermediate	Remote
Organics (C)	6.7	2.5	2.2	1.1
Nitrate Ion	2.4	1.4	0.85	0.46
Lead	1.1	0.21	0.10	0.02

Source: Council on Environmental Quality, <u>Environmental Quality 1971</u>

for the production of pollution might be imposed. Of the possible alternative methods of control (prohibition, charges and subsidies, establishment of property rights, taxation), this thesis is concerned with taxation of automobile exhaust emissions in a manner designed to reduce pollution generation to some legislatively designated acceptability standard.[4] Further, a major portion of the thesis will be concerned with the imposition of various taxes[5] and estimation of the incidence of each form selected. This is especially significant since the incidence questions have been ignored in the literature, as has an evaluation of such tax schemes in terms of equity.[6]

A brief description of the technology of automobile emissions and their potential for ecosystem damage is presented in Chapter II. Chapter III discusses automobile emissions by year of manufacture and the pattern of automobile ownership circa 1971. The methodology utilized in constructing the tax base is described

---

[4]Potential advantages of this method over customary regulatory methods might include provision of economic incentive to reduce pollution generating activities; provision of this incentive for any level of emission reduction desired; provision of incentive to maintain equipment in good working order to minimize pollution; encourage substitution of pollution-free activities where possible; and achieve any desired level of air quality at lowest cost to society.

[5]Including all likely tax structures and rates.

[6]See R. O. Zerbe, "Theoretical Efficiency in Pollution Control," Western Economic Journal (Dec. 1970); or D. C. Shoup, "Theoretical Efficiency in Pollution Control: Comment," Western Economic Journal (Sept. 1971); W. Baumol, "On Taxation and Control of Externalities," American Economic Review (June 1972); or Baumol and Oates,"Use of Standards and Prices," Southern Economic Journal (1971), to name only a few.

in detail in Chapter IV, and the static incidence of the various hypothetical tax structures is estimated in Chapter V. Finally, the analysis is extended to consider likely behavioral responses by consumers of taxed services and to evaluate this approach to the resolution of the automobile pollution problem within the context of efficiency and equity criteria (Chapter VI).

CHAPTER II

EXHAUST EMISSION FORMATION AND ENVIRONMENTAL CONSEQUENCES

Automobile exhaust emissions are best characterized as byproducts of a series of complex chemical processes taking place during the internal combustion engine's sequence of operations. The technology of the present 4-, 6-, or 8-cylinder automobile engine incorporates the reciprocating piston principle, wherein a piston slides up and down in a cylinder and transmits the power needed for locomotion through a simple connecting rod and crank mechanism to the drive shaft. In employing this principle, a series of four piston strokes is required to complete a single power production cycle within each cylinder. These strokes, which are diagrammed in Figure 2.1, are the input stroke, compression stroke, power production stroke and the byproduct stroke. The cycle begins when the intake valve opens, admitting a combustible mixture of fuel-air inputs from the carburetor into the cylinder of the engine (input stroke). The intake valve closes sealing the cylinder. The fuel-air input is then compressed by the rising piston and the temperature of the input rises. The spark from the sprak plug ignites the mixture near the end of the stroke (compression stroke) and combustion begins. Once the chemical reaction

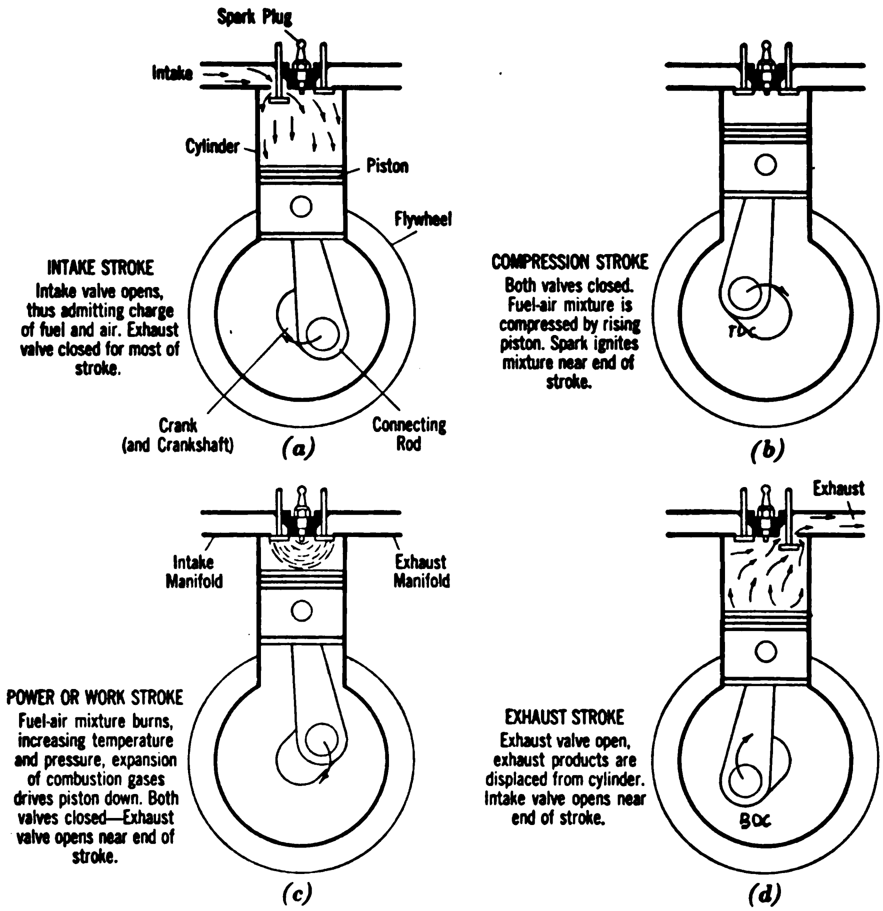

Figure 2.1.--The Four-Stroke Spark-Ignition Cycle.

Source: Edward Obert, Internal Combustion Engines (Great Britain: 1950), p. 2.

becomes self-sustaining, a spherical flame will advance across the chamber from the spark plug burning the air-fuel input, liberating energy, and further raising the temperature and pressure of the gases surrounding the flame. At this point, the unburned gases ahead of the flame front and the gas behind the flame front are compressed by expansion of the burning input and become combustible. The expansion of gases drives the piston down, work is done and power is produced (power production stroke). Finally, the exhaust valve opens as the flame front approaches the far chamber wall, combustion ends, and the exhaust byproducts are displaced from the cylinder (byproduct stroke). The intake valve opens near the end of the stroke and the process repeats itself.

The volume and composition of the byproducts removed from the cylinder during the byproduct stroke, and hence the quantity of potential pollutant emitted from the exhaust pipe into the atmosphere, are determined by the dynamics of combustion of the inputs to the power production process. These dynamics are influenced by numerous engine design and engine operating variables, the most important of which will be discussed in the context of their contribution to the formation of the individual pollutants of concern to this study--unburned hydrocarbons, carbon monoxide and oxides of nitrogen. It is important to realize at this time that byproducts inevitably will occur in the automobile's exhaust when a chemical reaction occurs involving the combustion of hydrocarbon fuels and air to produce power. One equation for <u>complete</u> combustion of a typical fuel molecule with a chemically correct amount of air is:

$$C_7H_{13.02} + 10.255\ O_2 + 38.6\ N_2 \longrightarrow$$

$$7\ CO_2 + 6.51\ H_2O + 38.6\ N_2 \qquad (1)$$

The combustion of one molecular weight of fuel requires 48.855 molecular weights of air (10.255 O_2 + 38.6 N_2) and produces 7 molecular weights of carbon dioxide, 6.51 molecular weights of water and 38.6 molecular weights of nitrogen (Patterson and Henein, 1972: 97). Note, however, that the byproducts of complete combustion with the chemically correct amount of air are naturally abundant in the atmosphere, pose no significant threat to the ecosystem, and are therefore not considered pollutants. It is only when factors impinge upon the combustion process that potentially harmful byproducts are emitted in the auto's exhaust. The likely process of formation of unburned hydrocarbons, carbon monoxide and oxides of nitrogen, and their potential for damage to the ecosystem are described in detail below.

Hydrocarbon Formation and Consequences

The quantity of unburned hydrocarbons present in automobile exhaust depends upon the quantity of hydrocarbons which are left unburned in the combustion chamber following the power production stroke of the engine cycle, and upon the degree to which chemical processes following this stroke are able to react with the unburned HC as it proceeds through the exhaust system to the tailpipe. The existence of unburned HC in the combustion chamber has been attributed to the phenomena known as flame quenching. This phenomena was first studied by W. A. Daniel with the aid of photographs of the combustion process. He showed that as the flame passed through the combustion chamber a dark region of unreacted mixture was left adjacent to the chamber wall and in the crevices between the cylinder wall and the piston (Daniel, 1957: 882). This flame quenching process results because the relatively cool chamber wall and the narrow passages between the cylinder wall and pistons do not permit the gas temperature or concentration of chemically active elements (oxygen, hydrogen, etc.) to increase to a sufficiently high level where appreciable reaction will take place. Figure 2.2 shows the temperature profile through the flame front as it leaves the spark plug and proceeds toward the far chamber wall. The spark plug ignites a small area of air-fuel input and a flame begins to propagate across the chamber surface. Unburned mixture immediately in front of the flame is heated in a preheat zone by heat conducted from burned gases behind the flame front and by diffusion of the combustible elements (oxygen, hydrogen, hydrogen radical) of the air-fuel mixture into the preheat zone. Ultimately, the temperature of the unburned mixture rises to a level where appreciable chemical reaction begins, T_i, with the result that internal heat generation is sufficient to make the reaction self-sustaining. The flame front proceeds across the chamber (curve 2) and continued reaction occurs at the burned gas temperature, T_b, until the leading edge of the preheat zone is just touching the wall surface. Shortly after,

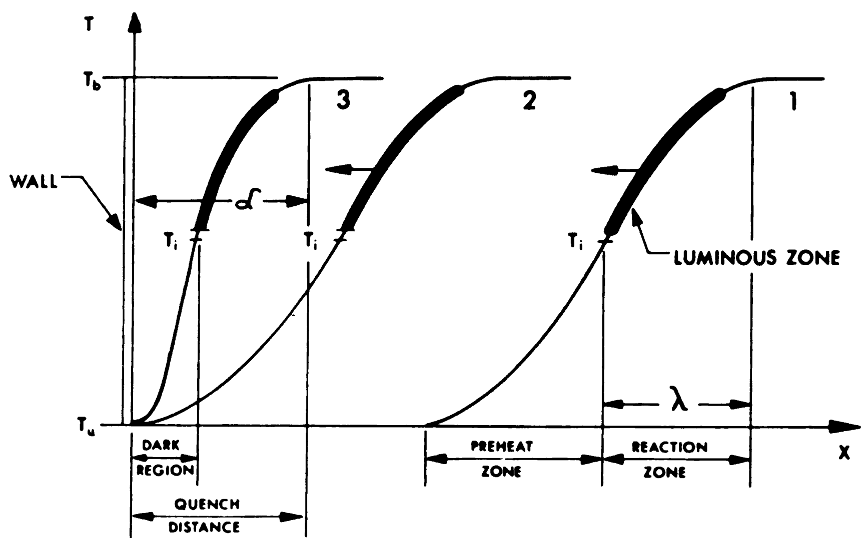

Figure 2.2.--A Flame Propagating Toward a Wall. The arrow indicates the direction of propagation.

Source: D. J. Patterson and N. A. Henein, Emissions from Combustion Engines and Their Control (Ann Arbor: Ann Arbor Science Publishers, 1972).

the heat transfer from the burned gases behind the flame front to the wall, plus inhibition of the chemically active elements (chain breaking) at the wall no longer permits the gas temperature or active centers to increase to a sufficiently high level where appreciable reactions take place ($T < T_i$). The flame is extinguished or quenched and a layer of unburned fuel, or dark region, remains near the chamber wall and in the chamber crevices.

Although the existence of the quenching phenomena is due to engine design parameters--the most important of which are combustion chamber area, surface to volume ratio and the presence of combustion chamber deposits--the thickness of the quench layer and thus the quantity of unburned HC available for emission from the exhaust pipe depends upon engine operating variables. The most important operating variables and their effect on exhaust HC emissions appear in Figure 2.3. The results of Figure 2.3 indicate that the air-fuel ratio has the greatest effect on total hydrocarbon emissions of any of the operating parameters studied (Springer and Patterson, 1973: 125).

Most of the principal effects of hydrocarbon emissions are not caused by hydrocarbons directly. Indeed, the ultimate products of hydrocarbons irradiated with light for a sufficient period of time (photooxidation) are carbon dioxide and water vapor, which are not atmospheric pollutants. The products of concern are the intermediate products of photooxidation--all of which are capable of further reaction in the atmosphere--which are produced because no parcel of air remains in the urban atmosphere long enough for HC

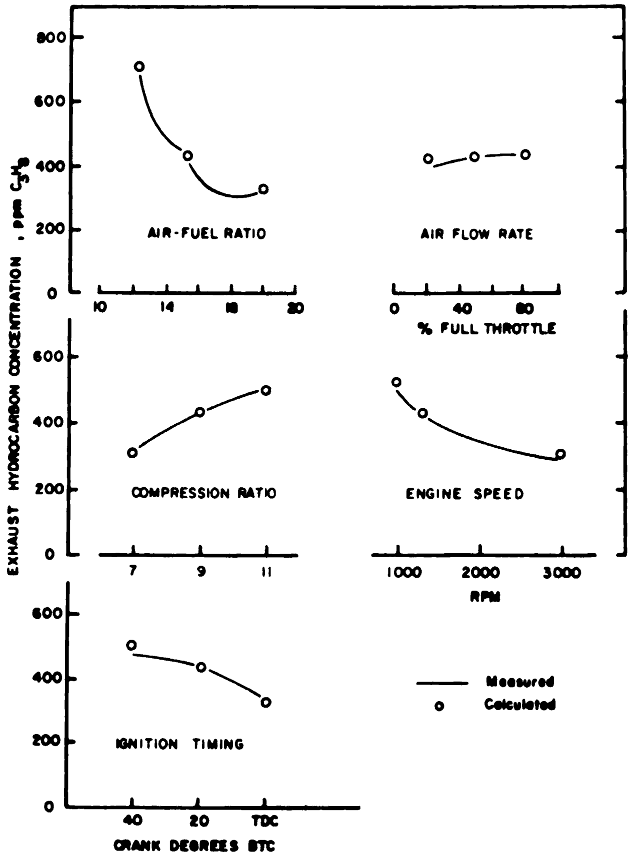

Figure 2.3.--Effect of Engine Operating Variables on Exhaust Hydrocarbon Emissions from a Single-Cylinder Spark-Ignition Engine.

<u>Source</u>: G. S. Springer and D. J. Patterson, <u>Engine Emissions: Pollutant Formation and Measurement</u> (New York: Plenum Press, 1973).

to be fully oxidized. The intermediate products for which HC is a precursor include aldehydes, ozone and nitrogen dioxide. Aldehyde formation is more closely related to the level of HC than any of the above photochemical oxidants. The specific aldehydes found in urban air are formaldehydes, which account for 50 percent of all aldelydes in polluted air, and acroleins, which account for 5 percent of all remaining aldehydes (Altschuller and McPherson, 1963: 109-111). Numerous toxicological studies have shown that formaldehyde irritates the mucous membranes of the eyes, nose and other portions of the upper respiratory tract. Inhalation of high concentrations has caused laryngitis, bronchitis, and bronchopneumonia with seious injury resulting to persons with respiratory tract infections. Symptoms which have been observed in humans subjected to nonfatal exposure to formaldehyde have included sneezing, coughing, headache and fluctuations in body temperature (U.S. Department of Health, Education and Welfare, 1970: Table 7-7, pp. 7-8). Toxicological studies on acrolein have shown that its vapors are highly toxic to humans and extremely irritating to the eyes and the respiratory tract. Although no cases of chronic toxicity are known, repeated contact with the skin may produce chronic irritation and dermatitis. Symptoms reported by humans subjected to acrolein vapor include swelling of the eyelids, bronchitis and asthma (U.S. Department of Health, Education and Welfare, 1970: Table 7-9, pp. 7-13). As the above studies reveal, aldehydes and acrolein are pollutants which are irritants to a healthy individual, but are dangerous health hazards to individuals in marginal health conditions.

Ozone and nitrogen dioxide formation, both of which are far more toxic than aldehyde, are facilitated by the presence of unburned hydrocarbons and their ready reactivity with sunlight and nitric oxide. Since their formation takes place during the photolytic cycle, the discussion of their environmental hazards will be delayed until the cycle is described.[1]

Carbon Monoxide Formation and Consequences

The quantity of carbon monoxide (CO) emitted from the tail-pipe of the spark ignition automobile engine is determined by the concentration of CO in the exhaust and the exhaust volume. These concentrations depend almost exclusively upon engine operating variables and the dynamics of combustion. As previously described, complete combustion of fuel with a chemically correct amount of air, can be expected to produce carbon dioxide, water vapor and nitrogen.[2] It has been pointed out that these byproducts of combustion are not harmful to the environment and are not considered pollutants. However, as Figure 2.4 shows, as the operating variable, air-fuel ratio, deviates from the chemically correct ratio (14.5/1),[3] the level of CO in the exhaust system changes. Specifically, when the air-fuel mixture is richer than chemically correct--low air-fuel ratios--

---

[1]See the section on oxide of nitrogen formation.

[2]See Equation (1), page 12.

[3]From Equation (1) it was found that 48.855 molecular weights of air were required to completely burn 1 molecular weight of fuel. This converts to 1,408 lbs. of air required to burn 97 lbs. of fuel, or an air-fuel ratio of 14.5/1.

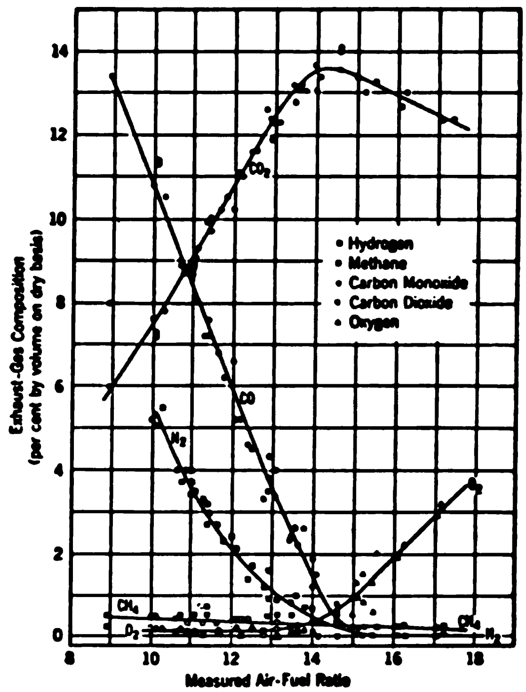

Figure 2.4.--Exhaust Gas Composition Versus Measured Air-Fuel.

Source: D. J. Patterson and N. A. Henein, Emissions from Combustion Engines and Their Control (Ann Arbor: Ann Arbor Science Publishers, 1972).

there is insufficient oxygen present to permit significant conversion of CO formed in the primary reaction zone of the flame front to carbon dioxide (CO_2) as temperatures in the reaction zone begin to decrease. This is shown by the steep downward slope of the CO curve in Figure 2.4, and steadily rising CO_2 curve in the same figure as the air-fuel ratio increases to its chemically correct level. At the chemically correct ratio, CO concentration is lowest and CO_2 concentration peaks (maximum CO conversion to CO_2). Similarly, when the air-fuel mixture is leaner than is chemically correct--high air-fuel ratios--the excessive amount of oxygen (O_2) present permits nearly complete conversion of CO to CO_2 and also produces some O_2 in the exhaust system. This is evidenced in Figure 2.4 by the constant volume of O_2 present in low air-fuel ratios, the falling CO curve and the rising CO_2 curve. The implication is that almost all O_2 is combining with CO to form CO_2. Notice that at air-fuel ratios greater than 14.5 to 1 oxygen volume rises indicating that significant quantities of O_2 are remaining uncombined in the engine.

Although other operating variables impact upon the quantity of CO emitted from the exhaust system, Table 2.1 demonstrates further that the air-fuel ratio, expressed as idle CO, has the greatest impact of all operating variables on the level of CO emissions. Referring to Table 2.1, in fleet 1 automobiles, model year pre-1966 in California and pre-1968 in the U.S., which had no emission controls, the correction of the air-fuel setting to manufacturer's specifications accounts for 35 percent of the total change in CO

TABLE 2.1.--Fraction of Total Emissions Change Due to Change in Operating Variable.

Parameter	Fleet 1	Fleet 2	Fleet 3
Timing, degrees	0.0256	0.0190	0.0189
Idle RPM, speed	0.2685	-0.0240	0.0056
Positive crankcase ventilation, cfm	0.0483	0.0340	0.1322
Air cleaner restriction, degrees	0.3077	0.1299	0.1989
Idle CO (% vol.)	0.3499	0.8412	0.6444

Source: Coordinating Research Council, "Experimental Characterization of Vehicle Emissions and Maintenance States," A Study of Mandatory Engine Maintenance for Reducing Vehicle Exhaust Emissions, Vol. VIII (July 1973): 2-77.

emissions obtainable from a tune-up. The air-fuel setting plus air cleaner restriction, which would tend to lean the air-fuel mixture, account for nearly 65 percent of the total emission change per vehicle from the untuned state. In fleet 2 automobiles, 1966-70 California manufacture and 1968-70 U.S., which had HC and CO exhaust controls, the air-fuel setting accounts for 84 percent of this total emission change, and the air cleaner restriction plus air-fuel setting account for 97 percent of this total change. Finally, in fleet 3 automobiles, California manufacture 1971, which had HC, CO and oxide of nitrogen (NO_X) controls, the air-fuel setting plus air cleaner restriction accounted for 84 percent of the total. Thus, of all operating variables, maladjustments in the air-fuel ratio play the most significant role in the production of CO emissions.

The primary impact of CO on the ecosystem manifests itself in toxicological effects on human beings. When carbon monoxide is breathed into the lungs, it combines with hemoglobin (H_b) to form carboxyhemoglobin (COH_b). Since hemoglobin, the agent in the red blood cell that carries oxygen to the tissues, has an affinity for CO which is 210 times greater than its affinity for O_2 (Dinman, 1971: 36), body tissues receive less oxygen than normal. The estimated amount of hemoglobin unavailable for oxygen transport due to carbon monoxide inhalation can be calculated as follows:

$$\% \text{ unsaturated } H_b = 2.76\ e^{h/7000} + 0.0107\ aC^{0.9}t^{0.75}$$

where:

e = base natural logs

h = elevation above sea level

a = activity level

c = CO concentration

t = duration of exposure in a traffic congested area

Calculations using the above relationship (Larsen, 1966: 281) reveal that a two-hour exposure to 250 parts per million CO at sea level[4] will cause about 16 percent of the blood's hemoglobin to be unavailable for transport of oxygen. The effects expected are that 20 percent of the population will experience respiratory changes or difficulty, 15 percent will feel dizzy, and 30 percent will have headaches. For populations not exposed to the above traffic

---

[4]These concentrations are equivalent to those arising in the immediate vicinity of stalled urban traffic.

congestion concentrations of CO, the most important CO values are those which are averaged over 8 hours in particular community atmosphere. Exposure to 30 ppm of CO for 8 hours produces 5 percent carboxyhemoglobin and results in reactions akin to the loss of one pint of blood (Larsen, 1966: 281-283). This is clearly no problem for a healthy person, but is definitely dangerous to the physically imperfect such as anemics, respiratory or cardiac cripples or for a normally healthy individual who happens to be seriously ill. Table 2.2 shows that 30 ppm CO for 8 hours was exceeded during the 1962-1967 study period a significant percentage of the time. Continuous exposure to CO at levels which produce 5 percent or greater COH_b, or short term exposure to excessive quantities of CO, may ultimately produce CO poisoning with a progression of symptoms as follows: headache, dizziness, ringing in the ears, nausea, vomiting, difficulty in breathing, apathy, collapse, unconsciousness and death.

TABLE 2.2.--Carbon Monoxide Concentrations in Selected Cities, 8-Hour Averaging Time, 1962-67.

City	% Time Concentration is Exceeded		
	10 ppm	30 ppm	50 ppm
Chicago	21	16	12
Los Angeles	15	12	10
St. Louis	10	7	6
Denver	12	9	7
Philadelphia	12	8	7
Washington	8	5	4

Source: U.S. Dept. of Health, Education and Welfare, Air Quality Criteria for Carbon Monoxide (Washington: G.P.O., 1970), Table 6-1, p. 6-6.

Oxides of Nitrogen Formation and Consequences

The quantity of oxides of nitrogen emitted from any automobile depends on the combustion thermodynamics which take place during the power production stroke of the engine cycle. It has been noted that the process of propagation of the flame front across the chamber surface is marked by a phenomena of successive burning.[5] As described earlier, this phenomena means that a temperature gradient exists across the flame front and combustion chamber. It is within the high temperature luminous zone that atmospheric oxygen and nitrogen combine to produce nitric oxide.

$$N_2 + O_2 \longrightarrow 2NO \qquad (2)$$

Were sufficient time and oxygen concentrations available, one could expect nitric oxide decomposition into N_2 and O_2 as temperatures cooled and no harmful emission would result. However, because of the rapid cooling of the byproducts of combustion in the exhaust stroke, time is inadequate for decomposition to fully take place and NO will persist in the exhaust byproducts. Figure 2.5 shows the effect of combustion temperature, which is a function of the intake manifold pressure, combustion chamber surface to volume ratio, compression ratio, and air-fuel injection rate, and the air-fuel ratio on the production of nitric oxide. The figure generally shows that NO production is directly related to internal combustion temperature and parabolically related to the air-fuel ratio.

---

[5]See Figure 2.2 and the explanation on pages 13 and 15.

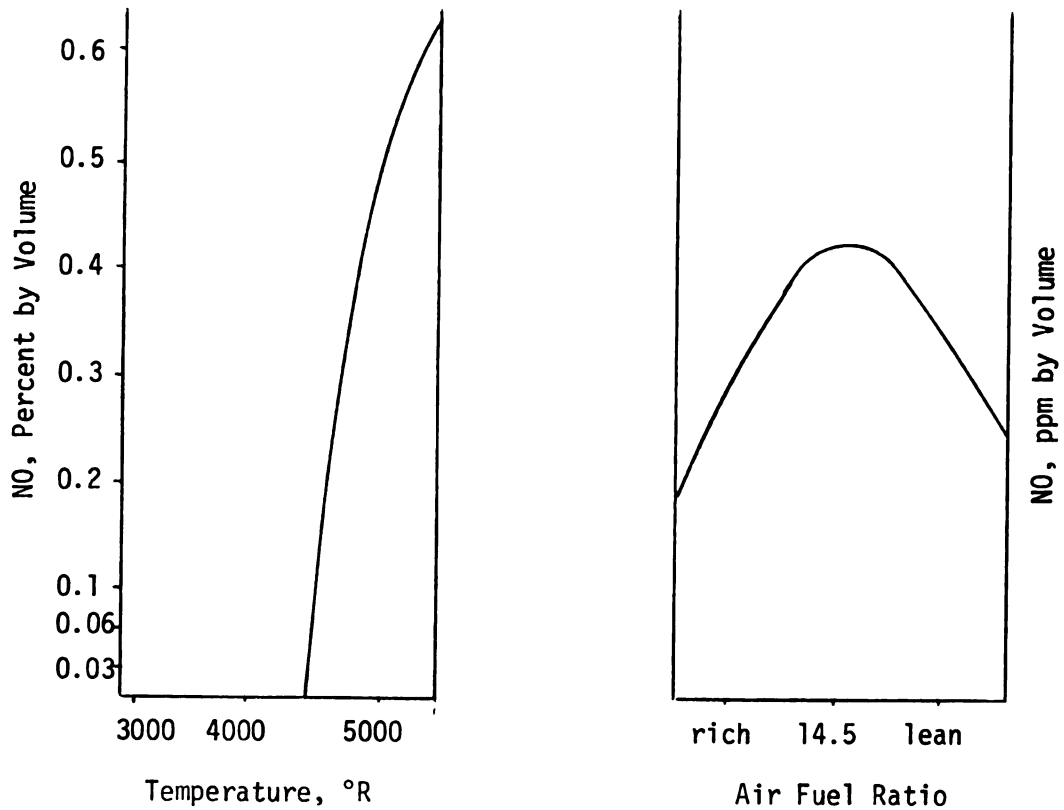

Figure 2.5.--Effect of Temperature and Air-Fuel Ratio on Nitric Oxide Formation.*

*Derived from D. J. Patterson and N. A. Henein, Emissions from Combustion Engines and Their Control (Ann Arbor: Ann Arbor Science Publishers, 1972), pp. 101 and 103.

Nitric oxide, although found to damage certain textile dyes, natural and synthetic textile fabrics, metals, and to reduce plant growth (U.S. Environmental Protection Agency, 1971: 7-7), is not an irritant and is not considered to have adverse effects on human health at concentrations normally found in the atmosphere. Its real environmental hazard is found in its role as precursor to photochemical oxidant creation through its tendency to undergo oxidation into nitrogen dioxide and its subsequent participation in the photolytic cycle. This cycle involves the following processes: during daylight hours atmospheric NO is quantitatively converted to NO_2 by reactions which involve the absorption of sunlight energy; continued absorption of energy disrupts NO_2 formation and breaks some of it down into NO and O. The molecular oxygen combines with atomic oxygen ($O + O_2$) and produces the highly toxic and most environmentally harmful oxidant, ozone (O_3). This process continues, facilitated by HC reactions, until the nitric oxide in the atmosphere is completely oxidized, leaving NO_2, ozone and residuals.

Nitrogen dioxide is five times as toxic as nitrogen oxide (Larsen, 1966: 287). Being insoluble it is not stopped in the moist nasal passages and hence can be inhaled deep into the respiratory system. Some of it unites with water to form nitrous or nitric acids which irritate the tissues of the lungs and windpipe, cause chest pains, and in sufficient quantities can cause pulmonary edema (fluid in the lungs), shock and death. In an epidemiological study of community exposure to nitrogen dioxide in the Chattanooga school system (Shy et al., 1970: 539-545), it was found that ventilatory performance of children in the high NO_2 area was significantly reduced when compared to children in the two control "clean" areas. In addition, an 18.8% relative excess of respiratory illness occurred among families in the high NO_2 area. The conclusion drawn from this study by the Environmental Protection Agency and upon which air quality criteria for NO_x are based was that any site where a concentration of 0.06 ppm of nitrogen dioxide is measured over 24 hours exceeds the Chattanooga health-effect related value, and a dangerous health hazard exists. The scope of this hazard is large. Ten percent of all U.S. cities with populations less than 50,000 have a yearly average greater than 0.06 ppm NO_2; 54 percent of the U.S. cities with populations ranging from 50,000 to 500,000 have a yearly average in excess of 0.06 ppm; and 84 percent of all U.S. cities in the population range greater than 500,000 have yearly averages exceeding 0.06 ppm (Environmental Protection Agency, 1971: 10-9).

In summary, this chapter has discussed the functioning of the internal combustion engine, the process of formation of the emissions which are of importance to this study and for which emission standards have been promulgated, and has highlighted the more dangerous effects of HC, CO, and NO_x pollution on the ecosystem, with special attention to their impact on human health. It was shown that the quantity of emissions exiting from an automobile's tailpipe is governed by complex interactions among chemical combustion dynamics, engine design variables and engine operating variables. Hydrocarbon formation was shown to be primarily dependent upon the thickness of the quench layer, carbon monoxide was shown to be a function of the air-fuel ratio, and oxide of nitrogen formation was a result of processes going on in the high temperature phase of fuel combustion. The next chapter quantifies the distribution of the above emissions by model year of car as well as the distribution of the ownership of these cars by income class.

CHAPTER III

AUTOMOBILE OWNERSHIP AND IN-USE EMISSIONS

Two sources of data are utilized by this study to provide information required for an evaluation of the distribution of automobiles of a particular model year by level and type of pollution generation and an identification of the ownership of these polluting units by various income categories. When merged, the data sources produce a system of four-dimensional "tax base" tables (income by pollutant by quantity of pollutant by model year). Each matrix identifies the number of polluting units of a particular model year owned by a specific income category and the level and type of pollutant attributable to these units. For example, Table 3.1 presents one of eleven matrices which form the hydrocarbon system. The other ten matrices and the system of matrices for carbon monoxide and oxides of nitrogen emissions appear in the next chapter, as does a detailed description of the assumptions required for and the derivation of these systems. Cell (1,1) is to be interpreted in the following manner: of the total number of 1971 model year automobiles owned by the less than $1,000 income category, 20,943 had in-use emissions of approximately 1.7 grams per

---

[1]By in-use is meant an automobile operating under normal operating and maintenance conditions.

TABLE 3.1.--The Distribution of Cars Owned by Income Category < $1,000 by Model Year by Hydrocarbon Emissions.

Year	Number of Cars with Stated Cell Emissions (g/mi.)									
	0.01-3.4	3.4 -4.0	4.01-5.0	5.01-6.0	6.01-7.0	7.01-8.0	8.01-10.0	10.01-12.0	12.01-20.0	20.0 +
1971	20,943	3,963	3,678	1,131	282	0	0	0	0	0
1970	17,539	9,232	9,694	4,154	462	0	0	0	924	0
1969	12,600	14,591	15,914	8,618	4,643	1,991	2,652	662	0	1,329
1968	2,434	957	1,826	1,218	348	174	522	261	174	89
1967	6,152	7,176	16,408	13,336	5,128	9,232	10,256	3,080	9,232	0
pre-1967	20,700	28,750	72,400	75,850	68,950	57,450	63,200	47,150	40,250	23,500

Source: Environmental Protection Agency, Office of Air and Water Programs, A Study of Emissions from Light Duty Vehicles in Six Cities, Publication No. APTD-1497 (Ann Arbor: EPA, 1973).

mile[2] hydrocarbon. The data sources which permit the above identification are discussed in detail below.

Emissions of In-Use Private Automobiles

The source of the emissions data on in-use automobiles was a comprehensive study of emissions from vehicles performed under the sponsorship of the Office of Air Programs, United States Environmental Protection Agency (Environmental Protection Agency, 1973). The broad objective of the study was to accumulate precise emission data which would provide a true measure of the polluting characteristics of vehicles on the nation's roadways (circa 1971), and thereby provide an accurate measure of the automobile's contribution to the nation's total annual pollution. To achieve this objective, privately owned cars spanning model years 1957-71[3] were procured for the study using an n^{th} driver sampling technique for each of six test regions[4] (Environmental Protection Agency, 1973: 2-4, 2-5). A subsample of 1,020 vehicles was then selected in a manner which would create a test fleet which best fit the nation's vehicle population profile of model year, make and number of engine cylinders. Thus, although the initial selection process was purely random, the

---

[2]When actual annual output of the pollutants comes under consideration, mileage driven annually will be specified and become a part of the matrices.

[3]In 1971, model years 1957-71 accounted for 95 percent of the total vehicle population.

[4]The regions were selected to represent the disparate demographic, topographic, and meteorological characteristics of the U.S. as well as to capture diverse driving, operating and maintenance practices.

vehicles ultimately selected for testing were fitted to a desired profile. This test fleet was then subjected to precise and repeatable emissions tests using procedures described as the 1972 CVS-C and the 1975 CVS-CH federal test procedures (Federal Register, 1971), and the data utilized by this study was generated (Environmental Protection Agency, 1973: 4-5 to 4-54).

Tables 3.2, 3.3, 3.4 and the accompanying Figures 3.1, 3.2 and 3.3 present the 1975 Federal Test Procedure (hereafter referred to as FTP) distribution of hydrocarbon, carbon monoxide, and oxides of nitrogen emissions, respectively, for private automobiles by model year. Certain information should be noted regarding the tables. Although mass emission distributions based on both the 1972 FTP and 1975 FTP were available for use in the present study, the 1975 FTP results were selected because the test procedure adds a "hot start" sequence to the 1972 FTP "cold start"[5] test sequence. This additional sequence permits a truer measure of automobile emission characteristics since it permits the consideration that not all trips made by a vehicle originate from a cold start. Further, information available regarding make, number of cylinders and identifying pre-1967 automobiles by model year was not utilized for two reasons: (1) A breakdown of 15 model years, 14 makes and 3 cylinder classes would have created a large number of matrix cells for which either little or not data were available and resulting

---

[5]A cold start is defined in the Federal Register as a start preceded by a 12-hour, no-use period.

TABLE 3.2.--The Distribution by Hydrocarbon Emissions by Model Year of Automobile.

Year	Percent of Cars with Stated Cell Emissions (g/mi.)*									
	0.01-3.4	3.4-4.0	4.01-5.0	5.01-6.0	6.01-7.0	7.01-8.0	8.01-10.0	10.0-12.0	12.01-20.0	20.0 +
1971	69.81	13.21	12.26	3.77	0.94	0.0	0.0	0.0	0.0	0.0
1970	41.76	21.98	23.08	9.89	1.10	0.0	0.0	0.0	2.2	0.0
1969	20.00	23.16	25.26	13.68	7.37	3.16	4.21	1.05	0.0	2.11
1968	30.43	11.96	22.83	15.22	4.35	2.17	6.52	3.26	2.17	1.09
1967	7.69	8.97	20.51	16.67	6.41	11.54	12.82	3.85	11.54	0.0
pre-1967	4.14	5.75	14.48	15.17	13.79	11.49	12.64	9.43	8.05	4.60

Source: Calculated from Environmental Protection Agency, Office of Air and Water Programs, A Study of Emissions from Light Duty Vehicles in Six Cities, Publication No. APTD-1497 (Ann Arbor: EPA, 1973).

*Rows may not add to 100% due to rounding.

TABLE 3.3.--The Distribution of Carbon Monoxide Emissions by Model Year of Automobile.

Year	Percent of Cars with Stated Cell Emissions (g/mi.)*											
	0.01-39	39.01-50	50.01-60	60.01-70	70.01-80	80.01-90	90.01-100	100.01-110	110.01-120	120.01-140	140.01-200	200 +
1971	59.43	11.32	7.55	6.60	4.72	1.89	0.00	0.00	0.00	0.00	0.94	0.00
1970	45.05	15.40	13.19	6.59	6.59	4.40	5.49	3.30	0.00	0.00	0.00	0.00
1969	21.05	21.05	18.95	9.47	8.42	5.26	4.21	4.21	1.05	2.10	4.21	0.00
1968	32.61	20.65	15.22	3.26	1.09	2.17	4.35	2.17	3.26	3.26	7.67	4.35
1967	6.41	10.26	8.97	11.54	11.54	14.10	3.85	7.67	8.97	5.13	8.97	1.28
pre-1967	8.97	11.95	7.82	11.72	9.66	11.26	8.97	7.36	4.60	8.74	8.05	0.92

Source: Calculated from Environmental Protection Agency, Office of Air and Water Programs, A Study of Emissions from Light Duty Vehicles in Six Cities, Publication No. APTD-1497 (Ann Arbor: EPA, 1973).

*Rows may not add to 100% due to rounding.

TABLE 3.4.--The Distribution of Oxides of Nitrogen Emissions by Model Year of Automobile.

Year	Percent of Cars with State Cell Emissions (g/mi.)*							
	0.01-3.0	3.01-4.0	4.01-5.0	5.01-6.0	6.01-7.0	7.01-8.0	8.01-11.0	11 +
1971	16.04	25.47	18.89	12.26	16.98	5.66	5.66	0.00
1970	9.89	24.18	19.78	15.38	14.29	8.79	4.40	3.30
1969	9.47	15.79	13.68	12.63	16.84	9.47	12.63	9.47
1968	14.13	17.39	15.22	14.13	13.04	4.35	3.26	18.48
1967	23.08	19.23	15.38	6.41	6.41	0.0	0.0	29.49
pre-1967	24.60	20.00	11.26	7.13	5.29	3.2	2.99	25.52

Source: Calculated from Environmental Protection Agency, Office of Air and Water Programs, A Study of Emissions from Light Duty Vehicles in Six Cities, Publication No. APTD-1497 (Ann Arbor: EPA, 1973).

*Rows may not add to 100% due to rounding.

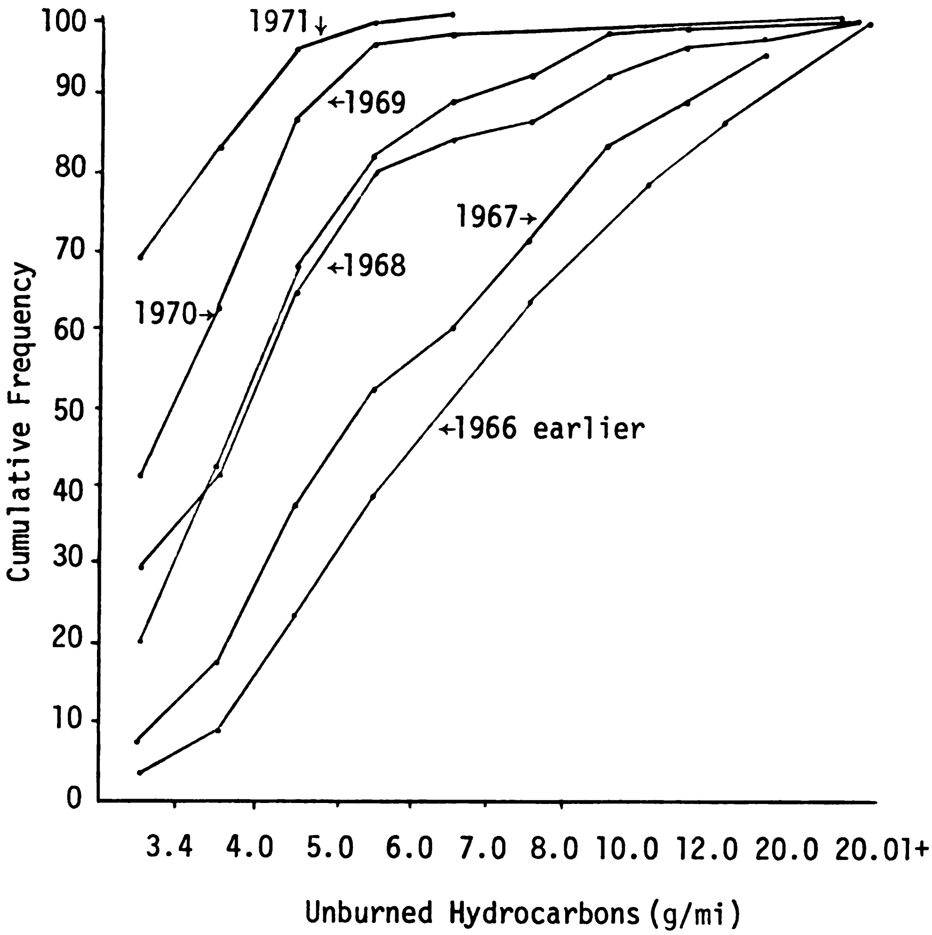

Figure 3.1.--Cumulative Frequency Distributions by Emission of Unburned Carbons by Model Year of Car Manufacture.

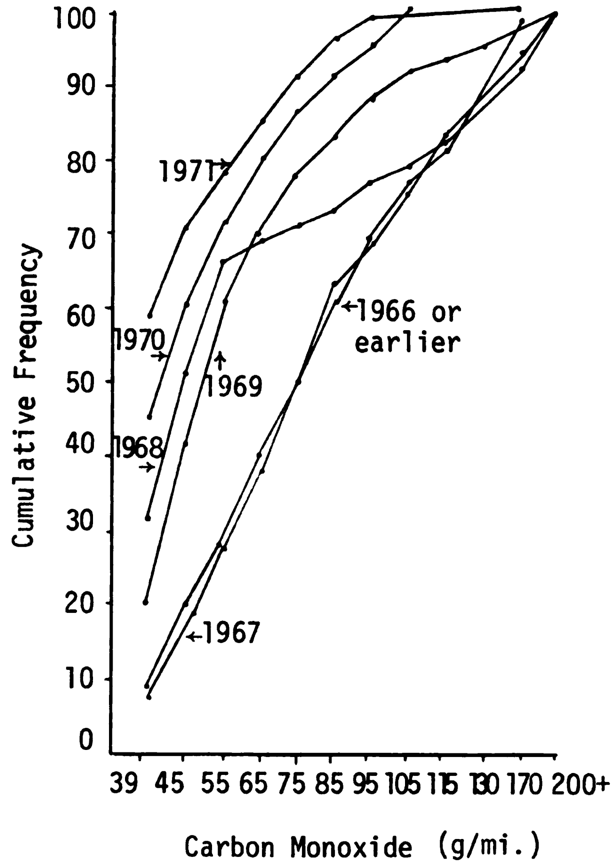

Figure 3.2.--Cumulative Frequency Distributions by Emission of Carbon Monoxide by Model Year of Car Manufacture.

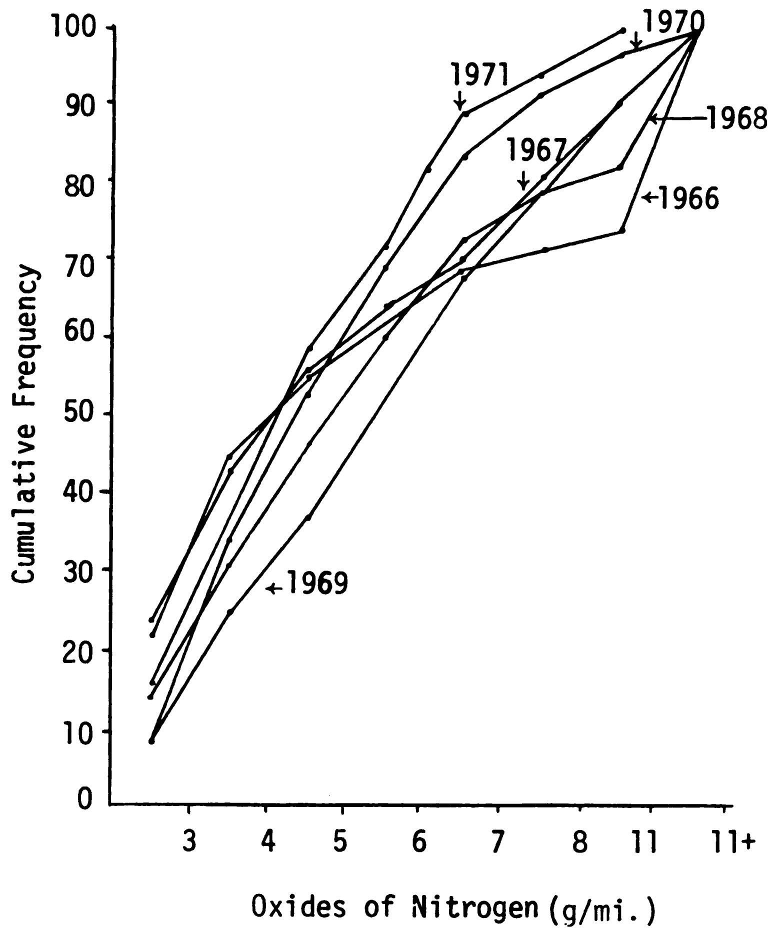

Figure 3.3.--Cumulative Frequency Distributions by Oxides of Nitrogen Emissions by Model Year of Car Manufacture.

emission distributions based on unacceptably small sample sizes. (2) Since the emission distribution data is to be merged with other data sources, it must be tabulated in a manner compatible and constrained by limitations of other data sources. Limitations imposed by other data sources effectively constrained the breakdown of the emissions data to the six model year categories presented in the tables. Although this causes a large number of automobiles of model years 1957-1966 to be grouped as pre-1967, it doesn't impose severe limitations on the present study. This is so because chi-square tests performed on the data revealed no significant differences among the pre-1967 distributions at the 90% level (Environmental Protection Agency, 1973).

Well defined trends in emission distribution by model year are apparent from Tables 3.2 and 3.3 and Figures 3.1 and 3.2 for hydrocarbon and carbon monoxide emissions, respectively. The frequency of automobiles with high emissions of HC and CO declines steadily as model year increases from pre-1967 to 1971. This results in the observed shifting of the cumulative frequency distributions for these pollutants toward the upper left-hand corner of the respective charts over time. This signifies that a greater proportion of test vehicles exhibit low levels of emission generation. These trends over time clearly reflect the impact of increasingly stringent HC and CO emission controls, notably, the establishment of emission standards for all new cars in the United States beginning in 1968. Further evidence supporting the above trends is provided in Table 3.5. The table shows the mean and

TABLE 3.5.--$\overline{X}$, s and % Below 1972-74 Standards by Model Year and Pollutant.

Year	Hydrocarbons (g/mi.)			Carbon Monoxide (g/mi.)		
	$\overline{X}$	s	% Below	$\overline{X}$	s	% Below
1971	3.06	1.26	69.8	40.13	24.48	59.0
1970	3.90	1.95	41.8	48.16	24.67	45.0
1969	5.19	4.27	20.0	61.66	31.03	21.0
1968	5.56	7.12	30.4	68.10	57.72	32.6
1967	6.89	3.14	7.7	87.25	44.34	6.4
pre-1967	8.72	7.73	4.1	82.83	39.00	8.9

standard deviation for each model year category as well as the percent of model year "y" vehicles exhibiting less than some arbitrarily chosen HC and CO emission level.[6] The means for both distributions decline steadily as model year increases, with significant declines occurring when federal standards were first imposed nationwide in 1968 and further strengthened in 1970. The disperion of the distributions also declines as model year increases, again reflecting the impact of emission standards on newer cars. Finally, the percentage of the total number of automobiles of a particular year which had measured emissions below the arbitrary level shows nearly uninterrupted increases from the pre-1967 model year through the 1971 model year.

[6]The levels chosen are the 1972-74 federal emission standards 3.4 g/mi hydrocarbons, 39 g/mi carbon monoside and 3.0 g/mi oxides of nitrogen.

The trend in emission levels by model year is not as clear for oxides of nitrogen emissions. Table 3.4 shows that although the percentage of automobiles with very high NO emissions (11+ g/mi.) declines as model year increases, the percentage of automobiles with minimal and low NO emissions has generally declined more rapidly. The net result is that oxides of nitrogen emissions, in total, have generally increased with increasing model year. This result is substantiated in Table 3.6, which shows that the means and dispersion of the distribution have generally increased with increasing model year, with the percentage below the arbitrary level declining most notably in 1968, when HC and CO standards were first imposed. This decline is consistent with decreasing CO levels in post-1967 automobiles.[7]

TABLE 3.6.--$\overline{X}$, s and % Below 1972-74 Standards by Model Year and Pollutant.

Year	Oxides of Nitrogen (g/mi.)		
	$\overline{X}$	s	% Below
1971	4.81	1.78	16.04
1970	5.06	1.67	9.89
1969	5.46	2.02	9.47
1968	4.34	1.93	14.13
1967	3.32	1.47	23.08
pre-1967	3.65	2.00	24.60

[7]Refer back to Figures 2.4 and 2.5 which show that to reduce CO emissions to meet federal standards, the vehicle must operate at a leaner air-fuel ratio. However, as the air-fuel ratio is adjusted towards 14.5, oxide of nitrogen emissions increase.

In sum, the trend in the emission distributions over time is for improved CO and HC distributions, particularly as a result of the imposition of federal standards, and for deterioration in the NO emission distributions, which were uncontrolled through 1971. The magnitude and direction of these trends are of particular significance for this study, since any reduction in the number of automobiles with high emission generating capabilities will tend to reduce the overall contribution made by the private automobile to the nation's annual pollution.

Automobile Ownership Patterns

The source of the data on household ownership of private automobiles by money income was a special cross-tabulation provided by the Bureau of the Census based on data obtained in the Quarterly Housing Survey of July, 1971 (Department of Commerce, Bureau of the Census, 1974). The Quarterly Housing Survey data are obtained by interviews conducted in approximately 12,500 households located in 484 counties or independent cities in the United States. As with all data collected in this manner, the results of the survey are subject to errors of response and of reporting as well as subject to sampling variability (U.S. Department of Commerce, Bureau of the Census, 1971: 3-5). In addition to these sources of error, a number of other limitations have been imposed on the special cross-tabulations. The limitations which are deemed most significant include the following:

1. Tables showing the total number of cars owned by households or total owned per 100 households are biased for two reasons.

The consumer buying indicator's questionnaire on Motor Vehicle Ownership (U.S. Department of Commerce, Bureau of the Census, 1971: Appendix) limited the number of cars per household for which ownership data was obtained to three, and no attempt was made to adjust the data for the fact that some households own more than three cars. Since multicar ownership patterns are a function of increasing money income, it is likely that this introduces an underestimate of the number of cars owned by the upper income categories. This introduces a downward bias in all calculations pertaining to the upper income categories to the extent that upper income categories own four or more cars. The count of cars was further biased downward for all income categories because ownership data were not collected for those persons residing in households who were not related to the head of the household. It is assumed, however, that the unrelated individual's car ownership patterns are identical to household ownership patterns throughout all income categories so that the bias is confined to the total number of cars and does not bias the distribution of those cars by model year.

2. The definition of income used in the survey was money income,[8] which includes money wages and salaries, net income from business or farm, dividends, interest, rent and any other money income received by members of the household before deductions. This is a relatively narrow definition of income which ignores many imputations that are often made when a broader income measure is

---

[8]The bias inherent in using income data from one year is discussed in detail in Chapter V.

used. As such, income categories are biased to the extent that such imputations account for a large portion of annual money receipts. It is expected that this bias is most important at the uppermost income categories.[9]

3. A final limitation of the ownership data is that the survey collected data for model year categories 1971, 1970, 1969, 1968, 1967 and prior to 1967 only. Therefore, no means is provided for identifying the distribution of a large portion of the automobile stock which is of pre-1967 vintage. However, this data limitation in no way limits the study because the statistical tests performed on the emissions data,[10] and referred to previously, showed that pre-1967 model years could be grouped with little loss of required information.

Table 3.7 presents information on car ownership patterns derived by manipulation of data provided in the special cross-tabulation. The data reveal a number of important aspects of private automobile ownership. The proportion of households in any income category who have access to private transportation is shown to bear a direct relationship to money income. Further, for all but the lowest two income categories, a majority of the households in any income group own at least one car. Therefore, although the expected result that car ownership depends heavily on the level of

---

[9]This is because imputations to income are primarily imputed rent for owner-occupied dwellings and employees' contributions to private funds, both of which are proportionally greater at higher incomes.

[10]Chi-square tests at the 90 percent level of significance.

TABLE 3.7.--Car Ownership by Money Income (July 1971).

Income ($)	% Households Owning at Least One Car	No. of Cars Owned Per Household (All Households)
Less than 1,000	30.15	.376
1,000- 1,999	39.06	.423
2,000- 2,999	52.34	.579
3,000- 3,999	63.69	.728
4,000- 4,999	76.05	.909
5,000- 5,999	81.29	1.019
6,000- 7,499	87.39	1.145
7,500- 9,999	91.13	1.284
10,000-14,999	94.62	1.479
15,000-24,999	96.60	1.710
25,000 and over	94.67	1.803

money income is borne out by the data, the data also reveals the generally unexpected result that even income categories as low as $2,000-$2,999 experience a majority of the households owning at least one car.[11] The table also reveals that the number of cars owned per household is a continuously increasing function of money income, with multicar ownership patterns developing with the $5,000-$5,999 income category and becoming more pronounced as money

[11]This may be partially explained by the fact that the transitory Engle curve is flatter than the permanent one. One year's money income data captures "transient" ownership patterns.

income rises. These patterns encompass 65 percent of all households in the income distribution and 75 percent of all car-owning households in the distribution. Thus, multicar ownership is a major characteristic of household car ownership, particularly with respect to the middle and upper income categories.

Table 3.8 presents data on the distribution of automobiles by age across income categories. The distribution of age of car (in 1971) by income class confirms the customary belief that the lower income categories own old cars while the upper income classes own new cars. For example, the $25,000 + income category owns 19 times as many new cars as does the lowest income category, although both categories account for approximately the same percentage of all households in the distribution. The data also reveal that the percentage of each age group owned by the lower income categories generally increases with age, while the percentage of each age group owned by the upper income categories decreases with age. However, although income categories inclusive of $6,000-$7,499 account for more than 50 percent of all households, they account for only 43 percent of all cars of vintage 5 years and older. The upper income categories are thus shown to own a much larger proportion of old cars than is conventional wisdom.

The distribution of household ownership of automobiles by income by model year presented in Table 3.9 exhibits the fact that the composition of the income category's stock of cars is highly dependent upon the level of money income. For lower income categories, the distribution of automobiles in both absolute numbers and

TABLE 3.8.--The Distribution of Cars by Age Across Income Categories (July 1971).

Age	Percent of Cars of a Given Age Owned by the Income Class										
	< $1,000	$1,000-1,999	$2,000-2,999	$3,000-3,999	$4,000-4,999	$5,000-5,999	$6,000-7,499	$7,500 9,999	$10,000-14,999	$15,000-24,999	$25,000 +
0	0.5	0.7	0.9	2.7	3.1	4.9	8.9	13.8	29.0	22.4	9.9
1	0.5	0.7	2.2	2.0	3.6	5.6	8.8	15.8	30.4	19.2	8.5
2	0.7	0.9	1.2	2.8	4.2	4.8	9.2	15.7	28.7	21.3	7.5
3	0.1	1.1	3.1	3.3	4.3	6.5	9.9	17.2	27.5	19.6	4.8
4	1.1	1.6	2.4	4.8	5.6	6.5	10.8	14.9	27.8	16.8	4.8
5 or more	1.4	3.9	5.4	6.9	6.9	7.6	11.1	16.9	22.5	11.8	2.4
% of households in income class	2.9	6.6	7.0	7.9	6.9	7.4	10.3	14.2	19.7	10.5	3.0

TABLE 3.9.--Household Ownership of Automobiles by Income and Model Year of Manufacture.

JULY 1971 CBE
(NUMBERS IN THOUSANDS)

CHARACTERISTIC	TOTAL HOUSEHOLDS		HOUSEHOLDS NOT OWNING A CAR		CARS OWNED BY HOUSEHOLDS: TOTAL		MODEL YEAR: 1971		1970		1969		1968		1967		1966 OR BEFORE		NA	
	NUMBER	HORI-ZONTL PCT	Households NUMBER	HORI-ZONTL PCT	Cars NUMBER	All Households NO. PER 100 HOUSE HOLDS	NUMBER	NO. PER 100 HOUSE HOLDS	NUMBER	NO. PER 100 HOUSE HOLDS	NUMBER	NO. PER 100 HOUSE HOLDS	NUMBER	NO. PER 100 HOUSE HOLDS	NUMBER	NO. PER 100 HOUSE HOLDS	NUMBER	NO. PER 100 HOUSE HOLDS	NUMBER	NO. PER 100 HOUSE HOLDS
ALL HOUSEHOLDS	64797	100.0	13197	20.4	73800	113.9	5002	7.7	7838	12.1	8556	13.2	8342	12.9	7205	11.1	36478	56.3	380	.6
INCOME																				
UNDER $1,000.......	1924	100.0	1344	69.9	724	37.6	30	1.6	42	2.2	63	3.3	8	.4	80	4.2	500	26.0	0	.0
$1,000 TO 1,999...	4252	100.0	2591	60.9	1799	42.3	38	.9	60	1.4	80	1.9	90	2.1	116	2.7	1411	33.2	4	.1
$2,000 TO $2,999...	4563	100.0	2174	47.6	2733	59.9	46	1.0	170	3.7	102	2.2	258	5.7	171	3.7	1985	43.5	0	.0
$3,000 TO $3,999....	5095	100.0	1850	36.3	3709	72.8	134	2.6	160	3.1	241	4.7	276	5.4	349	6.8	2523	49.5	26	.5
$4,000 TO $4,999...	4505	100.0	1079	24.0	4093	90.9	155	3.4	286	6.3	358	7.9	358	7.9	401	8.9	2536	56.3	0	.0
$5,000 TO $5,999...	4805	100.0	899	18.7	4895	101.9	247	5.1	442	9.2	413	8.6	545	11.3	466	9.7	2760	57.4	23	.5
$6,000 TO $7,499...	6646	100.0	838	12.6	7609	114.5	445	6.7	689	10.4	787	11.8	822	12.4	777	11.7	4042	60.8	46	.7
$7,500 TO $9,999...	9346	100.0	829	8.9	12000	128.4	692	7.4	1237	13.2	1347	14.4	1435	15.4	1072	11.5	6165	66.0	52	.6
$10,000 TO $14,999.	12769	100.0	687	5.4	18886	147.9	1449	11.3	2382	18.7	2457	19.2	2291	17.9	2002	15.7	8193	64.2	111	.9
$15,000 TO $24,999.	6792	100.0	231	3.4	11613	171.0	1120	16.5	1505	22.2	1824	26.9	1638	24.1	1209	17.8	4296	63.3	22	.3
$25,000 AND OVER...	1914	100.0	102	5.3	3451	180.3	497	26.0	666	34.8	639	33.4	399	20.8	343	17.9	882	46.1	25	1.3
N.A................	2186	100.0	573	26.2	2287	104.6	147	6.7	200	9.1	246	11.3	221	10.1	218	10.0	1184	54.2	70	3.2

Source: U.S. Department of Commerce, Bureau of the Census, Car Ownership by Model Year and Selected Household Characteristics: July 1971, Special Tabulation, 1974.

numbers per 100 households is skewed markedly toward ownership of the older model year cars. For example, of a total of 724,000 cars owned by the less than $1,000 class, 70 percent or 500,000 of these cars are of the oldest model year (pre-1967), while only 2.1% are new. Finally, taken as a group, the less than $3,000 category's stock of cars in 1971 was composed of 74 percent oldest model years and only 2.1% newest model years. This skewedness persists throughout the lower-middle income classes, becoming less pronounced as income rises.

Conclusions

This chapter has described the data sources for the study and discussed a few of their more important limitations. Data on the pollution characteristics of private in-use automobiles were presented by model year, as were data on the ownership of private automobiles by income by model year. The next chapter merges these data sources and elaborates on the procedure for determining the number of polluting units subject to the hypothetical taxes as proposed. As such, the next chapter describes the tax base.

CHAPTER IV

THE TAX BASE

The previous chapters of this study have documented the economic-environmental costs associated with the consumption of automotive services. It has been noted that these costs arise, specifically, because an individual's consumption of automotive services, through ownership and use of the private automobile, produces a quantity of automobile exhaust emissions which enter negatively into many individual's utility functions, reducing directly each individual's total satisfaction in direct proportion to his exposure to the supply of pollution. As such, the tax base for this study must include an identification of those consumers who are capable of contributing to the total supply of pollution (automobile owners) and their potential contribution to pollution (emission characteristics of the owned automobiles). Further, since the major thrust of this study is a determination of the distributional costs (incidence) of the various hypothetical taxes imposed on automobile pollution generating units and paid by their owners, this identification must be made by income class.

The general methodology employed in the determination of the tax base was as follows: (1) Identification of the distribution of automobile emissions, one distribution for each pollutant by model year.[1] The resulting table, one for each of the three emissions studied, contains the proportion of the total population of model "k" automobiles characterized by a given level of measured emissions. (2) Identification of the distribution of ownership by automobiles by model year by income.[2] The cells of this table contain the number of model year "k" automobiles owned by the income class. (3) Distribution of the number of model year "k" automobile owned by each income class across emission levels by model year in direct proportion to the distribution of the total population of that model year, for all three pollutants. The methodology may be summarized as follows:

Given:

(1) P^{e}_{kj} where e = 1...3; k = 1...5; and j = 1...max.

and

(2) N^{y}_{k} where y = 1...11; k = 1...5.

Multiply to obtain

(3) M^{ye}_{kj} where:

e = type of emissions

y = income class

k = model year of manufacture

j = emission level (varies with pollutant)

---

[1]See Tables 3.2, 3.3 and 3.4.

[2]See Table 3.9.

This procedure generates four dimensional tax base matrices: type of pollutant (unburned hydrocarbons, carbon monoxide, oxides of nitrogen), by income class, by quantity of pollution by model year of automobile manufacture. In general, this procedure requires an assumption that the relative distribution of emissions by model year is independent of the level of income of the owner.[3] Table 4.1 presents the unburned hydrocarbon tax base. The matrices, one for each income category, are of dimension 6 x 10. That is, all automobiles owned by a particular income class are distributed by six model years by ten levels of pollution generation. For example, cell HC_{34} of income class less than $1,000 shows that 8,618 model year 1969 autos owned by this class have a hydrocarbon generating capability of approximately 5.5 grams per mile. The set of matrices comprising this system has two important characteristics: (1) the number of autos in each matrix increases as income increases through $14,999 and then declines; (2) the number and proportion of all automobiles owned with a low unburned

---

[3]It is impossible to determine the magnitude of the bias that this assumption will produce in the later incidence calculations. However, a number of facts suggest that these biases may not be substantial, or may balance out: (1) The internal combustion engine's design, common to all autos in the study, contributes significantly to emission output. (2) Although higher (lower) income clases are better (worse) able to maintain their cars, they also own larger (smaller) engines. Emission reduction via maintenance may be offset by higher emissions from larger engines for high income classes (reverse argument for low incomes). (3) Emissions vary substantially with individual driving behavior--there is no evidence to suggest the driving habits of the poor (rapid acceleration) differ from those of the wealthy in any systematic manner.

TABLE 4.1.--Tax Base for Unburned Hydrocarbons (g/mi.).

INCOME LESS THAN $1000

YEAR	0.01-3.4	3.4-4	4.01-5	5.01-6	6.01-7	7.01-8	8.01-10	10.01-12	12.01-20	20 +
1971	20343	3963	3678	1131	232	0	0	0	0	0
1970	17539	9232	9594	4154	462	0	0	0	924	0
1969	12600	14591	15914	8618	4643	1991	2652	662	0	1329
1968	2434	957	1326	1218	348	174	522	261	174	87
1967	6152	7176	16408	13336	5128	9232	10256	3080	9232	0
PRE 1967	20700	28750	72400	75850	68950	57450	63200	47150	40250	23000

INCOME $1000 - $1999

YEAR	0.01-3.4	3.4-4	4.01-5	5.01-6	6.01-7	7.01-8	8.01-10	10.01-12	12.01-20	20 +
1971	26528	5020	4659	1433	357	0	0	0	0	0
1970	25056	13188	13848	5934	660	0	0	0	1320	0
1969	16000	18528	20208	10944	5896	2528	3368	840	0	1688
1968	27367	10764	20547	13698	3915	1953	5868	2934	1953	981
1967	8920	10405	23792	19337	7436	13384	14871	4465	13386	0
PRE 1967	58415	81133	204313	214049	194577	162124	178350	133057	113585	64906

INCOME $2000 - $2999

YEAR	0.01-3.4	3.4-4	4.01-5	5.01-6	6.01-7	7.01-8	8.01-10	10.01-12	12.01-20	20 +
1971	32113	6077	5640	1734	432	0	0	0	0	0
1970	70392	37366	39236	16813	1870	0	0	0	3740	0
1969	20400	23623	25765	13954	7517	3223	4294	1071	0	2152
1968	78509	30957	58901	39268	11223	5599	16822	8411	5599	2812
1967	13150	15339	35072	28506	10961	19733	21922	6584	19733	0
PRE 1967	82173	114138	287428	301125	273732	228076	250904	187186	159792	91310

TABLE 4.1.--Continued.

INCOME 33000 - $3999

YEAR	0.01-3.4	3.4-4	4.01-5	5.01-6	6.01-7	7.01-8	8.01-10	10.01-12	12.01-20	20 +
1971	53545	17701	16428	5052	1260	0	0	0	0	0
1970	66315	35186	36928	15824	1760	0	0	0	3520	0
1969	48200	55816	60877	32969	17762	7616	10145	2531	0	5085
1968	63387	33010	63011	42007	12006	5939	17395	8998	5989	3008
1967	26839	31305	71580	58178	22371	40275	44742	13437	40275	0
PRE 1967	104452	145072	365330	382739	347922	289893	318907	237919	203102	116058

INCOME $4000 - $4999

YEAR	0.01-3.4	3.4-4	4.01-5	5.01-6	6.01-7	7.01-8	8.01-10	10.01-12	12.01-20	20 +
1971	108205	20476	19003	5944	1457	0	0	0	0	0
1970	119434	62863	66009	28285	3146	0	0	0	6292	0
1969	71500	82913	90431	48974	25385	11313	15072	3759	0	7554
1968	108339	42817	81731	54488	15573	7769	23341	11671	7769	3902
1967	30937	35970	82245	66847	25704	46275	51408	15439	46275	0
PRE 1967	104390	145820	367212	384711	349714	291386	320550	239144	204148	116656

INCOME $5000 - $5999

YEAR	0.01-3.4	3.4-4	4.01-5	5.01-6	6.01-7	7.01-8	8.01-10	10.01-12	12.01-20	20 +
1971	172430	32629	30282	9312	2322	0	0	0	0	0
1970	184579	97152	102014	43714	4862	0	0	0	9724	0
1969	82500	95651	104323	56498	30438	13051	17387	4337	0	8714
1968	165944	65182	124424	82949	23708	11827	35534	17767	11827	5941
1967	25835	41800	95577	77692	29871	53776	59741	17941	53776	0
PRE 1967	114264	158700	399648	418692	380604	317124	348864	260268	222180	126960

TABLE 4.1.--Continued.

INCOME $6000 - $7499

YEAR	0.01-3.4	3.4-4	4.01-5	5.01-6	6.01-7	7.01-8	8.01-10	10.01-12	12.01-20	20 +
1971	310654	58785	54557	16777	4183	0	0	0	0	0
1970	287726	151442	159021	68142	7579	0	0	0	15158	0
1969	157400	182269	198796	14728	58001	24869	33133	8264	0	16606
1968	250135	98311	187653	125108	35757	17837	53594	26797	17837	8960
1967	59751	69697	159363	129526	49806	89666	99611	29915	89666	0
PRE 1967	167339	232415	585281	613171	557392	464426	510909	381161	325381	185932

INCOME $7500 - $9999

YEAR	0.01-3.4	3.4-4	4.01-5	5.01-6	6.01-7	7.01-8	8.01-10	10.01-12	12.01-20	20 +
1971	483085	91413	84839	26088	6505	0	0	0	0	0
1970	516571	271892	285500	122339	13607	0	0	0	27214	0
1969	269400	311955	340252	184263	99274	42565	56709	14144	0	28422
1968	436671	171628	327611	218407	62423	31139	93562	46781	31140	15642
1967	62437	96158	219867	178702	68715	123709	137430	41272	123709	0
PRE 1967	255231	354488	892692	935231	850154	708359	779256	581360	488233	283590

INCOME $10000 - $14999

YEAR	0.01-3.4	3.4-4	4.01-5	5.01-6	6.01-7	7.01-8	8.01-10	10.01-12	12.01-20	20 +
1971	1011547	141413	177647	54627	13621	0	0	0	0	0
1970	954723	523564	549756	235580	26202	0	0	0	52404	0
1969	491400	569041	620538	336118	181081	77641	103439	25799	0	51843
1968	697151	274004	523035	349690	99659	49715	14937	74687	49715	24972
1967	153354	179579	410610	333733	128328	231031	256656	77077	231031	0
PRE 1967	339190	471097	1186346	1242878	1129815	941376	1035595	772600	659537	376878

TABLE 4.1.--Continued.

INCOME $15000 - $24999

YEAR	0.01-3.4	3.4-4	4.01-5	5.01-6	6.01-7	7.01-8	8.01-10	10.01-12	12.01-20	20 +
1971	781372	147952	137312	42224	10528	0	0	0	0	0
1970	628488	330799	347354	148845	16555	0	0	0	33110	0
1969	364300	422438	450742	251986	134429	57638	76790	19152	0	38486
1968	498443	193904	373955	249304	71253	35545	106798	53399	35545	17854
1967	92972	108447	247966	201340	77497	139519	154994	46547	139519	0
PRE 1967	177854	247020	622051	651703	592418	493610	543014	405113	345828	197616

INCOME MOFE THAN $24999

YEAR	0.01-3.4	3.4-4	4.01-5	5.01-6	6.01-7	7.01-8	8.01-10	10.01-12	12.01-20	20 +
1971	346356	65654	60932	18737	4672	0	0	0	0	0
1970	278122	146386	153713	65967	7326	0	0	0	14652	0
1969	127900	187992	161411	87415	47094	20192	26902	6710	0	13483
1968	121416	477720	91092	60728	17357	8658	26015	13007	8658	4349
1967	26377	30767	70349	57178	21986	39582	43973	13206	39582	0
PRE 1967	36515	50715	127714	133799	121628	101342	111485	83173	71001	40572

hydrocarbon pollution generating characteristic[4] increases continuously as money income rises. Table 4.2 presents these two important characteristics more clearly, and points out that, generally, although a greater number of automobiles enter the tax base as income rises through $14,999, the proportion of this stock of cars with low hydrocarbon generating levels increases throughout all income categories. The proportion of the total stock of cars with low emissions rises from 9.0% for the income class $1,000-$1,999 to 27.16% for income class $2,4999 +, although the number of automobiles entering the base begins to decline after income class $14,999. These characteristics follow directly from the data presented in the previous chapter which showed that as income rises both the number of cars and the proportion of those cars which are new (low HC emissions) rise.[5] The implication of the above is that although the number of automobiles owned rises with money income, per unit emissions decline.

Table 4.3 presents the system of matrices which compose the carbon monoxide tax base. The matrices, one for each income category, are of dimension 6 x 12. That is, all automobiles owned by a particular income category are distributed by six model year categories and twelve levels of pollution generation, measured in grams per mile emitted. For example, cell CO_{12}, of income category $1,000-$1,999, states that 4,302 model year 1971 automobiles owned

---

[4]A low unburned hydrocarbon generating characteristic is defined as generation of 0.0-3.4 grams per mile hydrocarbon.

[5]See Table 3.2 and Table 3.9.

TABLE 4.2.--The Composition of the Automobile Stock by Income and Hydrocarbon Emission Category.

Income	Emission Category					
	Low		High		Total	
	No.	% of Stock	No.	% of Stock	No.	% of Stock
< $1,000	80,368	11.1	643,632	88.9	724,000	100
$1,000-$ 1,999	162,306	9.0	1,636,694	91.0	1,799,000	100
$2,000-$ 2,999	297,343	10.9	2,435,657	89.1	2,733,000	100
$3,000-$ 3,999	423,838	11.4	3,285,162	88.6	3,709,000	100
$4,000-$ 4,999	544,006	13.3	3,548,994	86.7	4,093,000	100
$5,000-$ 5,999	755,552	15.4	4,139,448	84.6	4,895,000	100
$6,000-$ 7,499	1,233,005	16.2	6,375,995	83.8	7,609,000	100
$7,500-$ 9,999	2,043,395	17.0	9,956,605	83.0	12,000,000	100
$10,000-$14,999	3,687,965	19.5	15,198,035	80.5	18,886,000	100
$15,000-$24,999	2,544,429	21.9	9,068,571	78.1	11,613,000	100
$25,000 +	937,186	27.2	2,513,814	72.8	3,451,000	100

TABLE 4.3.--Tax Base for Carbon Monoxide (g/mi.)

INCOME LESS THAN $1000

YEAR	0.01-39	39.01-50	50.01-60	60.01-70	70.01-80	80.01-90	90.01-100	100.-110	110.-120	120.-140	140.-200	200 +
1971	17929	3336	2265	2265	1980	1416	567	0	0	0	282	0
1970	18921	6468	5540	2768	2768	1848	2297	1395	0	0	0	0
1969	13262	13262	11939	5966	5305	3314	2652	2652	662	1323	2652	0
1968	2607	1552	1218	261	87	174	348	174	261	261	614	348
1967	5129	9208	7176	9232	9232	11280	3080	6152	7176	4104	7176	1024
PRE 1967	44850	59750	39100	58500	48300	56300	44850	36950	23000	43700	40250	4600

INCOME $1000 - $1999

YEAR	0.01-39	39.01-50	50.01-60	60.01-70	70.01-80	80.01-90	90.01-100	100.-110	110.-120	120.-140	140.-200	200 +
1971	22582	4302	2869	2869	2508	1794	718	0	0	0	357	0
1970	27030	9024	7914	3954	3954	2640	3282	1980	0	0	0	0
1969	16940	16340	15150	7576	6736	4208	3366	3366	840	1680	3368	0
1968	29349	18585	13678	2934	981	1953	3915	1953	2934	2934	6903	3915
1967	7436	11902	10405	13386	13386	16356	4466	8920	10405	5951	10405	1485
PRE 1967	126567	189615	110340	155369	136303	158879	126567	103850	64906	123321	113586	12981

INCOME $2000 - $2999

YEAR	0.01-39	39.01-50	50.01-60	60.01-70	70.01-80	80.01-90	90.01-100	100.-110	110.-120	120.-140	140.-200	200 +
1971	27338	5207	3473	3473	3036	2171	869	0	0	0	432	0
1970	76585	26180	22423	11203	11203	7480	9333	5610	0	0	0	0
1969	21471	21471	19329	9659	8588	5365	4295	4234	1071	2142	4294	0
1968	84134	53277	39268	8411	2812	5599	11223	5599	8411	8411	19789	11223
1967	10361	17545	15739	19733	19733	24111	6584	13150	15339	8772	15339	2189
PRE 1967	178355	237208	155227	232841	191715	223511	178055	146096	91310	173489	159793	14262

TABLE 4.3.--Continued.

					INCOME $15000 - $24999							
YEAR	0.01-39	39.01-50	50.01-60	60.01-70	70.01-80	80.01-90	90.01-100	100.-110	110.-120	120.-140	140.-200	200 +
1971	655615	126784	84560	84560	73920	52864	21168	0	0	0	10528	0
1970	678903	231770	199510	99180	99180	66220	82624	49665	0	0	0	0
1969	383352	383952	345648	172733	153581	95942	76790	76790	19152	38304	76790	0
1968	574152	338247	249304	53399	17654	35545	71253	35545	53399	53399	125635	71253
1967	77497	124043	108447	139519	139519	170459	40547	52972	108447	62022	108447	15475
PRE 1967	385351	513372	335947	503491	414394	483730	385351	316186	197616	375470	345828	33523
					INCOME MORE THAN $24999							
YEAR	0.01-39	39.01-50	50.01-60	60.01-70	70.01-80	80.01-90	90.01-100	100.-110	110.-120	120.-140	140.-200	200 +
1971	295367	56260	37524	37524	32802	23458	9393	0	0	0	4672	0
1970	310033	102564	87845	43989	43989	29304	36563	21978	0	0	0	0
1969	134510	134510	121091	60513	53804	33611	26902	26902	6709	13419	26902	0
1968	130114	82334	60728	13007	4349	8658	17357	8658	13007	13007	30603	17357
1967	21996	34192	30767	39582	39582	48363	13206	26377	30767	17596	30767	4390
PRE 1967	79115	105399	63972	103370	85201	99313	79115	64915	40572	77087	71001	8114

TABLE 4.3.--Continued.

INCOME $3000 - $3999

YEAR	0.01-39	39.01-50	50.01-60	60.01-70	70.01-80	80.01-90	90.01-100	100.-110	110.-120	120.-140	140.-200	200 +
1971	79635	15169	10117	10117	8844	6325	2533	0	0	0	1260	0
1970	72090	24640	21174	10544	10544	7040	8784	5280	0	0	0	0
1969	50731	50731	45670	22823	20292	12677	10146	10146	2531	5061	10146	0
1968	90004	56934	42007	9999	3008	5959	12005	5989	8998	8998	21169	12006
1967	22371	35807	31335	40275	40275	49209	13437	26839	31305	17904	31305	4467
PRE 1967	225313	301499	197239	295635	243722	284090	226313	165693	116058	220510	203102	23212

INCOME $4000 - $4999

YEAR	0.01-39	39.01-50	50.01-60	60.01-70	70.01-80	80.01-90	90.01-100	100.-110	110.-120	120.-140	140.-200	200 +
1971	92117	17546	11703	11703	10230	7316	2928	0	0	.0	1457	0
1970	128847	44044	37723	18847	18847	12584	15701	9438	0	0	0	0
1969	75359	75359	67841	33903	30144	18831	15072	15072	3759	7518	15072	0
1968	116743	73927	54438	11671	3902	7769	15573	7764	11671	11671	27459	15573
1967	25704	41143	35970	46275	46275	56541	15439	30837	35970	20570	35969	5133
PRE 1967	227479	303052	199315	297219	244978	285554	227479	166650	116656	221646	204148	23331

INCOME $5000 - $5999

YEAR	0.01-39	39.01-50	50.01-60	60.01-70	70.01-80	80.01-90	90.01-100	100.-110	110.-120	120.-140	140.-200	200 +
1971	146792	27960	18649	19649	16302	11658	4668	0	0	0	2322	0
1970	19312	63068	58300	29128	29126	19448	24266	14586	0	0	0	0
1969	86937	86337	78346	39111	34775	21724	17387	17387	4337	8673	17387	0
1968	17772	112542	82349	17767	5941	11627	23708	11927	17767	17767	41802	23708
1967	29971	47412	41800	53776	53776	65706	17941	35835	41800	23906	41800	5964
PPE 1967	247572	329820	215832	123472	266616	310776	247572	203136	126960	241224	222180	25392

TABLE 4.3.--Continued.

						INCOME $6000 - $7499						
YEAR	0.01-39	39.01-50	50.01-60	60.01-70	70.01-80	80.01-90	90.01-100	100.-110	110.-120	120.-140	140.-200	200 +
1971	264463	50374	33598	33598	29370	21004	8411	0	0	0	4183	0
1970	310334	106106	90879	45405	45405	30316	37826	22737	0	0	0	0
1959	165563	165663	149137	74529	66265	41396	33133	33133	8264	16527	33133	0
1958	268054	169743	125108	26797	8960	17837	35757	17837	26797	26797	63047	65757
1967	49806	79702	69597	89666	89666	109557	29915	59751	69697	39860	69697	9946
PRE 1967	362567	463019	316084	473722	390457	455129	362567	297491	185932	353271	325381	37186

						INCOME $7500 - $9999						
YEAR	0.01-39	39.01-50	50.01-60	60.01-70	70.01-80	80.01-90	90.01-100	100.-110	110.-120	120.-140	140.-200	200 +
1971	411256	78334	52246	52246	45672	32662	13079	0	0	0	6505	0
1970	557262	190498	163160	81518	81518	54428	67911	40821	0	0	0	0
1959	283544	283544	255257	127561	113417	70852	56709	56709	14144	28287	56709	0
1958	467954	296328	218407	46781	15642	31140	62423	31140	46781	46781	110064	62423
1967	68715	109987	96158	123709	123709	151152	41272	82437	96158	54994	96158	13722
PRE 1967	553001	736718	482133	722538	595539	694179	553001	453744	283590	538821	496283	55718

						INCOME $10000 - $14999						
YEAR	0.01-39	39.01-50	50.01-60	60.01-70	70.01-80	80.01-90	90.01-100	100.-110	110.-120	120.-140	140.-200	200 +
1971	817571	164027	109400	109400	95634	68393	27386	0	0	0	13621	0
1970	73091	366828	314186	156974	156974	104808	130772	78606	0	0	0	0
1969	517132	517139	465602	232678	205879	129238	103440	103440	25799	51597	103440	0
1968	747095	473092	348690	74687	24972	49715	99659	49715	74687	74687	175720	99659
1967	129328	205405	179579	231031	231031	282282	77077	153954	179579	102703	153954	25676
PRE 1967	734912	979064	640693	960220	791444	922532	734912	603005	376878	716068	659537	75376

by this income category have a carbon monoxide generation capability of approximately 45 grams per mile. The set of matrices comprising the carbon monoxide system has two important characteristics, which reflect the ownership patterns by income class and technological characteristics of the various model year automobiles described in the previous chapter.[6] They are (1) the number of automobiles appearing in each matrix is generally an increasing function of money income, and (2) the number and proportion of automobiles owned with a low carbon monoxide generating characteristic[7] generally increases as money income increases. Table 4.4 presents these two important characteristics of the tax base more clearly, and points out that, generally, although the number of automobiles entering the tax base increases as income rises to income class $10,000-$14,999 and then declines, the proportion of this stock of cars with low carbon monoxide generating characteristics increases throughout <u>all</u> income classes. Thus, excluding the lowest income category, the proportion of the total stock of cars with low emission characteristics increases continuously from 12.77% to 24.31% over the complete range of incomes while the total number of automobiles in the tax base rises only through income category $10,000-$14,999. This is due to the fact that the proportion of the total stock of cars owned by any income class which is <u>new</u>, a 1971 model with a low carbon monoxide (and unburned

---

[6]See Table 3.3 and Table 3.9.

[7]Low carbon monoxide emissions are defined arbitrarily as 0.0-3.90 grams per mile.

TABLE 4.4.--The Composition of the Automobile Stock by Income and Carbon Monoxide Emission Category.

Income	Emission Category					
	Low		High		Total	
	No.	% of Stock	No.	% of Stock	No.	% of Stock
< $1,000	102,599	14.2	621,401	85.8	724,000	100
$1,000-$ 1,999	229,804	12.8	1,569,196	87.2	1,799,000	100
$2,000-$ 2,999	398,544	14.6	2,334,456	85.4	2,733,000	100
$3,000-$ 3,999	541,135	14.6	3,167,865	85.5	3,709,000	100
$4,000-$ 4,999	666,245	16.3	3,426,755	83.7	4,093,000	100
$5,000-$ 5,999	858,146	17.5	4,036,854	82.5	4,895,000	100
$6,000-$ 7,499	1,420,948	18.7	6,188,052	81.3	7,609,000	100
$7,500-$ 9,999	2,341,739	19.5	9,658,261	80.5	12,000,000	100
$10,000-$14,999	4,018,296	21.3	14,867,704	78.7	18,886,000	100
$15,000-$24,999	2,724,571	23.5	8,888,429	76.5	11,613,000	100
$25,000 +	839,011	24.3	2,611,989	75.7	3,451,000	100

hydrocarbon) emission characteristic, increases as money income rises, with the $15,000 + categories owning the greatest proportion of new cars relative to their stock of cars. The implication of the above is that although a greater number of automobiles are owned as income rises, emissions per unit are less.

Table 4.5 presents the system of matrices which compose the oxides of nitrogen tax base. The matrices, one for each income category, are of dimensions 6 x 8. That is, all automobiles owned by the particular income category are distributed by six model years and eight levels of pollution generation, measured in grams per mile. For example, cell NO_{33}, of income category $2,000-$2,999, states that 13,958 model year 1969 automobiles owned by this income category have an oxides of nitrogen pollution generating capability of approximately 4.5 grams per mile. The set of matrices comprising the oxides of nitrogen system has two important characteristics which reflect the ownership patterns and technological characteristics of automobiles presented in the previous chapter.[8] These characteristics are (1) the number of automobiles appearing in each matrix is, generally, an increasing function of money income; and (2) although the number of automobiles owned with a low oxide of nitrogen emission characteristic[9] generally rises with money income, the proportion of these automobiles owned by income class

[8]See Table 3.4 and Table 3.9

[9]Low oxide of nitrogen emission has been arbitrarily defined as 0.0-3.0 grams per mile emitted.

TABLE 4.5.--Tax Base for Oxides of Nitrogen (g/mi.)

INCOME LESS THAN $1000

YEAR	0.01-3.0	3.01-4.0	4.01-5.0	5.01-6.0	6.01-7.0	7.01-8.0	8.01-11.0	11.0 +
1971	4800	7650	5490	3690	5100	1650	1650	0
1970	4116	10164	8316	6468	5964	3654	1848	1386
1969	5922	9954	8631	7938	10584	5922	7938	5985
1968	1128	1392	1216	1128	1040	344	264	1480
1967	18480	15360	12320	5120	5120	0	0	23600
PRE 1967	122500	100000	56500	35500	26200	16000	15000	127500

INCOME $1000 - $1999

YEAR	0.01-3.0	3.01-4.0	4.01-5.0	5.01-6.0	6.01-7.0	7.01-8.0	8.01-11.0	11.0 +
1971	6080	9690	6954	4674	6460	2090	2090	0
1970	5880	14520	11880	9240	8520	5220	2640	1980
1969	7520	12640	10960	10080	13440	7520	10105	7579
1968	12717	15652	13696	12717	11739	3913	2935	16630
1967	24769	22308	17846	7436	7436	0	0	3421
PRE 1967	347073	282200	158940	100554	74505	45411	42168	360048

INCOME $2000 - $2999

YEAR	0.01-3.0	3.01-4.0	4.01-5.0	5.01-6.0	6.01-7.0	7.01-8.0	8.01-11.0	11.0 +
1971	7377	11717	8679	5642	7811	2604	2604	0
1970	16813	41099	33626	26154	24286	14945	7473	5604
1969	9663	16105	13958	12884	17179	9663	12884	9663
1968	36457	44870	39261	36457	33552	11217	8413	47674
1967	39462	32805	26308	10962	10962	0	0	50423
PRE 1967	488264	397000	223597	141459	104354	63885	59322	506517

TABLE 4.5.--Continued.

INCOME $3000 - $3999

YEAR	0.01-3.0	3.01-4.0	4.01-5.0	5.01-6.0	6.01-7.0	7.01-8.0	8.01-11.0	11.0 +
1971	21491	34132	25283	16434	22755	7584	7584	0
1970	15824	38681	31648	24615	22957	14066	7033	5275
1969	22832	38053	32979	30442	40589	22832	30442	22832
1968	39000	48000	42000	39000	36000	12000	9000	51000
1967	80538	67115	53692	22372	22372	0	0	102910
PRE 1967	620599	504600	284200	179800	133400	81200	75400	643800

INCOME $4000 - $4999

YEAR	0.01-3.0	3.01-4.0	4.01-5.0	5.01-6.0	6.01-7.0	7.01-8.0	8.01-11.0	11.0 +
1971	17986	39478	29248	19003	26319	8773	8773	0
1970	28285	69155	56570	43987	40369	75139	12584	9438
1969	33903	56528	48974	45215	60287	33903	45215	33903
1968	50585	62256	54488	50585	46583	15573	11671	66158
1967	92551	77112	61674	25704	25704	0	0	118255
PRE 1967	623856	507200	285554	180817	134154	81659	75826	647187

INCOME $5000 - $5999

YEAR	0.01-3.0	3.01-4.0	4.01-5.0	5.01-6.0	6.01-7.0	7.01-8.0	8.01-11.0	11.0 +
1971	39619	62911	46609	30282	41941	13980	13980	0
1970	43714	106876	87428	67980	63162	38852	19448	14586
1969	39111	65213	56498	52162	69549	39111	52162	39111
1968	77009	94776	82949	77009	71068	23708	17767	100716
1967	107553	89612	71671	29871	29871	0	0	137423
PRE 1967	678960	552000	310776	196788	146004	88872	82524	704352

TABLE 4.5.--Continued.

INCOME $6000 - $7499

YEAR	0.01-3.0	3.01-4.0	4.01-5.0	5.01-6.0	6.01-7.0	7.01-8.0	8.01-11.0	11.0 +
1971	71378	113342	83972	54557	75561	25187	25187	0
1970	68142	166600	136284	105968	98458	60563	30316	22737
1969	74529	124267	107662	99398	132531	74529	99398	74529
1968	116149	142946	125108	116149	107189	35757	26797	151906
1967	179332	149417	119503	49806	49806	0	0	229137
PRE 1967	994332	808400	455129	288195	213822	130152	120856	1031518

INCOME $7500 - $9999

YEAR	0.01-3.0	3.01-4.0	4.01-5.0	5.01-6.0	6.01-7.0	7.01-8.0	8.01-11.0	11.0 +
1971	110997	176252	130580	84839	117502	39167	39167	0
1970	122339	299107	244677	190251	176767	108732	54428	40821
1969	127561	212691	184270	170126	226535	127561	170126	127561
1968	202766	249547	218407	202766	187124	62423	46781	265188
1967	247418	206146	164874	68715	68715	0	0	316133
PRE 1967	1516590	1233000	694179	439565	326129	198513	184334	1573308

INCOME $10000 - $14999

YEAR	0.01-3.0	3.01-4.0	4.01-5.0	5.01-6.0	6.01-7.0	7.01-8.0	8.01-11.0	11.0 +
1971	232420	369060	273426	177647	246040	80564	80564	0
1970	235580	575968	471160	366352	340388	209378	104808	78606
1969	232678	387960	336118	310319	413759	232678	310319	232678
1968	323718	398405	340690	323718	298746	99659	74687	423377
1967	462062	384985	307908	128328	128328	0	0	590390
PRE 1967	2015478	1638600	922532	584161	433409	263815	244971	2090854

TABLE 4.5.--Continued.

INCOME $15000 - $24999

YEAR	0.01-3.0	3.01-4.0	4.01-5.0	5.01-6.0	6.01-7.0	7.01-8.0	8.01-11.0	11.0 +
1971	179648	285264	211344	137312	190176	63392	63392	0
1970	148845	363909	297689	231469	215065	132290	66220	49665
1969	172733	288010	249523	230370	307709	172733	230371	172733
1968	231449	284848	249304	231449	213595	71253	53399	302702
1967	279037	232490	185944	77497	77497	0	0	356534
PRE 1967	1056816	850200	483730	306305	227258	138331	128450	1096339

INCOME MORE THAN $24999

YEAR	0.01-3.0	3.01-4.0	4.01-5.0	5.01-6.0	6.01-7.0	7.01-8.0	8.01-11.0	11.0 +
1971	79719	126586	93784	60932	84391	28130	28130	0
1970	65867	143057	131735	102431	95171	58541	29304	21978
1969	60513	100898	87415	80706	107508	60513	80706	60513
1968	56379	69386	60728	56379	52030	17357	13007	73735
1967	79164	65959	52753	21986	21986	0	0	101151
PRE 1967	216972	176400	99313	62887	46558	28400	26372	225086

declines as money income rises.[10] Table 4.6 presents the composition of the automobile stock by nitrogen emission category. One observes that the aforementioned characteristics produce a situation where the number of pollution generating units comprising the tax base is expanding through income category $10,000-$14,999, while the proportion of those units with low NO_x emission levels is declining throughout all income categories. The important implication of the above is that as income rises, both the number and average emissions of the total stock of cars owned by an income category rise, in terms of NO_x generation.

Conclusions

This chapter described the methodology employed in the construction of the set of systems of tax base matrices which identify the number of polluting units, by pollutant type, owned by income category and the degree to which these units can contribute to the degradation of the atmosphere. Each system of tax base matrices was characterized by an increasing number of polluting units entering the tax base as income rose through category $10,000-$14,999, whereupon the number of units declined. The hydrocarbon and carbon monoxide tax base systems were found to be characterized by a continuously increasing proportion of automobiles entering the base with low emission generating capability as income rose; i.e., the stock of cars of the higher income categories were composed of a

---

[10]This differs from the characteristics of the HC and CO tax base, but is expected; see note 7, p. 41.

TABLE 4.6.--The Composition of the Automobile Stock by Income and Oxides of Nitrogen Emission Catetory.

Income	Emission Category					
	Low		High		Total	
	No.	% of Stock	No.	% of Stock	No.	% of Stock
< $1,000	156,946	21.7	567,056	78.3	724,000	100
$1,000-$ 1,999	406,039	22.6	1,392,961	77.4	1,799,000	100
$2,000-$ 2,999	598,036	21.9	2,134,964	78.1	2,733,000	100
$3,000-$ 3,999	800,284	21.6	2,908,716	78.4	3,709,000	100
$4,000-$ 4,999	847,166	20.7	3,245,834	79.3	4,093,000	100
$5,000-$ 5,999	985,966	20.1	3,909,034	79.9	4,895,000	100
$6,000-$ 7,499	1,503,862	19.8	6,105,138	80.2	7,609,000	100
$7,500-$ 9,999	2,327,671	19.4	9,673,000	80.6	12,000,000	100
$10,000-$14,999	3,501,936	18.5	15,384,064	81.5	18,886,000	100
$15,000-$24,999	2,068,528	17.8	9,544,472	82.2	11,613,000	100
$25,000 +	558,614	16.2	2,892,386	83.8	3,451,000	100

smaller proportion of high HC and CO polluting automobiles than was the lower income categories. The oxide of nitrogen tax base system was found to exhibit the opposite characteristic. The stock of cars of the higher income categories was composed of a greater proportion of high NO_X polluting automobiles than was the lower income categories. The next chapter discusses the various hypothetical pollution taxes imposed, in this study, on the owners of polluting automobiles and presents a determination of the distributional cost (incidence) of each hypothetical tax.

CHAPTER V

HYPOTHETICAL AUTOMOBILE POLLUTION TAXES AND THEIR DISTRIBUTIONAL CONSEQUENCES

The previous chapter, which discussed the construction of the tax base for this study, identified the source and degree of automobile pollution generation associated with the private consumption of automotive services. In so doing, the tax base provides empirical identification of those consumers whose consumption activities impose negative externalities on other members of society. The magnitude of this pollution generation, and the resulting environmental consequences have already been documented, and are of considerable concern. Further, the pervasiveness of the externality, the large number of individuals involved, and the resulting high transactions costs associated with negotiations to reduce the total supply of the externality produces, eliminate the possibility that "trade" among affected parties will take place. It has therefore been presumed in this study that the auspices of the "state" will be required to bring about a reduction in the total amount of pollution generation. More specifically, this study assumes that the state will adopt, as a method of control, the taxation of automobile exhaust emissions designed to reduce pollution generation to some legislatively designated national acceptability standard. When the acceptability standard is achieved on average, an approximation to an equilibrium level of pollution abatement will be deemed to be achieved.[1] As has been suggested by Baumol (Baumol, 1972: 319-327) regarding an optimal pollution control policy, the hypothetical taxes will be imposed on the emittor of pollutants into the atmosphere with each tax scheme becoming effective when the relevant pollution characteristics of the auto are found to exceed the acceptability standards.[2] In this way, incentive will be provided the pollutor to reduce his pollution output toward the acceptable level.

Since the concern of this study is a determination of the likely distributional impact of the costs of the various hypothetical

---

[1]The federal law under which current standards have been promulgated specifies that "the Secretary shall . . . giving appropriate consideration to technological feasibility and economic cost, prescribe . . ." standards [42 U.S.C.A. § 1857f-1(a)]. This is a rough approximation to an efficiency criterion where "reasonable" cost represents an estimate of the benefits to be achieved, and the standard is set to equate marginal cost to marginal benefit. See Donald Dewees, Economics and Public Policy: The Automobile Pollution Case (MIT Press: 1974), Chapter 8, for further elaboration of this point.

[2]Questions regarding the optimality of a standards-taxes approach to pollution control will not be addressed in this paper. However, literature on this topic includes: W. J. Baumol, "On Taxation and the Control of Externalities," American Economic Review 62 (June 1972); W. J. Baumol and W. E. Oates, "The Use of Standards and Pricing for the Protection of the Environment," Swedish Journal of Economics 73 (March 1971); T. H. Tietenberg, "Specific Taxes and the Control of Pollution: A General Equilibrium Analysis," Quarterly Journal of Economics 87 (Nov. 1973); Earl A. Thompson and Ron Batchelder, "On Taxation and the Control of Externalities: Comment," American Economic Review 64 (June 1974); A. M. Freeman and R. H. Haveman, "Residuals Charges for Pollution Control," Science (July 1972), 177; T. Ferrar, "Nonlinear Effluent Charges," Management Science 20 (Oct. 1973); and A. V. Kneese, "Pollution and Pricing," American Economic Review 62 (Dec. 1972).

taxes,[3] an estimate of the incidence of each of the taxes, in the absence of any tax induced changes in the pattern of automobile service consumption or maintenance expenditure, is presented in this chapter. The burden of the various hypothetical taxes on the various income groups will depend on four variables: the tax rate; the emission characteristics of the stock of automobiles possessed by the income class; the number and distribution by model year of automobiles owned by the income class; and, for the emission output form of the tax, the average number of annual miles driven per polluting automobile by each income class. The various hypothetical taxes, the resulting costs and distributional impact in a static short run setting are described below in detail.

The hypothetical taxes imposed on the consumers of automotive services which produce external pollution effects in excess of the acceptability standard are designed to encompass all likely tax proposals and range from a lump sum fee to a per unit emissions variety. The structure of the hypothetical taxes are of the same general form: the tax borne by the income group is the sum (5) of the tax borne by its individual members, i.e., $Z_y = \Sigma\, Z_y^i = \Sigma\, bT_y^i$ where:

---

[3]The distributional consequences of the standards-taxes approach to reducing automobile emissions have yet to be explored in the literature. However, a recent contribution by Nancy S. Dorfman, "Who Will Pay for Pollution Control--the Distribution by Income of the Burden of the National Environmental Protection Program," National Tax Journal 28 (1974), No. 1, marks an initial look at the incidence of meeting national pollution standards, some of which apply to new automobile emissions.

Z_i = the total tax borne by the income class,

Z_y = the amount of tax paid by the i^{th} individual classified by income,

b = the tax base, one for each pollutant (HC, CO, NO_X), which specifies the number of taxable units with certain pollution characteristics owned by the "i" individuals and their distribution across incomes;

T_y^i = the tax rate applicable to the i^{th} individual classified by income which becomes effective when emissions exceed the acceptability standard.[4]

This general form is altered to accommodate the specific forms of the various hypothetical taxes described below:

1. Lump sum: An annual tax is imposed on the owner of an automobile if measured emissions for any pollutant exceed the acceptability standard.[5] All owners of automobiles with measured emissions below the standard are exempt from taxation. This tax is similar to an excise tax or traffic citation and may affect the choice of vehicle but will not affect the subsequent operation of the vehicle.

---

[4]The actual dollar value attached to T_y^i has been arbitrarily chosen in this study. In practice, this value should be legislated so as to create the behavioral responses required to achieve the specified standards. This requires the structure of taxation be flexible so that it can be readily adjusted as information is received by public authorities with regard to consumer responses to the initial tax level (if the response is insufficient, the tax will be raised).

[5]Acceptability standards applicable to all cars have been chosen at the following levels: HC = 3.4 g/mi.; CO = 39 g/mi.; NO_X = 3.0 g/mi. The methodology utilized in the study is applicable to any standard.

2. <u>Fleet average emissions tax</u>: If the measured emissions of the vehicle exceed the acceptability standard, an annual tax whose rate is equivalent in magnitude to the mean emissions of the fleet of model year "i" automobiles, of which the vehicle is a member, is imposed. For example, a 1969 model year vehicle found to have measured hydrocarbon emissions in excess of 3.4 g/mi. (the acceptability standard) will be taxed at the rate determined by the fleet's average emissions, 5.19 g/mi. The "payment to pollute" is related to a measure of actual pollution capability and may encourage prople to choose vehicles with low emission characteristics and to maintain their cars properly.

3. <u>Measured emission tax</u>: The annual tax is based on the measured emissions of the individual vehicle as recorded during the exhaust emission tests. The tax borne by the income class is determined by the entire emission distribution for each pollutant. This emission characteristic tax will encourage people to choose vehicles with lower emission characteristics and to maintain their cars properly.

4. <u>Level of emissions tax</u>: If measured emissions exceed the chosen standard, an annual tax is imposed with the rate equal in magnitude to the measured emissions weighted by an index (the index ranges from 1, . . . n; where n = number of columns in the appropriate tax base) which increases as measured emissions increase. The index embodies the concept that the environmental consequences of each gram emitted increase as the total number of grams emitted increases. Hence, the rax rate, which is set at zero

for emissions below the standard, is incremented linearly as emissions reach a higher index. Since the tax becomes more severe as the level of emissions rises, owners of high emission characteristic automobiles will be strongly encouraged to choose vehicles with lower emission characteristics, and all automobile owners will be encouraged to maintain their vehicles properly.

5. Exponential level of emissions tax: Similar to (4), except the rate is determined by an index of emissions which increases non-linearly as emissions reach a higher index.[7] The marginal tax rate is initially set at zero and incremented exponentially as emissions reach a higher index. Emissions greatly in excess of the standard will be penalized severely, and owners of those vehicles will have strong incentive to reduce their tax liability.

6. Emission output taxes: These taxes are all forms of effluent taxation. An annual tax is imposed on those vehicles whose annual expected output of the individual pollutants exceed the acceptability standard. The estimated annual output of each vehicle is defined as the product of the relevant pollution characteristic and the average annual mileage driven per vehicle. The annual tax per gram annual output is determined as described in (2), (3), (4) and (5) above. This tax may encourage people to drive less, to choose vehicles with lower emission characteristics and to maintain their vehicles properly.

---

[7]The index for this tax scheme has been defined as:
$i = 2^{L-1}$ where L = the j^{th} colum of the relevant tax base.

Summary of Empirical Results

The short run results of the imposition of the various hypothetical taxes on the owners of polluting automobiles are summarized in Tables 5.1-5.6, and the respective Figures 5.1A-B through 5.6A-B. These tables and figures present comparisons of the sensitivity of the patterns of incidence to each form of the hypothetical hydrocarbon, carbon monoxide, and oxide of nitrogen taxes. The comparison is facilitated by relating the incidence of the hypothetical taxes borne by all income groups to that borne by the uppermost income group. Thus the tables and charts represent measures of relative incidence which have been calculated using the incidence borne by the uppermost class for each hypothetical tax as the common base.

The tables and charts were developed from the estimated costs and incidence of each of the hypothetical taxes which are described in detail in Appendix B. These costs and incidence were calculated on a per car-owning and per household basis. The calculations on a per car-owning basis will provide an accurate assessment of the direct impact of the hypothetical taxes, since these are the individuals upon whom the pollution tax will be levied and who will bear the burden of the tax. The calculations on a per household basis obscure the differences between the impact of those who are vulnerable to the tax (owners of polluting vehicles) and those who are not (non-owners). However, this is a widely used measure of tax incidence (Richard A. and Peggy Musgrave, 1973: Chapter 15) and is most useful in making comparisons between alternative pollution control policies or other taxation schemes. It should also be noted that although the calculated costs of the hypothetical taxes are based on arbitrarily chosen values for the tax rate, the patterns of incidence presented are relevant for all total tax levels since alternative costs calculated using the tax schemes hypothesized in this study will produce patterns of incidence proportional to those presented. A final point to be noted is that the results pertaining to the extremes of the income distribution should be interpreted with the knowledge that these brackets may contain significant numbers of individuals whose current money incomes (those utilized here) differ from their permanent incomes. Inclusion of these households will tend to bias the true burden of the taxes to the extent that these "transient" individuals possess a stock of cars which is abnormal in relation to their current money income.[8]

Hydrocarbon Tax Results

Tables 5.1 and 5.2 and their respective Figures 5.1A-B and 5.2A-B present comparisons of the sensitivity of the patterns of incidence to each form of the hypothetical hydrocarbon taxes. Referring to Table 5.1 and Figure 5.1A, one notes that, per household, all hydrocarbon emission characteristic taxes are strongly regressive with the heaviest burden of the tax falling on the lowest income categories. Even were one to ignore the lowest income category, where the relative burden is overstated, the burden of the taxes borne by the lower income classes is still nearly nine

---

[8]This bias will be greatest at the lowest incomes.

TABLE 5.1.--The Relative Incidence of the Hypothetical Taxes on Hydrocarbons (All Households).

Money Income ($)	Emission Characteristics Taxes					Emission Output Taxes			
	Lump Sum	Fleet Ave. Emissions	Measured Emissions	Level of Emissions	Exponential Emissions	Ave. Fleet Output	Measured Output	Level of Output	Exponential Level of Output
< 1,000	16.49	21.07	17.78	22.58	25.56				
1,000- 1,999	7.27	9.09	7.78	9.81	11.32				
2,000- 2,999	5.81	7.48	6.30	8.02	9.18	2.22	2.07	2.37	2.59
3,000- 3,999	4.97	6.35	5.19	6.78	7.69	1.87	1.75	1.99	2.14
4,000- 4,999	4.73	5.87	5.00	6.21	6.98	2.07	1.95	2.18	2.32
5,000- 5,999	4.24	4.87	4.37	5.39	6.01	2.08	2.09	2.30	2.44
6,000- 7,499	3.84	4.61	3.89	4.76	5.30	1.98	1.87	2.05	2.17
7,500- 9,999	3.32	3.96	3.37	4.10	4.52	1.85	1.76	1.90	1.99
10,000-14,999	2.62	3.00	2.55	3.04	3.31	1.40	1.34	1.41	1.46
15,000-24,999	1.95	2.13	1.89	2.15	2.29	1.00	1.00	1.00	1.00
25,000 +	1.00	1.00	1.00	1.00	1.00				

TABLE 5.2.--The Relative Incidence of the Hypothetical Taxes on Hydrocarbons (Car-Owning Households Only).

Money Income ($)	Emission Characteristics Taxes					Emission Output Taxes			
	Lump Sum	Fleet Ave. Emissions	Measured Emissions	Level of Emissions	Exponential Emissions	Ave. Fleet Output	Measured Output	Level of Output	Exponential Level of Output
< 1,000	53.16	65.44	58.89	71.08	80.15				
1,000- 1,999	17.10	21.95	19.25	23.90	27.44				
2,000- 2,999	10.79	13.29	12.00	14.55	16.59	4.94	4.60	5.29	5.76
3,000- 3,999	7.63	9.15	8.40	10.13	11.44	2.82	2.30	3.00	3.24
4,000- 4,999	6.05	7.24	6.59	7.77	8.69	2.61	2.46	2.75	2.94
5,000- 5,999	5.00	5.61	5.40	6.32	6.99	2.46	2.46	2.73	2.88
6,000- 7,499	4.21	4.92	4.30	5.20	5.74	2.18	2.05	2.26	2.39
7,500- 9,999	3.68	4.07	3.70	4.28	4.69	1.95	1.85	2.01	2.11
10,000-14,999	2.71	2.97	2.59	3.05	3.31	1.42	1.36	1.52	1.49
15,000-24,999	1.95	2.07	1.93	2.13	2.24	1.00	1.00	1.00	1.00
25,000 +	1.00	1.00	1.00	1.00	1.00				

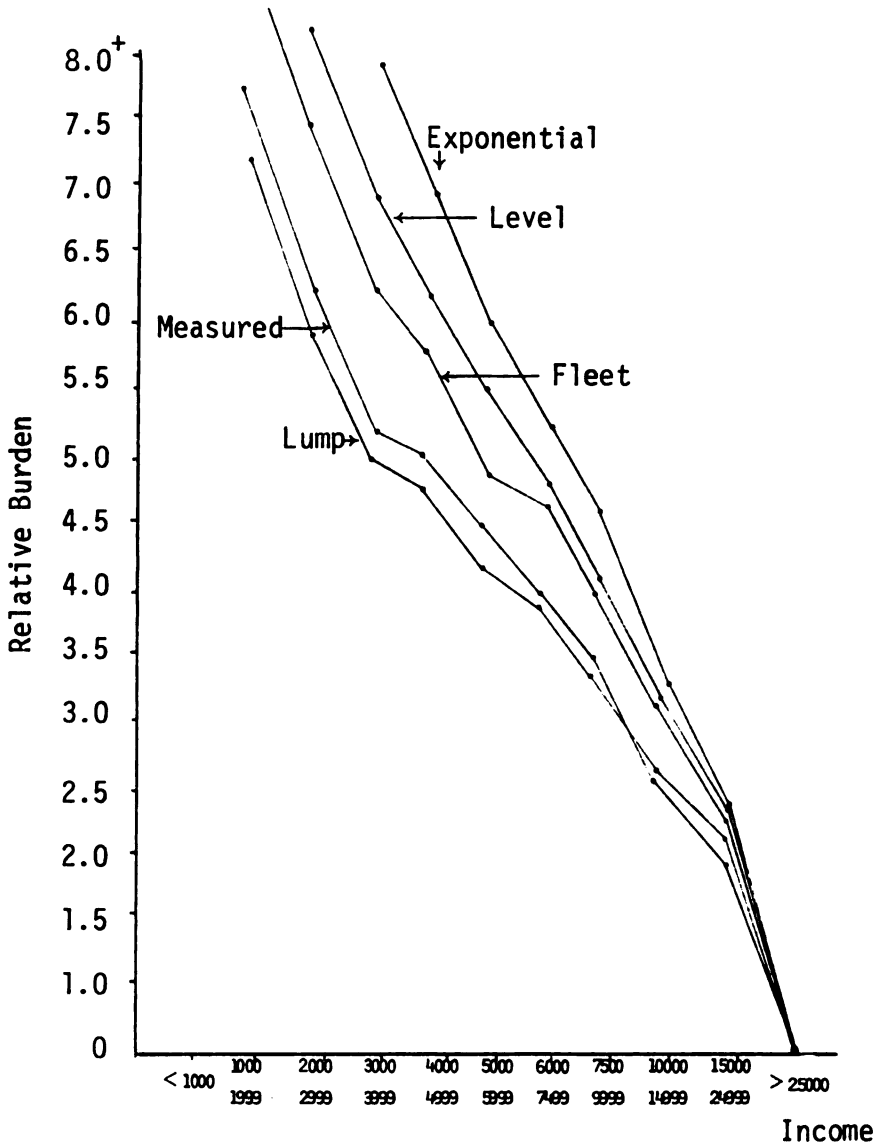

Figure 5.1A.--Relative Incidence of the Hypothetical Characteristic Taxes on Hydrocarbon Emissions (All Households).

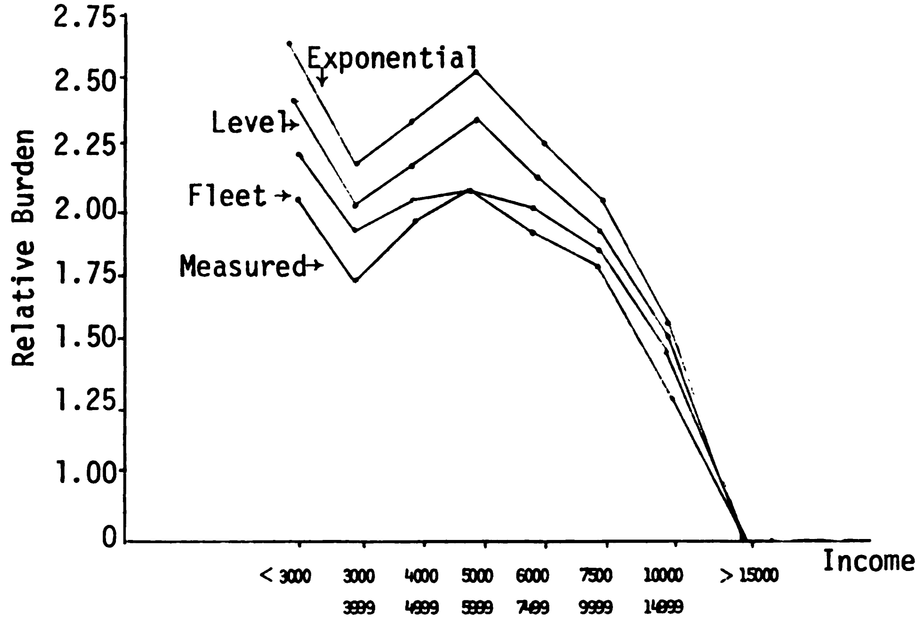

Figure 5.1B.--Relative Incidence of the Hypothetical Output Taxes on Hydrocarbon Emissions (All Households).

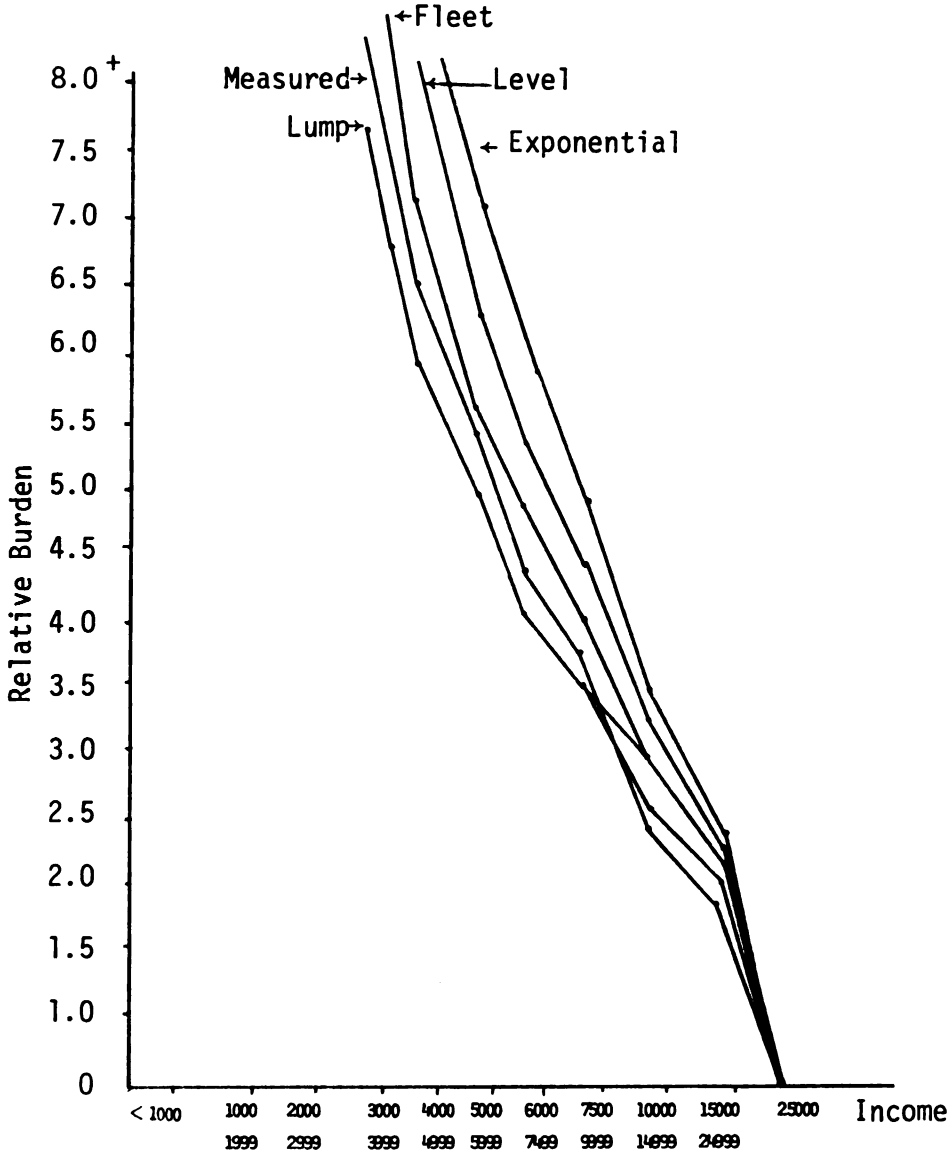

Figure 5.2A.--Relative Incidence of the Hypothetical Characteristic Taxes on Hydrocarbon Emissions (Car-Owning Households).

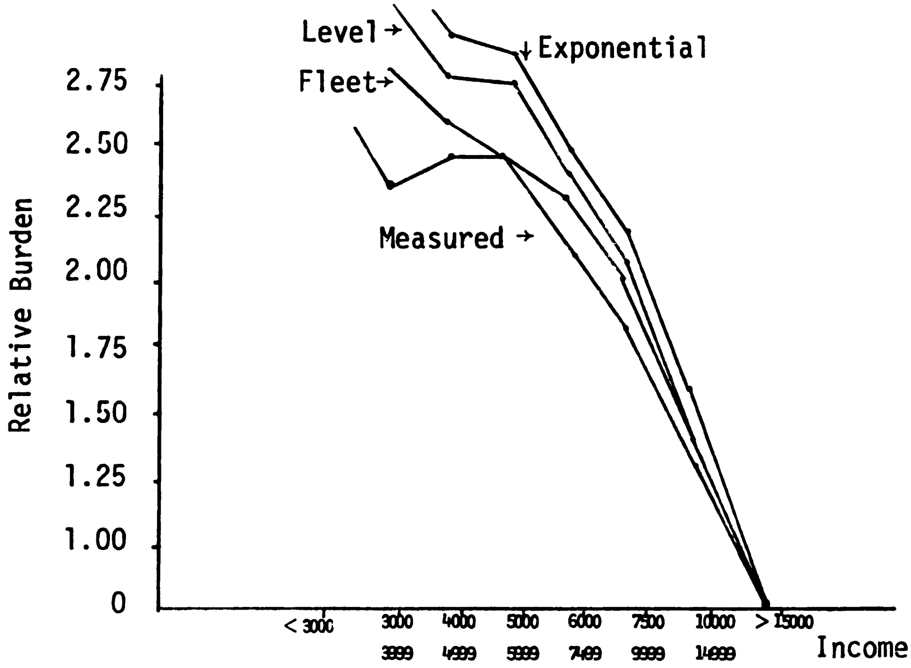

Figure 5.2B.--Relative Incidence of the Hypothetical Output Taxes on Hydrocarbon Emissions (Car-Owning Households).

times that borne by the uppermost income class. These strongly regressive patterns of relative incidence result from the interaction of automobile ownership and in-use emission components of the tax base.

The discussion of automobile ownership in the previous chapter revealed the prevalence of private automobile ownership at all income levels. For example, it was noted that even households with money incomes as low as $2,000-$2,999 in 1971 experienced a majority of households owning at least one car. Since the emission taxes are based partially upon these ownership patterns, the overall tendency is for the resulting incidence to be regressive.[9] (The overall tendency toward regressivity is moderated slightly by middle income, multicar ownership.). The lump sum form of the tax, which imposes a fixed fee on polluting automobiles regardless of the degree of pollution, is most reflective of the patterns of incidence generated by taxes on automobile ownership.[10]

The distribution of in-use automobile emissions tends to further compound the regressivity of the characteristic taxes. The previous discussion (Chapter III) revealed that the composition of the stock of automobiles was highly dependent upon income with the

---

[9]In particular, at the uppermost income categories, where the mean group income is nearly 35 times that of the lowest income class, the number of automobiles owned is only 6 times as great. The income elasticity of ownership is low.

[10]The lump sum incidence pattern is slightly more regressive than would be the pattern of an ownership tax, since owners of "non-polluting" autos are not taxed and there are more of these owners (proportionally) at higher income classes.

distribution by model year skewed markedly toward ownership of older model years at lower income levels. Since a direct relationship between model year and in-use hydrocarbon emissions exists (see Table 3.5), because late model year cars have emission controls and thus lower emissions, the automobiles with high hydrocarbon pollution characteristics will comprise a greater proportion of the stock of cars owned by lower income classes than higher income classes. Therefore, the tendency will be for taxes based on hydrocarbon emissions to increase the tax burdens of all classes relative to the uppermost income class. The patterns of relative incidence presented in Figure 5.1A reveal this compounding factor. The regressivity of the incidence patterns increases as emissions are taxed more heavily.

These patterns of regressivity do not prevail when the hypothetical taxes impose a rate based upon annual emission output. All hydrocarbon output taxes, Table 5.1 and Figure 5.1B, exhibit patterns of incidence which are progressive through the middle income categories, exclusive of the lowest income category, becoming regressive only at incomes above $6,000. The progressivity of the incidence patterns is attributable solely to the rapid increases in annual per vehicle mileage driven as incomes rise from less than $3,000-$5,999. These increases become less pronounced at incomes above $6,000, increasing from 11,200 annual miles to only 15,000 annual miles at the uppermost income categories, and the dominant regressive patterns of incidence reemerge. The relationship between income and per vehicle annual mileage driven for all income classes is shown in Table B.6, Appendix B.

Table 5.2 and Figure 5.2A-B show the patterns of relative incidence when the total tax liability is spread across only car-owning households. The patterns are more regressive at the lower end of the income distribution, where a smaller percentage of all households own an automobile than is the case at the upper end of the distribution (see Table 3.7). As incomes rise, the patterns of regressivity approach those of the all household patterns displayed in Table 5.2. A comparison of Tables 5.1 and 5.2 will confirm this observation.

Carbon Monoxide Results

The results of the imposition of the various hypothetical taxes on carbon monoxide emissions are presented in Tables 5.3 and 5.4 and Figures 5.3a-B and 5.4A-B. The relative burdens of the emission characteristic taxes are strongly regressive with the burdens at the lowest income classes relative to the burden at the uppermost income class ranging upward to 19 times as great. The patterns of incidence of the characteristic taxes result from interactions between automobile ownership patterns and in-use emissions which are nearly identical to the interactions described with respect to the hydrocarbon emission tax results.

The ownership patterns and their impact on the incidence of the various taxes is unchanged from that applicable to the hydrocarbon taxes. However, the distribution of carbon monoxide

TABLE 5.3.--The Relative Incidence of the Hypothetical Taxes on Carbon Monoxide (All Households).

Money Income ($)	Emission Characteristics Taxes					Emission Output Taxes			
	Lump Sum	Fleet Ave. Emissions	Measured Emissions	Level of Emissions	Exponential Emissions	Ave. Fleet Output	Measured Output	Level of Output	Exponential Level of Output
< 1,000	15.95	18.72	17.37	19.38	16.26				
1,000- 1,999	6.48	7.88	7.30	8.52	8.56				
2,000- 2,999	5.40	6.52	6.10	6.95	7.32	2.01	1.93	2.09	2.02
3,000- 3,999	4.78	5.64	5.27	5.93	6.19	1.71	1.65	1.77	1.77
4,000- 4,999	4.54	5.28	4.87	5.53	5.76	1.92	1.84	1.98	1.97
5,000- 5,999	4.08	4.68	4.40	4.90	5.16	2.08	2.03	2.13	2.15
6,000- 7,499	3.73	4.20	4.00	4.49	4.98	1.89	1.87	1.97	2.08
7,500- 9,999	3.24	3.64	3.47	3.79	4.00	1.76	1.72	1.79	1.81
10,000-14,999	2.43	2.84	2.70	2.90	3.00	1.37	1.34	1.37	1.37
15,000-24,999	2.00	2.04	1.96	2.10	2.23	1.00	1.00	1.00	1.00
25,000 +	1.00	1.00	1.00	1.00	1.00				

TABLE 5.4.--The Relative Incidence of the Hypothetical Taxes on Carbon Monoxide (Car-Owning Households Only).

Money Income ($)	Emission Characteristics Taxes					Emission Output Taxes			
	Lump Sum	Fleet Ave. Emissions	Measured Emissions	Level of Emissions	Exponential Emissions	Ave. Fleet Output	Measured Output	Level of Output	Exponential Level of Output
< 1,000	51.32	59.60	57.70	62.05	50.94				
1,000- 1,999	16.31	19.23	18.10	21.05	20.75				
2,000- 2,999	10.26	11.90	11.32	12.82	13.22	4.48	4.30	4.68	4.69
3,000- 3,999	7.32	8.46	7.97	9.00	9.16	2.60	2.49	2.68	2.77
4,000- 4,999	5.84	6.65	6.23	7.00	7.16	2.43	2.32	2.50	2.59
5,000- 5,999	4.89	5.53	5.25	5.82	6.00	2.45	2.38	2.52	2.64
6,000- 7,499	4.13	4.61	4.45	4.94	5.36	2.08	2.05	2.17	2.38
7,500- 9,999	3.45	3.85	3.67	4.00	4.13	1.86	1.82	1.89	1.98
10,000-14,999	2.65	2.86	2.74	2.94	3.01	1.39	1.35	1.40	1.44
15,000-24,999	1.92	2.03	1.97	2.12	2.18	1.00	1.00	1.00	1.00
25,000 +	1.00	1.00	1.00	1.00	1.00				

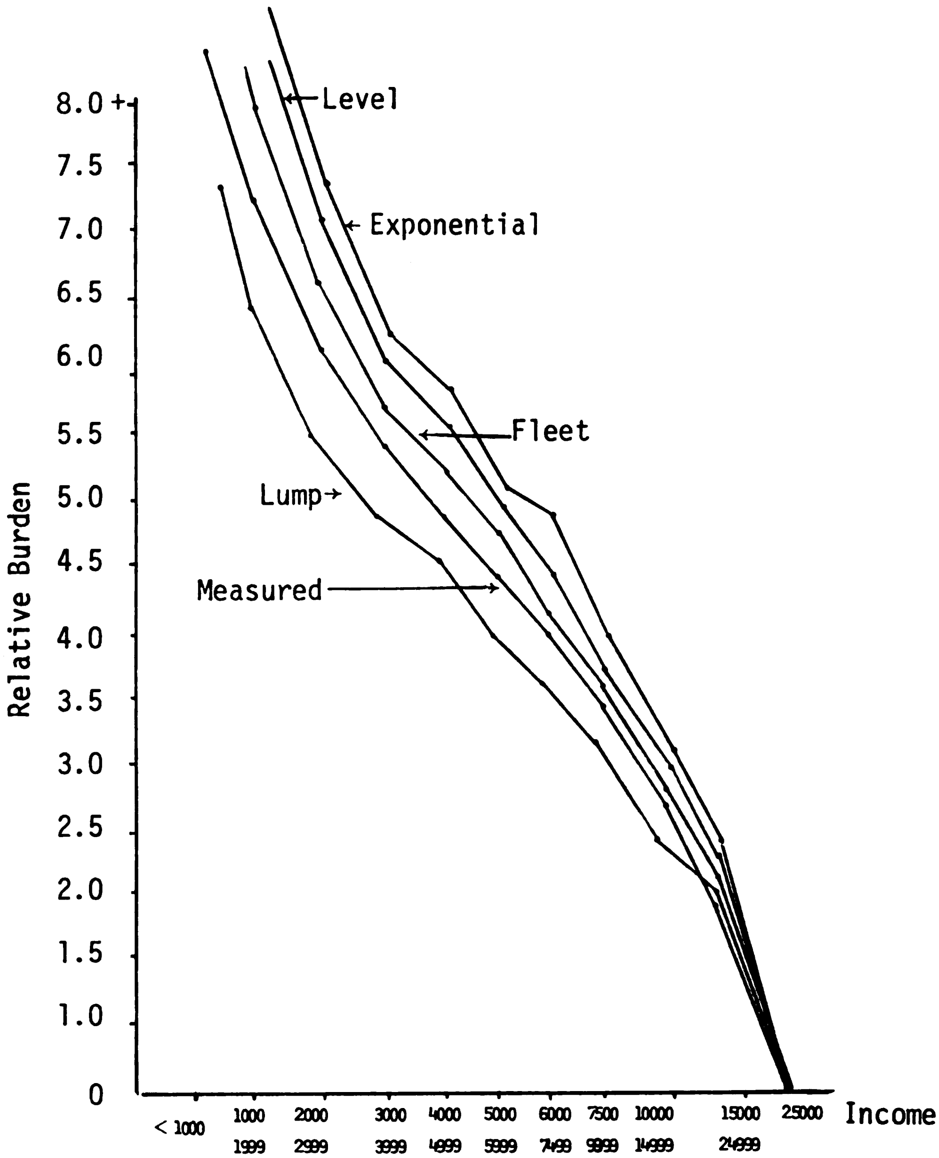

Figure 5.3A.--Relative Incidence of the Hypothetical Characteristic Taxes on Carbon Monoxide Emissions (All Households).

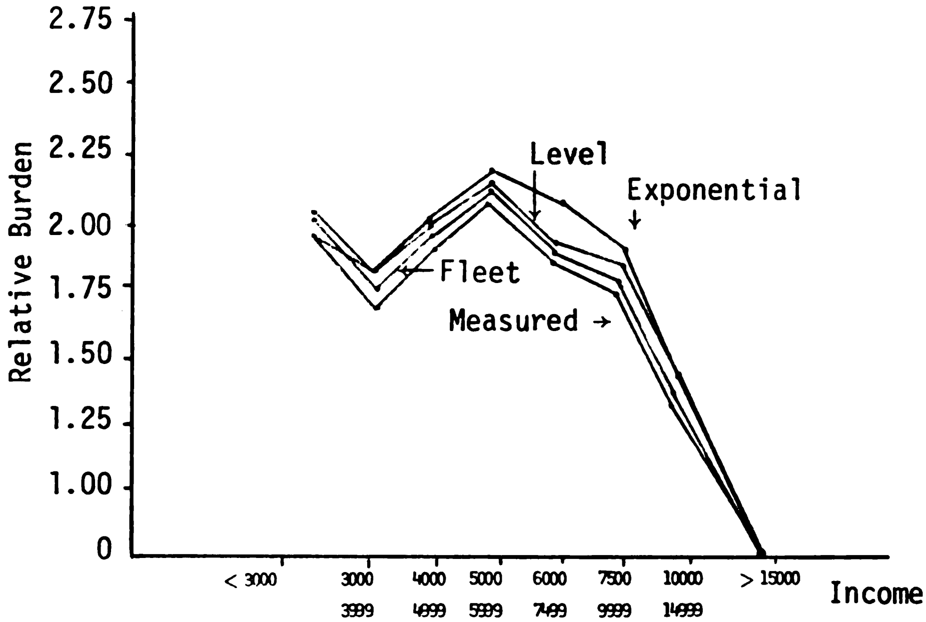

Figure 5.3B.--Relative Incidence of the Hypothetical Ouput Taxes on Carbon Monoxide Emissions (All Households).

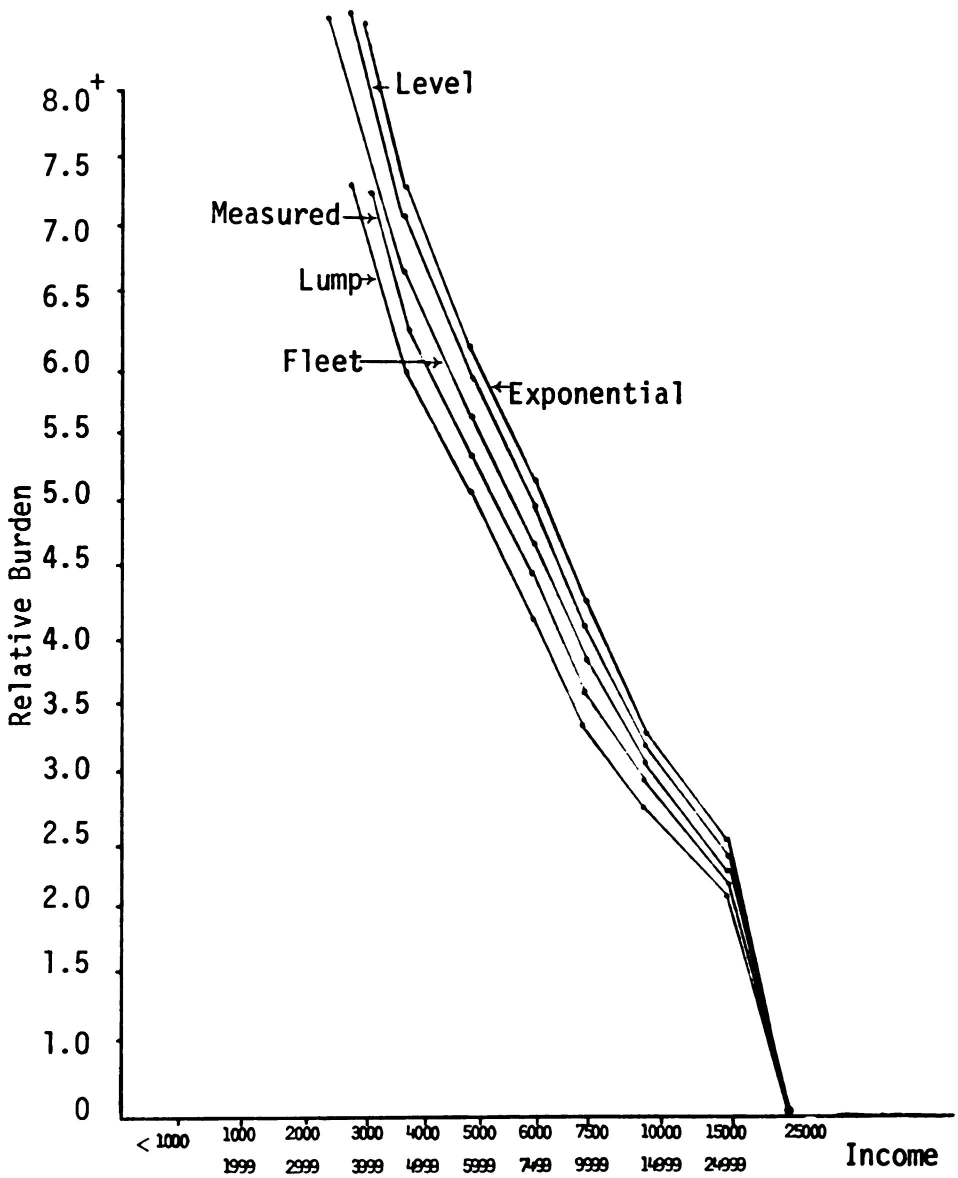

Figure 5.4A.--Relative Incidence of the Hypothetical Characteristic Taxes on Carbon Monoxide Emissions (Car-Owning Households).

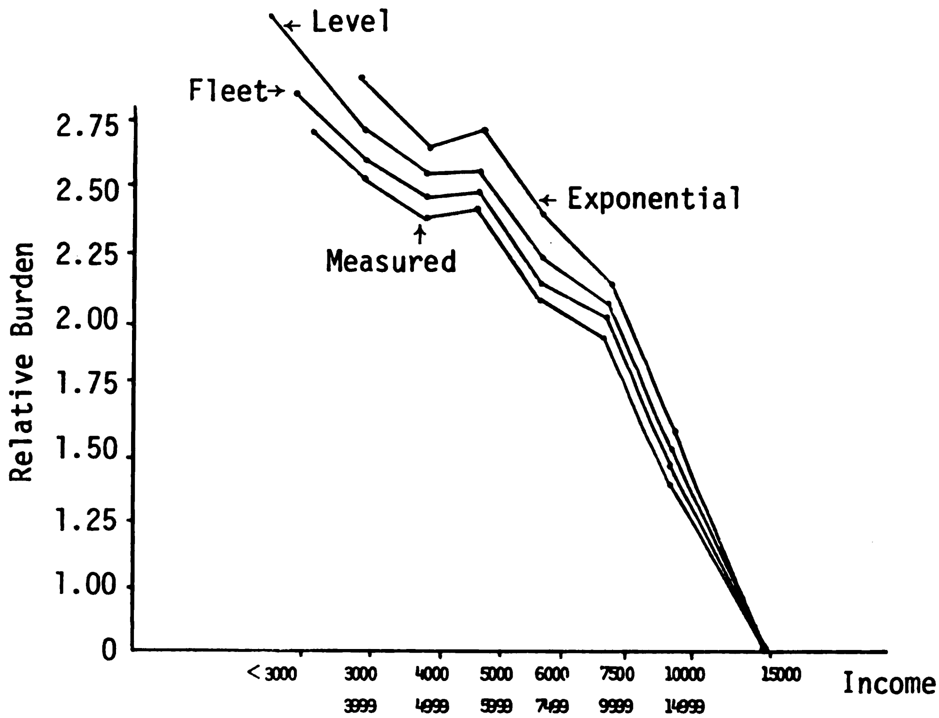

Figure 5.4B.--Relative Incidence of the Hypothetical Output Taxes on Carbon Monoxide Emissions (Car-Owning Households).

emissions differs slightly from that of hydrocarbon emissions. Average carbon monoxide emissions by model year generally decrease with later model years, but the percentage of new automobiles with emissions below the standard (and exempt from taxation) is less than was the case with hydrocarbons (see Table 3.5). Further, a greater percentage of pre-1967 model year automobiles have low emissions. Thus, although the overall incidence patterns of the carbon monoxide characteristic taxes will be regressive throughout all income classes, the compounding effect of the distribution of carbon monoxide emissions by model year will be less pronounced. Once again, though, the regressivity of the patterns of incidence of the characteristic taxes increases as emissions are taxed more heavily.

The patterns of incidence of the various carbon monoxide output taxes are nearly identical to one another. The pattern of relative burden is dominated by the sharp increases in annual per vehicle mileage driven through income category \$5,000-\$5,999. The progressive impact of mileage driven on the resulting incidence patterns moderates at incomes above \$6,000 and the predominant regressive pattern of the taxes reemerges. The exponential output tax appears slightly more progressive than the other tax forms through \$6,000 and slightly less regressive than the other tax forms thereafter. This is a direct reflection of the greater tax exposure experienced by higher income classes owning newer cars, a smaller percentage of which are low polluters.

Table 5.4 and Figures 5.4A-B which present the patterns of incidence of the various carbon monoxide taxes when the burden is distributed across only car-owning households reveal a more regressive pattern than that exhibited by the all household pattern. This is due solely to the fact that the proportion of all households in an income class owning a car (and potentially taxed) declines as income falls. Thus the tax is borne by fewer households at low incomes than at high incomes, and the patterns appear more regressive at the lower income classes. For example, the relative burden of the various taxes on low income classes ranges upward to 62 times that of the high income burden.

Oxide of Nitrogen Results

Tables 5.5, 5.6 and Figures 5.5A-B, 5.6A-B present comparisons of the sensitivity of the patterns of incidence to each form of the hypothetical oxide of nitrogen emission taxes. The patterns of incidence, per household, of all oxide of nitrogen characteristic taxes are moderately regressive throughout the income distribution. The overall regressive patterns reflect the regressivity of tax systems based in part on existing patterns of automobile ownership as discussed earlier. Unlike the patterns of incidence of the hydrocarbon or carbon monoxide taxes, where the distribution of emissions of in-use automobiles tended to enhance the regressivity of the taxes, the distribution of oxide of nitrogen emissions by model year acts to reduce the relative burdens of the taxes imposed on the lower income classes. For example, the relative burden

TABLE 5.5.--The Relative Incidence of the Hypothetical Taxes on Oxides of Nitrogen (All Households).

Money Income ($)	Emission Characteristics Taxes					Emission Output Taxes			
	Lump Sum	Fleet Ave. Emissions	Measured Emissions	Level of Emissions	Exponential Emissions	Ave. Fleet Output	Measured Output	Level of Output	Exponential Level of Output
< 1,000	12.81	11.07	14.07	15.31	14.11				
1,000- 1,999	5.17	4.10	5.54	6.00	5.61				
2,000- 2,999	4.50	3.82	4.96	5.38	5.03	1.30	1.60	1.73	1.84
3,000- 3,999	3.88	3.33	4.25	5.15	4.31	1.17	1.41	1.52	1.61
4,000- 4,999	3.81	3.33	4.21	4.54	4.07	1.40	1.65	1.77	1.82
5,000- 5,999	3.52	3.15	3.79	4.00	3.58	1.60	1.81	1.91	1.95
6,000- 7,499	3.24	2.92	3.43	3.62	3.23	1.50	1.67	1.75	1.77
7,500- 9,999	2.86	2.61	3.04	3.15	2.79	1.45	1.58	1.65	1.65
10,000-14,999	2.36	2.19	2.46	2.54	2.16	1.22	1.28	1.31	1.28
15,000-24,999	1.81	1.72	1.86	1.85	1.57	1.00	1.00	1.00	1.00
25,000 +	1.00	1.00	1.00	1.00	1.00				

TABLE 5.6.--The Relative Incidence of the Hypothetical Taxes on Oxides of Nitrogen (Car-Owning Households Only).

Money Income ($)	Emission Characteristics Taxes					Emission Output Taxes			
	Lump Sum	Fleet Ave. Emissions	Measured Emissions	Level of Emissions	Exponential Emissions	Ave. Fleet Output	Measured Output	Level of Output	Exponential Level of Output
< 1,000	39.55	35.50	44.83	50.54	44.21				
1,000- 1,999	12.22	10.00	13.79	15.38	13.57				
2,000- 2,999	8.00	7.00	8.97	10.23	9.06	2.89	3.56	3.86	4.10
3,000- 3,999	5.56	5.00	6.55	7.30	6.38	1.76	2.12	2.30	2.43
4,000- 4,999	4.67	4.20	5.17	5.92	5.05	1.77	2.09	2.24	2.30
5,000- 5,999	4.00	3.70	4.48	4.92	4.16	1.90	2.14	2.26	2.31
6,000- 7,499	3.33	3.20	3.79	4.15	3.48	1.65	1.83	1.93	1.95
7,500- 9,999	2.89	2.75	3.21	3.46	2.89	1.53	1.67	1.74	1.74
10,000-14,999	2.20	2.25	2.53	2.69	2.16	1.22	1.30	1.33	1.30
15,000-24,999	1.78	1.70	1.86	1.92	1.53	1.00	1.00	1.00	1.00
25,000 +	1.00	1.00	1.00	1.00	1.00				

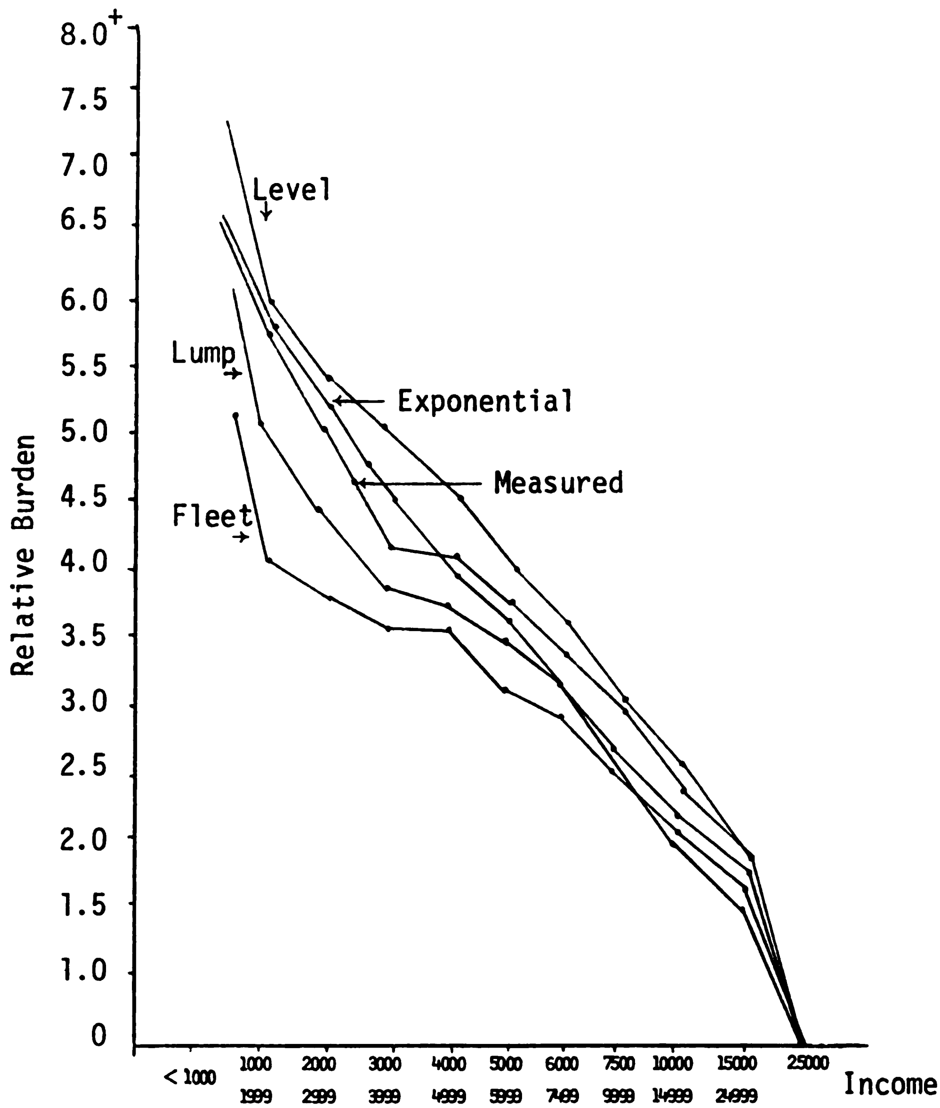

Figure 5.5A.--Relative Incidence of the Hypothetical Characteristic Taxes on Oxides of Nitrogen Emissions (All Households).

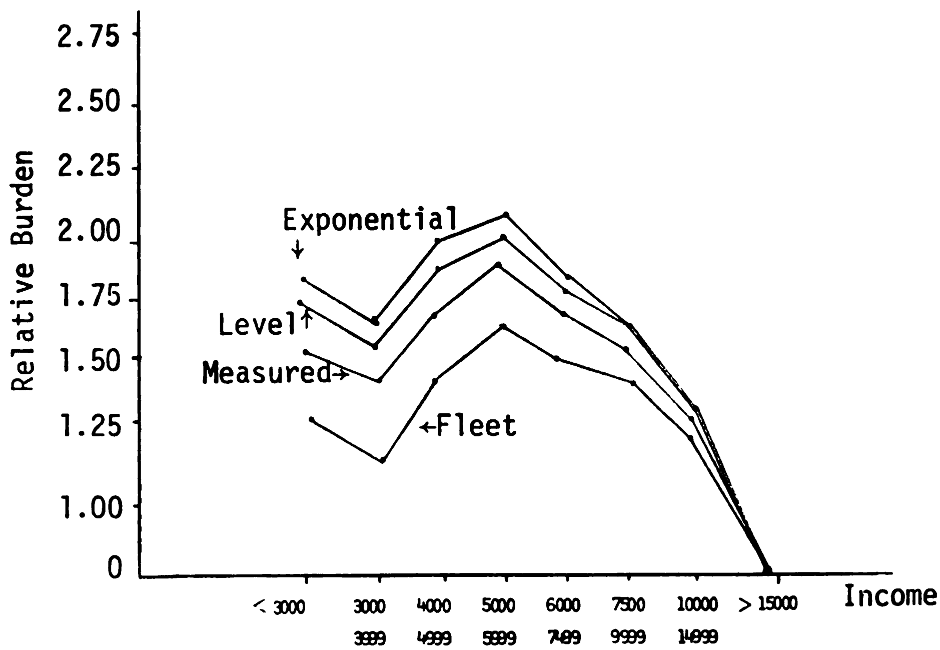

Figure 5.5B.--Relative Incidence of the Hypothetical Output Taxes on Oxides of Nitrogen Emissions (All Households).

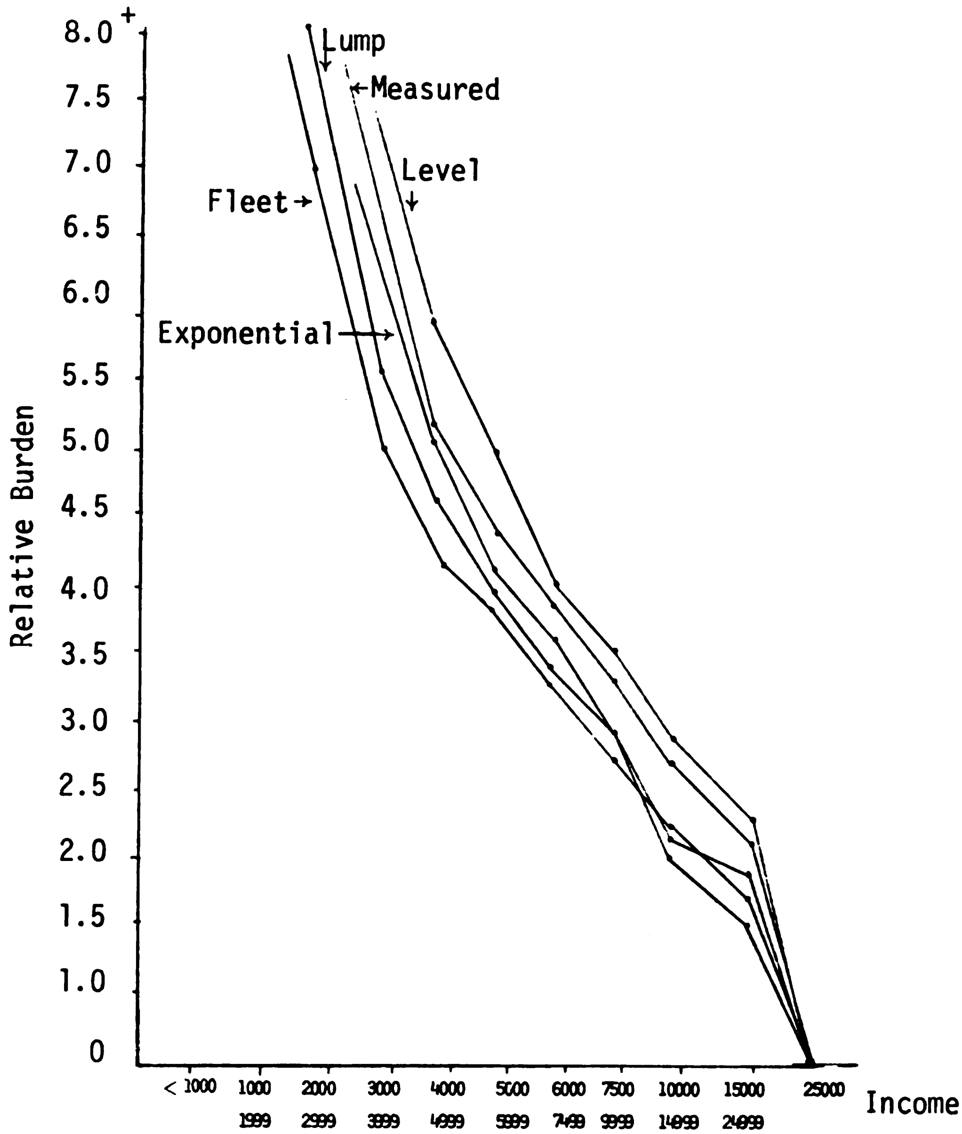

Figure 5.6A.--Relative Incidence of the Hypothetical Characteristic Taxes on Oxides of Nitrogen Emissions (Car-Owning Households).

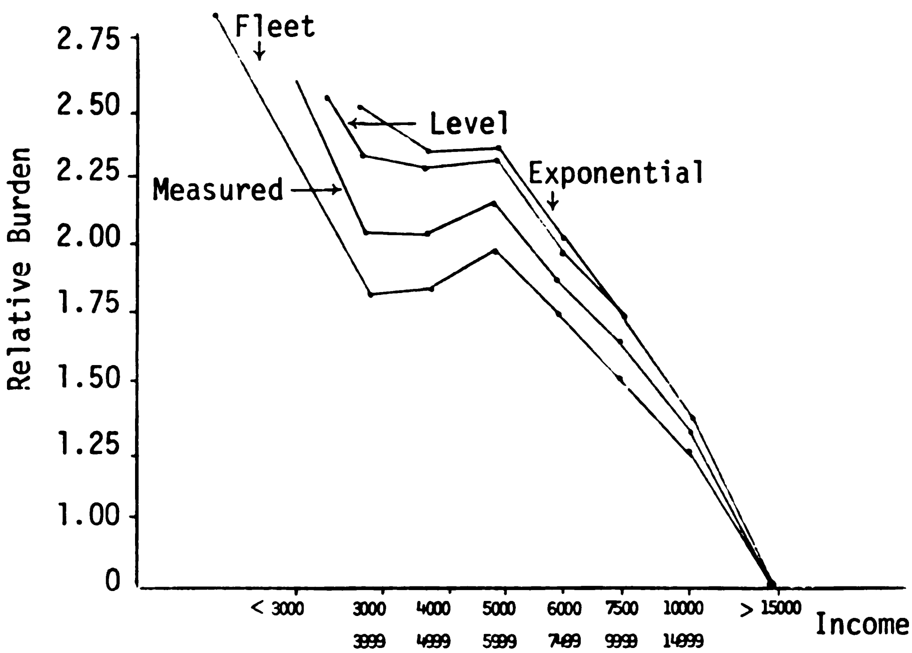

Figure 5.6B.--Relative Incidence of the Hypothetical Output Taxes on Oxides of Nitrogen Emissions (Car-Owning Households).

imposed on the lowest income class by the fleet average emission characteristic tax is 11.07 times as great as the burden imposed on the uppermost class when NO_X is taxed, 18.72 times as great when CO is taxed, and 21.07 times as great when HC is taxed. This lessening of relative burdens is a direct result of the deterioration of mean NO_X in late model automobiles (newer). As Table 3.6 revealed, mean emissions for older model year automobiles were generally lower than mean NO_X emissions for new, later model year automobiles. Further, the percentage of the fleet of a particular model year with emissions exempt from taxation declined with later model years. Given that the stock of automobiles owned by the lower income classes contain a greater proportion of older model year autos, the result, revealed by comparisons of the appropriate taxes, is a tendency for taxes based on oxide of nitrogen emissions to be less regressive than taxes based either on ownership or on CO or HC emissions.

The patterns of incidence of the various oxide of nitrogen output taxes are progressive throughout income classes \$3,000-\$5,999, slightly regressive or proportional through income classes \$6,000-\$14,999, and moderately regressive thereafter. The relative burden of the various taxes fell, unanimously, most heavily on the \$5,000-\$5,999 income category. The pattern of relative incidence is dominated, as was previously the case, by the rapid increases in annual per vehicle mileage driven. However, the progressivity is increased for income classes \$3,000-\$5,999 by the "progressive" distribution of NO_X emissions just described. The progressive impact of these factors moderates at incomes above $6,000 and a slightly regressive pattern once again dominates the distribution.

Table 5.6 and Figures 5.6A-B, the patterns of incidence resulting when the total tax liability is distributed across only car owners, reveals a pattern of regressivity more severe than when the burden is distributed across all households. The progressive patterns of the NO_X output taxes are severely lessened, and a nearly proportional pattern emerges for incomes less than $3,000-$5,999.

Conclusions

This chapter has presented various hypothetical tax schemes designed to internalize the external costs imposed upon the environment by consumers of automotive services. It has been shown that, as a byproduct of their automobile use, these individuals produce negative externalities, HC, CO, NO_X emissions, which degrade the environment and reduce a large number of the members of their social group's enjoyment of an unpolluted environment. The hypothetical taxes were imposed on the owners of polluting automobiles, thus forcing the individual to pay for the right to pollute, when emissions exceed the legislated standard. The various hypothetical taxes were constructed so that the structure and determination of the rate level encompassed a wide variety of tax schemes, including the lump sum and per unit variety. The various taxes were then applied to a tax base which identified the emission characteristics of polluting automobiles by model year and the ownership of these autos by income class, or to an appropriate scalar transformation thereof, and estimates of the short run relative incidence of each of the taxes were presented. The short run patterns of incidence of all hypothetical taxes based on emission characteristics, HC, CO, NO_X, separately, were shown to be regressive throughout all income categories regardless of whether incidence was measured per household or per car-owning household. Reference to the various summary tables permits comparison of the differences in regressivity of the taxes on HC, CO and NO_X by comparing the least regressive tax for each of the three pollutants and the most regressive. Of the three pollutants, taxation of NO_X is shown to be less regressive than taxation of either HC or CO. The burden of the characteristics taxation falls most heavily on the poor, although the burden borne by those classes is substantially less for NO_X taxation than for HC or CO taxation. The patterns of incidence of all of the hypothetical taxes on annual emission output of HC, CO and NO_X were found to be progressive through the lower-middle income classes (exclusive of the lowest income class) and became increasingly regressive as incomes rose above $6,000, when calculations were on an all household basis. When calculations were per car-owning household, all hypothetical taxes on the three pollutants exhibited patterns of incidence which were regressive throughout the income distribution, although the NO_X patterns were less regressive. The actual costs and incidence of each of the hypothetical taxes on each pollutant appear, and are discussed in detail, in Appendix B. The summary tables presented previously in the text were developed directly from the results presented in the Appendix.

The next chapter will consider likely behavioral responses to the various taxes in an attempt to estimate the longer run impact of the taxes proposed in this study. The chapter will also evaluate the various pollution taxes by comparing the results to those obtained by the U.S. tax system as a whole, the sales and excise portion of the U.S. tax system, and current pollution control strategies.

CHAPTER VI

BEHAVIORAL RESPONSES AND CONCLUSIONS

The previous chapters of this study have discussed in detail a technique for developing a tax base for a strategy that relies on taxation of emissions as a system for controlling automobile pollution. This tax base was then employed in an empirical study of the distributional consequences of various hypothetical taxes on pollution from private automobiles. Although the study was constrained to the short run due to data limitations, the results that were generated provided insight into the patterns of incidence of the various schemes. The primary purpose of this concluding chapter is to provide an evaluation of the various hypothetical taxes analyzed in this study. Although the primary concern of the study continues to be the incidence of the taxes, a complete evluation of the tax system requires the inclusion of questions of efficiency which are not addressed when a study focuses on equity.

The evaluation of the tax schemes will include consideration of the following:

1. Efficiency--Which of the hypothetical taxes is most likely to produce behavioral responses which achieve the desired level of pollution reduction? Since information is far from complete in this area, the evaluation will be qualitative rather than

quantitative. That is, behavioral responses which indicate movements toward a desired level of automobile pollution will be hypothesized, and the various tax schemes will be evaluated in terms of their likely effectiveness and ability to induce these responses.[1]

2. Equity--Are the patterns of incidence of the individual emission tax schemes significantly different from one another? Are they significantly more or less regressive than the pattern of incidence of similar federal taxes? of the current method of automobile pollution control, new car standards? The patterns of incidence will be compared and the patterns which are found to be least regressive in the short run will be presumed most equitable.[2]

Efficiency

The theory of public finance requires that an efficient tax system weigh both the benefits and costs of a control strategy and establish a level of taxation which equates the marginal private and social costs to the marginal private and social benefits. Beyond this a related criterion is often invoked that taxes should be as neutral as possible, since "unintended interference with the market mechanism may result in an excess burden which should be avoided"

---

[1]More specifically, this approach has been selected because the magnitude of the tax necessary to produce optimal results is unknown; data on a number of likely behavioral responses was unavailable, thus prohibiting estimates of responses even if tax costs were known.

[2]This is generally accepted, particularly in terms of ability to pay.

(Musgrave, 1958: 141). With respect to efficiency and automobile pollution, it has previously been suggested that the regulatory standards used in the study were promulgated in a manner which roughly satisfies the economic efficiency criteria.[3] Reductions in emissions, induced by the imposition of taxes, toward an acceptable level imply a movement toward a better utilization of scarce environmental resources. Further, with respect to neutrality and avoidance of excess burden, a tax on a negative externality is specifically designed to be non-neutral and interfere with the mechanism by which consumers arrive at their decisions. That is, the tax should impose the greatest excess burden on generators of the external diseconomy to be efficient.[4] In the context of automobile pollution, and for purposes of evaluation of the various taxes hypothesized in this study, the "best" hypothetical tax scheme is defined as that which is most likely to interfere with motoring decisions and induce behavioral changes which reduce total emission output toward the optimal level implied by the federal standard.

The hypothetical emission tax schemes presented in this study are designed to impose a social cost on the polluter and seek to induce behavioral responses which will reduce the total output of pollution attributable to the taxed individual. In so doing,

---

[3]Refer to note 1, Chapter V, p. 74.

[4]Since taxes of this type are not designed as revenue collection systems, the taxes are designed with hopes of generating minimum tax revenue.

a reduction in the annual pollution from automobiles will be achieved. The amount of this reduction depends upon a number of factors: (1) the magnitude of the tax, which will be determined by authorities; (2) the structural form of the tax; (3) the price and income elasticities of the various activities which will be affected by the tax induced rise in the total cost of automobile ownership and use; and (4) the individual[5] taxpayer's evaluation of the net benefits of paying for the right to continue polluting, or seeking to reduce or eliminate the tax burden by undertaking pollution reducing activities. Since many of these factors have not been quantified, the actual reduction in pollution attributable to the various taxes can only be roughly approximated by reference to the alternative activities that the various taxes are likely to induce.

In order to determine what alternatives are available to the automobile owner who is subject to the pollution tax, an identification of the determinants of the demand for automobile motoring is required. The primary determinants of motoring demand are the decision to own an automobile and the decision to utilize the automobile for a particular purpose. Numerous studies have been conducted regarding the decision to own an automobile.[6] A recent

---

[5]The emphasis on the individual's evaluation is due to the great variability of motoring behavior both across and within income classes.

[6]See, for example, J. R. N. Stone and D. Rowe, "The Market for Durable Goods," Econometrica 25 (1957): 423-443; Dan B. Suits, "The Demand for New Automobiles in the U.S.," ReStat 40 (Aug. 1958): 273-280; G. C. Chow, Demand for Automobiles in the U.S.: A Study in

study by Smith (1975), notable for its time series of cross-sections data base which is more extensive than other previous studies in this area, provides some insight into the likely impact of the hypothetical taxes on new car purchases. Smith suggests the conventional definition of new car demand (being composed of new net investment and replacement demand). He departs from the conventional definition of replacement demand, used car scrapping or depreciation, which requires an assumption of strong substitutibility between new and used car markets, and suggests that replacement demand be viewed as the process by which new car buyers trade in an older car for a new one every few years. Replacement demand, which has been found to account for a majority of post World War II new car demand, is specified by two components: (1) normal replacement pressure or the holding period for automobile ownership and (2) the timing of replacement which reflects the extent to which replacement demand is advanced or postponed in comparison with the normal pattern in response to economic conditions (Smith, 1975: 47-49). The author found that for the period 1950-69 normal replacement pressure was largely unchanged and, although there were large fluctuations in the timing of replacement, these fluctuations were not well explained by changes in relative prices (Smith, 1975: 48). Short run purchase behavior, reflected in the volatility of the timing of replacement,

---

Consumer Durables (N. Holland Publishing: 1957); H. Taylor and Houtaker, Consumer Demand in the U.S., 1929-70 (Cambridge: 1966); or a survey piece by A. Brown and A. Deaton, "Models of Consumer Behavior: A Survey," Economic Journal 82, No. 238 (Dec. 1972): 1145-1236.

was dominated instead by variations in the subjective state of expectations.[7] Since the hypothetical emission taxes will be unlikely to alter individual evaluations on the state of the economy (expectations), they will likely have little impact on the timing of replacement and short run purchases of new cars. Therefore, rapid increases in replacement demand and a resulting rapid change in the composition of the vehicle fleet is unlikely in the period immediately following the imposition of the taxes. Over the longer run, where more stable pressures of ownership and normal replacement dominate demand, the hypothetical taxes can be expected to contribute to an alteration in the composition of the automobile fleet because they will increase the costs of holding polluting automobiles relative to non-polluters. Since, in general, older automobiles (particularly those without emission controls) are higher polluters, their holding period will be reduced and the demand for new "controlled" automobiles will be enhanced.[8] These tenative conclusions suggest that the hypothetical emission taxes might have more immediate impact on the maintenance and use of automobiles subject to the emission taxes than on replacement per se.

What behavioral responses can be readily made by current owners of polluting automobiles in response to the imposition of the

---

[7]The subjective state of expectations' best proxies were the unemployment rate and the University of Michigan Survey of Consumer Confidence results.

[8]Clearly the amount of tax liability the individual is subject to and can avoid by trading in his polluting auto will determine the degree to which holding periods will be altered.

hypothetical taxes? Three responses, which are not necessarily mutually exclusive, can be hypothesized. First, the pollution taxes can potentially encourage maintenance of automobiles since a tune-up that saved the owner more on his pollution charge than it cost would provide a positive financial incentive for better maintenance. Second, the pollution taxes can potentially encourage the installation of systems which are designed solely to reduce emissions (retrofit systems) since a system that saved the owner more on his pollution charge annually than the sytem's annualized purchase and upkeep cost would find financial incentive in installing the system. Finally, the pollution charges would tend to reduce total mileage driven to the extent that the charge increases with additional mileage. Because the annual tax cost is higher for pollution prone automobiles, an additional incentive is provided for the worst polluters to reduce mileage driven the most. Each of these likely behavioral responses will be discussed in detail below, and potential reductions in emissions are presented where possible.

Maintenance

A wide range of literature and research have established that current consumer automobile maintenance practices do not keep the in-use vehicle population at the minimum emission levels which are capable of achievement.[9] In brief, it has been established that partly as a result of inadequate and improper maintenance, emissions

---

[9]A good summary of the literature can be found in "Control Strategies for In-Use Vehicles," U.S. Environmental Protection Agency, Office of Air and Water Programs, Mobile Source Pollution Control Program, Washington, 1972.

from pollution controlled vehicles (post-1968) in-use increase with accumulated mileage and at 50,000 miles are typically 20-40 percent above the level of emissions at low mileage (Grad et al., 1975: 232). It has also been established that significant reductions in aggregate emissions could be attained for all cars through an inspection/maintenance system which identifies specific engine components and adjustments which have significant effect on vehicle emissions and corrects these malfunctions and maladjustments (Horowitz, 1973: 395-398). As a result, a number of recent proposals have suggested the implementation of mandatory inspection/maintenance systems to reduce automobile emissions.

Improvements in maintenance of in-use vehicles can potentially be more readily achieved, at lower cost,[10] through imposition of some of the hypothetical emissions taxes discussed in this study. A tax charge linked directly to the emission characteristics of the automobile and payable by the auto owner will clearly provide incentive to undertake activities which reduce the tax liability.[11] Estimates of how much maintenance consumers will seek in response to the imposition of an emission tax at a certain level cannot be quantified due to data limitations. However, one can gain an indication of the impact of tax induced maintenance on the total annual output of automobile pollution by reviewing Table 6.1. The table

---

[10]Studies of mandatory inspection/maintenance as a method of pollution control have found this method to be cost ineffective.

[11]As long as the tax savings exceed the cost of maintenance.

TABLE 6.1.--Percent Reduction in Emissions Due to Proper Maintenance.[a]

Emission	Pre-1967	1967-1970	1971
HC	-10.1[b]	-13.8[b]	-1.0
CO	- 6.7[b]	- 7.3[b]	-8.7[b]
NO_X	+ 6.9	+ 2.8[b]	-2.3

[a]Substance of proper maintenance mentioned in text.

[b]Statistically significant reduction in emissions (90 percent level).

Source: N. A. Richardson, "The Economic Effectiveness of Mandatory Engine Maintenance for Reducing Vehicle Exhaust Emissions," CRC Extended Phase I Study, TRW Systems Group in support of APRAC Project CAPE-13 for the Coordinating Research Council, 1972, Table 2.7.

reveals that statistically significant reductions in hydrocarbon emissions from 10-14 percent and in carbon monoxide emissions ranging from 6-8 percent can be obtained immediately by the owner of a taxed automobile simply by insuring proper maintenance of his automobile.[12] Proper maintenance will usually involve an engine tune-up and includes replacing components of the ignition system, air cleaner filter, PCV valve, and making adjustments in the idle parameters (RPM, % CO, timing) approximately two or three times

[12]Numerous other studies on this topic are found to generate comparable results. For example, J. Panzer, "Idle Emissions Testing," SAE Paper 720937, Oct.,1972; or M. F. Chew, "Auto Smog Inspection at Idle Only," SAE Paper 690505, May, 1969.

per year.[13] Although these corrections would involve a cost to the automobile owner, it is likely that the reduction in emissions and resulting tax savings will more than offset the maintenance cost for those automobile owners subject to a large number of the hypothetical taxes proposed which tax the quantity of emissions directly.[14] For example, assuming annual tune-up costs are $100, the owner drives 10,000 miles per year, and his auto normally emits 75.0 grams/mile CO (about average for the fleet)--a hypothetical emission tax based on as little as 0.13 cents per gram CO output would produce tax savings to the automobile owner equivalent to the tune-up costs.[15]

Emission Reduction Systems

Devices that may be added or modifications that may be made to in-use vehicles for the purpose of reducing their emissions are referred to as retrofits. A wide variety of automobile retrofit devices are currently being produced commercially, ranging from a fairly simple device designed for vehicles with no emission controls to the more complex catalytic converter. The simplest and least expensive retrofit, the GM system, involves modifications in engine

---

[13]This approximation is based upon the N. A. Richardson study which showed HC, CO and NO_x emissions deteriorating by approximately 5-10 percent over four months of operation following a tune-up.

[14]This would be particularly true of the taxes which tax greater quantities of emissions progressively more heavily.

[15]Since tune-ups have other benefits, i.e., improved fuel economy, the tax could probably be far less than indicated.

operation which lower emissions. The modifications involve a carburetor adjustment which leans the idle air-fuel ratio, and adjustments in ignition timing and idle RPM (engine speed at idle). A thermostatic vacuum switch is added to prevent engine overheating.[16] The more complex catalytic converter system requires that a converter be installed in the engine exhaust system close to the exhaust manifold. The converter chamber contains a platinum or palladium pellet-type catalyst bed which reacts with and burns up HC and CO as the emissions pass through the bed.[17] Table 6.2 shows the reduction in emissions that can be achieved by an automobile owner wishing to reduce his emission tax liability by installing either of these retrofit systems.

TABLE 6.2.--Reductions in Emissions Via Retrofit.[a]

Emission	Catalyst	GM System	GM System[b]
HC reduction	68%	25%	25%
CO reduction	63%	9%	16%
NO_X reduction	48%	23%	22%
Installation cost	$90.00	$20.00	$20.00

[a]Vehicles tuned to manufacturers' specifications prior to test.

[b]Reduction from untuned state.

Source: Joel Horowitz, "Inspection and Maintenance for Reducing Automobile Emissions: Effectiveness and Cost," Journal of the Air Pollution Control Assn. 23 (1973): 397, Table II.

[16]This system is most suitable for pre-1968 automobiles.

[17]Control of NO_X requires an additional system be installed. The systems are as yet not commercially produced on a large scale.

The reductions in emissions are substantial for those owners of taxed automobiles who respond to the tax by retrofitting their automobile. The greatest reductions in all three emissions can be achieved by installation of a catalytic converter. However, since the converter is the most expensive retrofit system, the choice of retrofit system actually installed will depend heavily on the automobile owner's evaluation of the annual cost of the system (maintenance cost of the catalyist is twice that of the GM system) and the value, in terms of reduced tax liability of the resulting reduction in emissions.[18] Clearly, the structure of the tax which the installer of a retrofit system seeks to avoid is crucial to the above evaluation. For example, the lump sum form of the tax will encourage retrofitting only to the extent that emissions can be reduced below the standards and thereby become exempt from taxation, whereas the exponential emissions taxes provide incentive to reduce emissions on a gram basis with large reductions producing proportionally greater tax savings than smaller reductions.

Vehicle Mileage Driven

Studies in the demand for motoring almost unanimously show a low price elasticity of demand.[19] As such, the implication is usually drawn that vehicle miles traveled (and thus pollution output)

---

[18]It might also depend on the ability of the owner to capitalize his retrofit investment cost into the value of the used car at time of trade-in or resale.

[19]A summary of these results can be found in S. Wildhorn, How to Save Gasoline, prepared for the National Science Foundation, R1560-NSF, 1974.

can be reduced only through large increases in motoring costs, and that in general the result of increased motoring cost in the short run is simply to increase expenditures on motoring with little reduction in pollution output. A number of authors have recently suggested an explanation which leads to an alternative conclusion. Since demand for transportation is usually a derived demand arising from the desire to be at a certain place at a certain time, the factors a person considers when weighing trip decisions include not only monetary costs, but also other travel parameters such as waiting time, travel time, comfort, etc. (Dewees, 1975: 86-94). Further, monetary costs can be divided into fixed costs (insurance, etc.) and variable costs. Within variable costs, certain major costs (depreciation, maintenance, tires, etc.) are not perceived by motorists as variable with mileage driven. Since these non-monetary and unperceived variable costs represent a large portion of total trip cost, studies on the demand for motoring which contain as independent variables only perceived monetary costs will necessarily produce lower price elasticities than would be the case if perceptions changed to include hitherto unperceived costs. The alternative conclusion is that actual reductions in mileage driven brought about by a rise in the cost of motoring (through taxation per mile) may be greater than is suggested by current low price elasticity estimates since it is likely that motorists will perceive the gram per mile taxes as variable costs of motoring. In either event, emission output taxes can be expected to discourage non-essential driving, with greatest reductions in mileage driven expected from owners of automobiles that pollute the most since the marginal costs of motoring per mile will be significantly higher for this group and the pollution charge will be a greater proportion of their total motoring costs.

Evaluation

Table 6.3 presents estimates of the degree to which each of the hypothetical emission taxes will succeed in inducing the behavioral responses discussed in the previous pages. The evaluation is solely in terms of the structure of the taxes and the resulting probability that the structure can induce the responses as elaborated.

Tentative conclusions from the table and the previous discussion are (1) the emission output forms of the hypothetical taxes are likely to be the most effective forms of the tax; (2) within the output taxes, the tax scheme which bases tax liability on the fleet's average emissions may produce a pollution "free rider" problem, since maintenance activities of the individual cannot guarantee any reduction in tax liability unless all owners of the fleet of that model year undertake such activities; (3) the least effective forms of the tax are the emission characteristics taxes, which provide incentive to reduce gram emissions without providing incentive to reduce total mileage driven; and (4) within the emission characteristics taxes, the lump sum (license) will be the least effective since it is likely to affect the choice of vehicle only.

TABLE 6.3.--Evaluation of the Hypothetical Emission Taxes--Effectiveness.

Behavioral Response	Characteristic					Output			
	Lump Sum	Fleet Ave.	Measured Emission	Level of	Expon. Level	Ave. Fleet	Measured Output	Level of	Expon. Level
Choice of automobile	a	b	a	a	a	b	a	a	a
Improve maintenance	b	b	a	a	a	b	a	a	a
Install retrofit	b	b	a	a	a	b	a	a	a
Reduce mileage driven	c	c	c	c	c	a	a	a	a

a = effective
b = effective only if emissions can be reduced below the standard
c = not effective, and/or free rider problem

Feasibility

While the question of feasibility of a pollution tax system was not addressed directly in this dissertation because the solution depends as much upon rapidly changing legal and political realities as it does upon existing technology, a number of oft mentioned drawbacks of the "charges" approach require consideration. The drawbacks usually mentioned are (1) the large amount of information necessary to set the optimal tax rate or optimal emission standard makes these systems impractical, and (2) the administrative costs involved in monitoring emissions and imposing the proper charge on the emitter are exceedingly high.

While emission charges set to reflect precisely damage caused by pollution would theoretically be ideal in terms of achieving the most efficient allocation of resources, such precision is not necessary for emission charges to be desirable. Charges which are set too high or too low in terms of the optimal rate will result in an enforcing level of air pollution which is too high or too low. However, this can be readily adjusted through changes in the tax rate, with the burden of responsibility for meeting the specified level of pollution distributed among polluters in a least cost manner (Baumol, 1962: 319-327). The excessive administrative cost mentioned in drawback (2) above is usually associated with the implicit assumption that to impose the appropriate charge on the emitter it is necessary to continuously monitor the level of emissions, and, further, that the appropriate monitoring technology is not available at reasonable cost. Again, this drawback is based on theoretically ideal circumstances. In reality, institution of mandatory annual inspection where mileage driven is recorded and actual levels of emissions in-use are measured provides a sufficient approximation to the ideal. Exhaust gas analyzers (including portable varieties) required for emission measurement are currently commercially produced at reasonable cost. Further, annual inspection is currently mandatory in a number of states as is automobile emission testing.[20] Procedures for implementing annual inspection are, therefore, available, and extension of mandatory emission inspection to all states should be feasible. The annual tax levy can be collected at time of annual inspection or declared, subject to possible audit verification, on the annual income tax statement. Although no estimates of the administrative costs of either method of tax collection is available, they should not exceed current costs of collecting sales or excise taxes.

Equity

The imposition of any tax system may impact on the uses of individual incomes in either of three ways: (1) the ratio of the tax to income may fall as incomes rise (regressivity); (2) the ratio of tax to income may rise as incomes rise (progressivity); or (3) the ratio of tax to income may be the same for all income classes (proportionality). The results of the study indicated that the structural form of the tax schemes and ownership patterns were

---

[20]This includes California, Colorado, Arizona, Oregon, New York State, Washington, D.C., Cincinnati and New Jersey.

of primary importance to the resulting patterns of tax incidence. In general, taxation based on emission characteristics produced a pattern of incidence which was regressive throughout the income distribution, whereas taxation based on emission output produced a pattern of incidence which was progressive through the lower-middle income classes, becoming regressive only at incomes in excess of $6,000 (in 1971 dollars). Since it is generally agreed that a tax system which can be designed to yield incidence patterns which are progressive (and in this case achieve at least the same efficiency results) is more equitable and preferred to one whose incidence patterns are regressive, it may be concluded that the emission output taxes will be preferred to emission characteristic taxes on equity grounds.

How do the hypothetical taxes compare, in terms of incidence patterns, to the patterns of (1) currently existing federal taxes and (2) alternative systems for controlling automobile pollution? A comparison of this study's tax scheme with existing federal taxes will be made with reference to the 1974 Pechman and Okner study, Who Bears the Burden? An evaluation in the context of alternative control methods will be made by reference to the 1975 study by Nancy Dorfman, "Who Will Pay for Pollution Control?"

The purpose of the Pechman and Okner study of the U.S. tax system was to estimate the effect of all U.S. taxes on the distribution by size of income and by other characteristics of the tax-paying population (Pechman and Okner, 1974: 2). The study was performed utilizing a sample of 72,000 families which were representative of the demographic and economic distribution of U.S. families in 1966. Of particular relevance to an evaluation of the "burden" imposed by this study's hypothetical taxes are the patterns of incidence reported by Pechman and Okner for the entire federal system and for the federal sales and excise taxes.[21] Comparisons of the overall patterns of incidence of these taxes with the proposed taxes of this study appear in Table 6.4. As can be seen from the table, the relative burden imposed on the money income groups is greater for the lump sum and measured hydrocarbon emission characteristic taxes[22] than the relative burden of either the total federal system or the federal sales and excise taxes. The characteristic taxes produce relative burdens which are strongly regressive throughout, whereas the total federal system and sales and excise taxes display patterns of incidence which are proportional or slightly progressive and mildly regressive, respectively. As such, introduction of the emission characteristic forms of the taxes into the total tax system would contribute to a reduction in the slight progressivity that currently exists. The evaluation is different for the emission output taxes.[23] These taxes produced a pattern of

---

[21]Pechman and Okner adjust money income for capital gains and non-money income. This results in strict noncomparability at both extremes of the distribution between the two study's results.

[22]The results for the other characteristic taxes are nearly identical and have been omitted.

[23]The relative burdens are similar for HC and CO and differ only in magnitude for NO_X. Therefore only one representative tax was necessary.

TABLE 6.4.--Relative Burdens of Various Taxes.

Income ($)	Tax				
	Total Federal[a]	Sales & Excise[a]	Lump Sum HC	Measured Hydrocarbon	Exponential Output Hydrocarbon
< 3,000	.62	2.9	6.0	6.5	2.6
3,000- 4,999	.68	2.3	4.8	5.1	2.2
5,000- 9,999	.75	2.0	3.4	3.5	2.3
10,000-14,999	.76	1.7	2.6	2.6	1.5
15,000-24,999	.78	1.4	1.9	1.9	1.0
25,000 +	1.0	1.0	1.0	1.0	--

[a]Calculated from Joseph Pechman and Benjamin Okner, Who Bears the Tax Burden? (Washington, D.C.: The Brookings Institution, 1974), Table 4-8, p. 59.

incidence which was strongly progressive throughout the lower-middle income classes, exclusive of the lowest income class, regressive thereafter. Although this pattern is obscured in Table 6.4 because of the necessity to generate relative burdens for the wide income intervals used by Pechman and Okner, these forms are clearly less regressive overall than the sales and excise taxes. Further, for those income categories where the tax is progressive, it is generally more progressive than the total federal system.[24] As such, the introduction of the emission output taxes into the total federal

[24]This is more apparent if one refers back to Chapter V where results are broken down into smaller income intervals.

system will tend to improve the system's progressivity, particularly in the lower-middle income categories.

A recent study by Nancy Dorfman (1975: 81-100) attempted to estimate the burden of the current national environmental control program borne by the various income groups in the U.S. The chief empirical base for the distribution by income classes was identical to that of the Pechman study, the MERGE[25] file. The third section of her study presents estimates of the incidence of the costs of automobile emission control based upon current federal emission control strategy, i.e., enforcing emission standards on new cars only. Estimates of incremental costs of antipollution measures were obtained from the Environmental Protection Agency and initial automobile driving and ownership patterns were obtained from the Department of Commerce P-65 Series (May 1972) and the Federal Highway Administration's National Personal Transportation Survey (April 1972), respectively. Although the study presents incidence patterns in 1976, the similarity of data sources used in that study with those utilized in the current study provide an opportunity to compare the respective patterns of incidence and evaluate the burden imposed by current federal policy with reference to the various hypothetical automobile pollution taxes.

The distribution of federally mandated emission control costs in 1976 are found to be extremely regressive, much more regressive than the pattern of incidence of the federal sales tax (Dorfman,

[25]A description of this file can be found in Pechman and Okner (1974).

1975: 155). It appears that the burden of current emission control is nearly 3.5 times greater for the lower-middle income classes than it is for the uppermost classes (Dorfman, 1975: Table 6). As such, the pattern of incidence of the current emission control program appears similar to that of the lump sum and measured emission characteristic taxes herein studied, both of which fall far short of what is generally regarded as equitable. Reference to Figure 6.1 below, which presents the results of Dorfman's study, and to the tables and charts of Chapter V confirms the similarity of the patterns of incidence noted above.

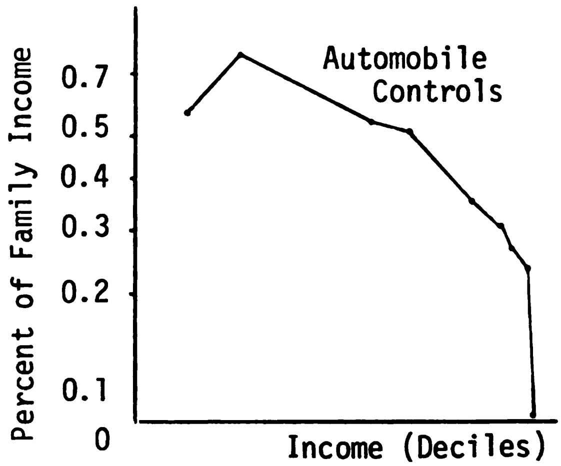

Figure 6.1.--The Burden of Automobile Control Costs.

<u>Source</u>: Nancy Dorman, "Who Will Pay for Pollution Control?--The Distribution By Income of the Burden of the National Environmental Protection Program," <u>National Tax Journal</u> 28 (1974): 113.

Summing Up

This study has presented an empirical investigation into the static incidence of a system for controlling automobile pollution. The system of control relied on the imposition of various taxes on owners of polluting automobiles. These hypothetical taxes were imposed on the automobile owner when emissions from his automobile exceeded a specified acceptability standard, thereby providing incentive for the polluter to reduce his pollution generating activities. The initial chapters of the study documented the magnitude of the environmental hazard created by automobile pollution, examined the functioning of the internal combustion engine and described the process of formation of the emissions which were of importance to the study. The discussion of data on in-use emissions and automobile ownership revealed (1) the trend in the emission distributions over time was for improved CO and HC distributions and for deterioration in the NO_X emission distribution; (2) a majority of all households with annual money incomes in excess of $2,000 owned an automobile; and (3) ownership of late model (new) automobiles is strongly dependent upon money income. These findings were embodied in the four-dimensional system of matrices which formed the tax base for the study, and were the major determinants of the pattern of short run incidence generated through the imposition of the various hypothetical taxes.

The short run patterns of incidence of all hypothetical taxes based on emission characteristics were shown to be regressive throughout all income categories regardless of whether incidence was measured per household or per car-owning household. A comparison of the differences in regressivity of the taxes on HC, CO, and NO_X revealed that taxation of NO_X produced the least regressive burdens. The pattern of incidence of all hypothetical taxes on annual emission output of HC, CO, and NO_X were found to be progressive through the lower-middle income classes (exclusive of the lowest income class), becoming increasingly regressive as incomes rose above $6,000 when calculations were on an all household basis. When calculations were per car-owning household, all hypothetical taxes displayed regressive incidence patterns, although the NO_X patterns were less regressive than those of either the HC or CO taxes.

These short run patterns of incidence were compared to the patterns of incidence of selected federal taxes and current methods of emission control. Results of the comparisons revealed similar distributions of tax burdens. Many of these patterns were strongly regressive, in terms of "ability to pay," and inequitable. Only patterns of incidence of the emission output taxes revealed ranges of progressivity. As such, one may tentatively conclude that, other things being equal, the emission output taxes are preferable to the other hypothesized taxes.

Potential behavioral responses to the imposition of the various taxes were then discussed and estimates of potential reductions in the total automobile pollution output were calculated where possible. The lack of adequate data prevented quantitative evaluation of the impact of the various taxes over time, although indications as to the likely effectiveness of the various taxes in inducing desirable behavioral responses were presented. The admittedly tentative conclusion reached was that the emission output taxes would be the most effective taxes since they impacted on more of the factors taken into consideration by consumers in their motoring decisions than the characteristic taxes. Further research in this area, however, would be desirable.

SELECTED BIBLIOGRAPHY

SELECTED BIBLIOGRAPHY

Altschuller, A, P., and McPherson, S. P. "Spectrophotometric Analysis of Aldehydes in the Los Angeles Atmosphere." Journal of the Air Pollution Control Association 13 (March 1963): 109-111.

Babcock, L. R. "A Combined Pollution Index for Measurement of Total Air Pollution." Journal of the Air Pollution Control Association 20 (October 1970): 653-657.

Baumol, W. J. "On Taxation and the Control of Externalities." American Economic Review 62 (June 1962): 319-327.

Brown, A., and Deaton, A. "Models of Consumer Behavior: A Survey." Economic Journal 82 (December 1972).

Buchanan, J., and Stubblebine, W. "Externality." Economica 29 (1962): 372.

Chew, M. F. "Auto Smog Inspection at Idle Only." Society of Automotive Engineers Paper 690505 (May 1969).

Chow, Gregory. Demand for Automobiles in the U.S.: A Study of Consumer Durables. Amsterdam: N. Holland Publishing Co., 1957.

Coordinating Research Council. "Experimental Characterization of Vehicle Emissions and Maintenance States." A Study of Mandatory Engine Maintenance for Reducing Vehicle Exhaust Emissions, Vol. VIII (July 1973), 2-77.

Council on Environmental Quality. Environmental Quality 1971. Washington, D.C.: Government Printing Office, 1972.

Daniel, W. A. "Flame Quenching at the Walls of an Internal Combustion Engine." 6th Symposium on Combustion (1957), p. 882.

Dewees, Donald N. Economics and Public Policy: The Automobile Pollution Case. Cambridge: MIT Press, 1974.

Dinman, B. "Basic Physiological of Carbon Monoxide." Medical Aspects of Air Pollution. New York: SAE, 1971, pp. 36-39.

Dorfman, Nancy. "Who Will Pay for Pollution Control?--The Distribution By Income of the Burden of the National Environmental Protection Program." National Tax Journal 28 (1974): 113.

Horowitz, Joel. "Inspection and Maintenance for Reducing Automobile Emissions: Effectiveness and Cost." Journal of the Air Pollution Control Association 23 (1973): 397.

Houthakker, H., and Taylor L. Consumer Demands in the U.S.: 1929-70. Cambridge: Harvard University Press, 1966.

Larsen, R. "Air Pollution from Motor Vehicles." Annals of the New York Academy of Science 136 (August 1966): 281-287.

Musgrave, R. The Theory of Public Finance: A Study in Public Economy. New York: McGraw Hill, 1959.

Musgrave, R. A., and Musgrave, P. B. Public Finance in Theory and Practice. New York: McGraw Hill, 1973, Chapter 15.

Panzer, J. "Idle Emissions Testing." SAE Paper 720937. New York: Society of Automotive Engineers, 1972.

Patterson, D. J., and Henein, N. A. Emissions from Combustion Engines and Their Control. Ann Arbor: Ann Arbor Science Publishers, 1972.

Pechman, Joseph, and Okner, Benjamin. Who Bears the Tax Burden? Washington, D.C.: The Brookings Institution, 1974.

Pigou, A. C. Economics of Welfare, 4th ed. London: 1932.

Richardson, N. A. "The Economic Effectivenss of Mandatory Engine Maintenance for Reducing Vehicle Exhaust Emissions." CRC Extended Phase I Study, TRW Systems Group in support of APRAC Project CAPE-13 for the Coordinating Research Council, 1972.

Shy, Carl, et al. "The Chattanooga School Children Study: Effects of Community Exposure to Nitrogen Dioxide." Journal of the Air Pollution Control Association 28 (August 1970): 539-545.

Smith, R. K. Consumer Demand for Cars in the U.S. Occasional Paper 44, Cambridge, 1975.

Springer, G. S., and Patterson, D. J. Engine Emissions: Pollutant Formation and Measurement. New York: Plenum Press, 1973.

Stein, J. L. "Priorities and Pollution: Reply." American Economic Review 64 (September 1974): 718-723.

U.S. Department of Commerce, Bureau of the Census. Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

________. Car Ownership by Model Year and Selected Household Characteristics: July 1971, Special Tabulation, 1974.

________. Consumer Buying Indicators, P-65 Series, No. 40 (May 1972).

U.S. Environmental Protection Agency, Air Pollution Control Office. Air Quality Criteria for Oxides of Nitrogen. Washington, D.C.: Government Printing Office, 1971, 7-7.

U.S. Environmental Protection Agency, Office of Air and Water Programs. Mobile Source Pollution Control, Control Strategies for In-Use Vehicles. Washington, D.C.: Government Printing Office, 1972.

________. A Study of Emissions from Light Duty Vehicles in Six Cities. Publication No. APTD-1497. Ann Arbor: EPA, 1973.

U.S. Federal Register 35, No. 219, November 10, 1970.

U.S. Federal Register 36, No. 128, July 2, 1971.

U.S. Health, Education and Welfare, Department of Public Health Service. Air Quality Criteria for Hydrocarbons. Washington, D.C.: Government Printing Office, 1970, 7-8.

________. Air Quality Criteria for Carbon Monoxide. Washington, D.C.: Government Printing Office, 1970.

U.S. Transportation Department. National Personal Transportation Study, Report No. 2. Washington, D.C.: Government Printing Office, April 1972, Table 5.

Walther, E. G. "A Rating of Major Air Pollutants and Their Sources by Effect." Journal of the Air Pollution Control Association 20 (September 1972): 727.

Wildhorn, S. How to Save Gasoline. Prepared for the National Science Foundation, R1560-NSF, 1974.

APPENDICES

APPENDIX A

SAMPLE PINDEXING CALCULATION

APPENDIX A

SAMPLE PINDEXING CALCULATION

The Pindexing technique is illustrated in the example below. Although not shown separately, the oxidant and synergism terms were calculated and added back into their respective precursors prior to determining the percentage of the grand total shown in Table 1.2.

1. Given information

Particulate Matter	(PM)	= 143.0 $\mu g/m^3$
Sulfur Oxides	(SOX)	= 123.0
Nitrogen Oxides	(NOX)	= 136.0
Carbon Monoxide	(CO)	= 7250.0
Hydrocarbons	(HC)	= 2157.0
Oxidant	(OOO)	= 43.2
Solar Radiation	(SR)	= 400.0 cal/cm^2 day

2. Convert reactants to $\mu mol/m^3$

NOX = 136.0/46.0 = 3.0 $\mu mol/m^3$
HC = 2157.0/16.0 = 134.5
OOO = 43.2/48.0 = 0.9

3. Determine limiting reactant for oxidant synthesis (NOX or HC): NOX is limiting.

4. Create Oxidant

OOO = 0.0006 x SR x (limiting reactant)
OOO = 0.006 x 400.0 x 3.0 = 0.72 $\mu mol/m^3$

5. Determine total oxidant and excess HC and NOX:

OOO = 0.9 + 0.72 = 1.6 $\mu mol/m^3$
HC = 134.5 - 0.72 = 133.8
NOX = 3.0 - 0.72 = 2.3

6. Convert reactants back to weight basis

```
OOO =   1.6 x 48.0 =   77.3
HC  = 133.5 x 16.0 = 2140.0
NOX =   2.3 x 46.0 = 105.0
```

7. Apply tolerance factors

```
PM  =  143.0/  375.0 = 0.381
SOX =  123.0/ 1430.0 = 0.086
NOX =  105.0/  514.0 = 0.204
CO  = 7250.0/40000.0 = 0.181
HC  = 2140.0/19300.0 = 0.111
OOO =   77.3/  214.0 = 0.361
```

8. Determine synergism term (SYN)

SYN = SOX or PM (whichever is smaller)
SYN = SOX = 0.086

9. Add oxidant levels and synergism term into their precursors

10. Determine % of grand "Pindexed" total

Source: L. R. Babcock, "A Combined Pollution Index for Measurement of Total Air Pollution," Journal of the Air Pollution Control Association 20 (October 1970): 653-657.

APPENDIX B

THE COSTS AND INCIDENCE OF THE HYPOTHETICAL POLLUTION TAXES

APPENDIX B

THE COSTS AND INCIDENCE OF THE HYPOTHETICAL POLLUTION TAXES

The costs and incidence of the various taxes for each of the taxed pollutants are presented in the following pages. The summary tables presented in the text of Chapter V were prepared directly from the results appearing in this appendix.

Hydrocarbon Results

Tables B.1 through B.5 show the estimated cost and short run incidence of the various hypothetical taxes imposed on the hydrocarbon emission characteristics of polluting automobiles. In general, the cost per household for each of the hypothetical taxes increases as money income rises. The pattern of incidence of each of the taxes is regressive throughout all income classes, with the implicit tax rate declining rapidly through the first three income categories (increasing regressivity), declining at a fairly constant rate through income categories \$3,000-\$3,999 to \$5,000-\$5,999 and again declining rapidly through the remainder of the income distribution. The cost per car-owning household for each of the hypothetical taxes is generally higher at the upper end of the income distribution than it is at the middle and lower ends of the distribution, although the range in cost across the income distribution is much narrower when measured on a per car-owning household basis than it is when measured on a per household basis.[1] The pattern of incidence, measured on a <u>per owner</u> basis, is also regressive throughout the entire income distribution. However, it is more regressive at the lower income categories than when the incidence is measured on a per household basis.[2]

The cost <u>per household</u> of the lump sum tax, Table B.1, ranges from 33¢ at the lowest income category to $1.30 at the highest income category. This result is expected since the number of units per household subject to the lump sum tax generally increases at higher income categories, even though the proportion of their fleet subject to the hydrocarbon tax declines. The pattern of incidence is regressive throughout the entire distribution, with the implicit tax rate declining from 0.061% at the lowest income category to 0.004% at the uppermost income class. The short run burden of the lump sum form of the tax is 15 times greater for the lowest income class than it is for the uppermost income class.[3] Even if

---

[1]Since a smaller percentage of all households in the low income categories own cars (30 percent own in the less than $1,000 class) than own cars in the upper income categories (94.7% own in the $25,000 and above class), the total cost is spread over proportionately fewer households raising the cost per owner at the lower end proportionately greater than at the upper end and narrowing the cost range.

[2]See Table 3.7, Chapter II of this study and the explanation in note 1, above.

[3]These relative burdens will be unchanged for any magnitude of the tax (i.e., $1.00 fee, $2,00 fee, etc.) although the absolute burdents will change proportionately. This applies to all future statements regarding relative burdens. The arbitrary unit chosen for the tax rate is $1.00 for HC and NO_X and $.10 for CO.

TABLE B.1.--The Costs and Incidence of Lump Sum Taxation of Hydrocarbon.

Household Money Income	All Households				Car-Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $1,000	547	1,924	0.334	0.061	580	1.11	0.202
$1,000- $1,999	1,505	4,252	0.384	0.026	1,661	0.98	0.065
$2,000- $2,999	2,487	4,563	0.534	0.022	2,389	1.02	0.041
$3,000- $3,999	3,478	5,095	0.64	0.018	3,245	1.01	0.029
$4,000- $4,999	4,502	4,505	0.79	0.017	3,426	1.04	0.023
$5,000- $5,999	5,466	4,805	0.86	0.016	3,906	1.05	0.019
$6,000- $7,499	6,710	6,646	0.95	0.014	5,808	1.09	0.016
$7,500- $9,999	8,561	9,346	1.06	0.012	8,517	1.16	0.014
$10,000-$14,999	12,106	12,769	1.18	0.010	12,082	1.25	0.010
$15,000-$24,999	18,514	6,792	1.33	0.007	6,561	1.38	0.007
$25,000 and over	35,326	1,914	1.30	0.004	1,812	1.37	0.004

[a]Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

one omits the lowest income class, for which overstatement of the burden is likely, the burden on the $1,000-$1,999 income class is still seven times as great as that on the above $25,000 class.

The cost per owner of the tax ranges from a low of 98¢ at income category $1,000-$1,999 to $1.38 at the uppermost category. The range is narrower than that measured on a per household basis because the costs are spread over fewer households as income declines. The pattern of incidence is most regressive at the lower end of the income distribution, with the implicit tax rate declining from 0.202% at the lowest income category to 0.004% at the uppermost income category. The short run burden of the tax is 53 times as great as the burden borne by the uppermost income class for owners of polluting automobiles in the less than $1,000 category, 17 times as great for owners in the $1,000-$1,999 category and 10 times as great for owners in the $2,000-$2,999 income class.

The cost per household of the hypothetical tax based on average fleet emissions, Table B.2, ranges from $2.65 at the lowest income category to $9.12 at the $15,000-$24,999 income category. The pattern of incidence displayed is extremely regressive at the low income categories, mildly regressive in the middle income categories and increasingly more regressive at the upper end of the income distribution. The implicit tax rate declines from 0.485% to 0.023% as income rises. The short run burden of the tax on the lowest income category is 21 times greater than that borne by the uppermost income category and 5 times greater than that borne by the $5,000-$5,999 income class. The cost per owner of the

TABLE B.2.--The Cost and Incidence of a Fleet Average Hydrocarbon Output Tax.

Household Money Income	All Households				Car-Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $1,000	547	1,924	2.65	0.485	580	8.80	1.610
$1,000- $1,999	1,505	4,252	3.15	0.209	1,661	8.06	0.540
$2,000- $2,999	2,487	4,563	4.28	0.172	2,389	8.18	0.327
$3,000- $3,999	3,478	5,095	5.08	0.146	3,245	7.97	0.225
$4,000- $4,999	4,502	4,505	6.09	0.135	3,426	8.00	0.178
$5,000- $5,999	5,466	4,805	6.11	0.112	3,906	7.52	0.138
$6,000- $7,499	6,710	6,646	7.09	0.106	5,808	8.12	0.121
$7,500- $9,999	8,561	9,346	7.80	0.091	8,517	8.56	0.100
$10,000-$14,999	12,106	12,769	8.38	0.069	12,082	8.86	0.073
$15,000-$24,999	18,514	6,792	9.12	0.049	6,561	9.44	0.051
$25,000 and over	35,326	1,914	8.21	0.023	1,812	8.67	0.025

[a]Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

hydrocarbon tax ranges from a low of $7.52 at income class $5,000-$5,999 to a high of $9.44 at income class $15,000-$24,000. The lack of a discernible pattern to the cost <u>per owner</u> of this tax reflects the competing influences of changes in the percentage of households owning, numbers of autos owned, and fleet emissions across income categories. The pattern of incidence is regressive throughout the income distribution, being most extreme at the lower end of the distribution where the burden of the tax on owners of hydrocarbon polluting automobiles in the less than $1,000, $1,000-$1,999, and $2,000-$2,999 income classes is 65 times, 22 times and 13 times, respectively, as great as the burden in the uppermost income categories.

The cost <u>per household</u> of the measured emissions characteristics tax, Table B.3, increases from $2.62 to $9.50 as income rises. The pattern of incidence is regressive throughout with the implicit tax rate declining from 0.48% and 0.21%, at the lowest and next lowest income categories, to 0.027% at the $25,000 and above category. This represents a short run tax burden 18 times and 7 times, respectively, as great for these low income classes relative to the burden imposed on the uppermost income class. The cost per <u>car-owning household</u> falls within a narrow range bounded by $7.91 and $9.75, and exhibits no clear pattern across income classes. The pattern of incidence is more regressive than the pattern exhibited by the per household incidence, with the burden of the tax falling most heavily on the lower income categories. The implicit tax rate ranges from 1.59% of household income at the less than $1,000

TABLE B.3.--The Cost and Incidence of a Measured Emission Tax on Hydrocarbon.

Household Money Income	All Households				Car-Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $1,000	547	1,924	2.62	0.480	580	8.72	1.590
$1,000- $1,999	1,505	4,252	3.09	0.210	1,661	7.92	0.520
$2,000- $2,999	2,487	4,563	4.23	0.170	2,389	8.09	0.324
$3,000- $3,999	3,478	5,095	5.04	0.140	3,245	7.91	0.227
$4,000- $4,999	4,502	4,505	6.08	0.135	3,426	7.99	0.178
$5,000- $5,999	5,466	4,805	6.50	0.118	3,906	8.00	0.146
$6,000- $7,499	6,710	6,646	7.08	0.105	5,808	8.10	0.116
$7,500- $9,999	8,561	9,346	7.86	0.091	8,517	8.64	0.100
$10,000-$14,999	12,106	12,769	8.47	0.069	12,082	8.96	0.070
$15,000-$24,999	18,514	6,792	9.42	0.051	6,561	9.75	0.052
$25,000 and over	35,326	1,914	9.50	0.027	1,812	9.50	0.027

[a]Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

class to 0.027% at the uppermost income class. The implicit tax rate is nearly 60 times as great for the lowest income category; the burden clearly falls heaviest on the lower income classes.

Table B.4 exhibits the cost and incidence of the hydrocarbon tax based on a level of emissions characteristic. The cost per household and per car-owning household ranges from \$14.42-\$46.72 and \$42.50-\$48.36, respectively. The patterns of incidence calculated under both methods of cost bearing are regressive throughout. The implicit tax rate per household declines continuously as income rises, from an implicit rate of 2.636% and 1.148% to an implicit rate of 0.117%. This implies a tax burden on the lowest two income classes which is 23 times and 10 times, respectively, the burden borne by the \$25,000 and above income class. The implicit tax rate per owner falls from 8.64% and 2.94% at the lowest two income categories to 0.123% at the uppermost income category, representing burdens relative to the uppermost income class of 71 times and 24 times as great.

Table B.5 presents the costs and incidence of the hypothetical hydrocarbon characteristic tax based on an exponential rate. The costs per household range from \$173.36 to \$526.51 and generally increase as income increases. The incidence on a per household basis is extremely regressive with the implicit tax rate declining from a high 31.69% of household money income at the less than \$1,000 class to only 1.24% at the \$25,000 and more class. The relative burden on the lower income categories ranges as high as 25 times as great as the burden placed on the upper income

TABLE B.4.--The Cost and Incidence of a Level of Emissions Tax on Hydrocarbon.

Household Money Income	All Households				Car-Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $1,000	547	1,924	14.42	2.636	580	47.83	8.643
$1,000- $1,999	1,505	4,252	17.27	1.148	1,661	44.22	2.940
$2,000- $2,999	2,487	4,563	23.33	0.938	2,389	44.56	1.790
$3,000- $3,999	3,478	5,095	27.60	0.793	3,245	43.34	1.246
$4,000- $4,999	4,502	4,505	32.74	0.727	3,426	43.05	0.956
$5,000- $5,999	5,466	4,805	34.55	0.631	3,906	42.50	0.777
$6,000- $7,499	6,710	6,646	37.44	0.558	5,808	42.84	0.639
$7,500- $9,999	8,561	9,346	41.08	0.480	8,517	45.08	0.527
$10,000-$14,999	12,106	12,769	43.05	0.356	12,082	45.50	0.375
$15,000-$24,999	18,514	6,792	46.72	0.252	6,561	48.36	0.261
$25,000 and over	35,326	1,914	41.24	0.117	1,812	43.56	0.123

[a] Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

TABLE B.5.--The Cost and Incidence of an Exponential Level of Emissions Tax on Hydrocarbon.

Household Money Income	All Households				Car-Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $1,000	547	1,924	173.36	31.690	580	575.10	105.00
$1,000- $1,999	1,505	4,252	211.34	14.040	1,661	541.00	35.95
$2,000- $2,999	2,487	4,563	282.96	11.380	2,389	540.45	21.73
$3,000- $3,999	3,478	5,095	331.92	9.540	3,245	521.14	14.98
$4,000- $4,999	4,502	4,505	389.65	8.650	3,426	512.36	11.38
$5,000- $5,999	5,466	4,805	407.22	7.450	3,906	500.94	9.16
$6,000- $7,499	6,710	6,646	441.03	6.570	5,808	504.65	7.54
$7,500- $9,999	8,561	9,346	479.88	5.610	8,517	526.59	6.15
$10,000-$14,999	12,106	12,769	496.94	4.101	12,082	525.20	4.34
$15,000-$24,999	18,514	6,792	526.51	2.838	6,561	545.04	2.94
$25,000 and over	35,326	1,914	439.01	1.242	1,812	463.72	1.31

[a]Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

categories. The cost per car-owning household is extremely regressive, the most regressive of all hypothetical hydrocarbon taxes discussed so far. This pattern is expected since this tax places the highest tax rate on high hydrocarbon polluting automobiles, and the lower income categories automobile stock is composed of a great proportion of high hydrocarbon emitting automobiles.[4] The implicit tax at the lowest income category is 105.00%, and represents a level which would be equivalent to a 100% income tax on each affected owner's current money income. This implicit rate declines to 35.95% at the $1,000-$1,999 income class and ultimately to 1.31% at the uppermost income category. The implied relative burdens are extremely unequal and it is doubtful if this hypothetical hydrocarbon tax is appropriate in the equity context of the "ability to pay" for pollution.

Tables B.7-B.10 present the estimated cost and short run incidence of the various hypothetical taxes imposed on the estimated annual output in grams of hydrocarbon. The estimated annual output in this context is defined as the product of the automobile's HC emission characteristic and the average mileage that the auto is driven. All hypothetical taxes are now imposed on the set of systems of tax based matrices presented in Chapter V, which have been transformed by multiplying the tax base for hydrocarbon emissions by its relevant annual mileage factor.[5] The factors are

---

[4]See Table 4.2, Chapter IV of this study.

[5]Hypothetical output taxes imposed on CO and NO_X emissions are imposed on similarly transformed tax bases.

presented in Table B.6. It should be noted that income categories representing 15 percent of the lower end of the income distribution and 12 percent of the upper end have been grouped in order to make the emission data by income and mileage data by income compatible.[6] In general, the cost per household and per car-owning household increases as money income rises for all output tax schemes. This is a direct result of the increasing numbers of automobiles owned as

TABLE B.6.--Average Annual Miles Driven Per Vehicle by Annual Household Money Income (1969-70).

Annual Income ($)	Per Vehicle Annual Miles (000)
< 3,000	6.6
3,000- 3,999	7.7
4,000- 4,999	9.2
5,000- 5,999	11.2
6,000- 7,499	11.3
7,500- 9,999	12.2
10,000-14,999	12.2
15,000 +	15.0

Source: U.S. Transportation Department, National Personal Transportation Study, Report No. 2, Table 5 (Washington, D.C.: Government Printing Office, April 1972).

[6]Since the sampling technique which generated the automobile ownership and mileage data are identical--drawn from the same survey--it is assumed that the data in Table B.6 is unchanged from 1969-70 to 1971.

income rises. However, compared to a licensing fee per auto with a tax rate of similar magnitude, the costs of the hydrocarbon output will be higher at low income levels--where fewer cars are owned but the fleet has high HC polluting characteristics--and lower at high income levels--where more cars are owned per household but the fleet has relatively low polluting characteristics.[7] The pattern of incidence of each of the taxes is progressive in the lower to middle income categories (exclusive of the lowest category) but becomes increasingly regressive for income categories above $6,000 when the estimated tax cost is distributed across all households in the income group. When the calculated costs are spread across only those households who are subject to the tax, <u>car owners</u>, the pattern of incidence becomes mildly regressive through income category $5,000-$5,999 and increasingly regressive thereafter, with the incidence that as measured <u>per household</u> as incomes rise above $6,000. Thus, although differences in annual mileage driven per vehicle across income classes contribute to the progressivity of the taxes, these differences are not sufficient in magnitude to overcome the regressive nature of the ownership-emissions patterns exhibited in the hypothetical <u>characteristics</u> taxes, when costs are distributed among those households that actually bear the tax burden.[8]

---

[7]See Table 4.1, Chapter IV of this study.

[8]All taxes calculated on the hydrocarbon emission output base are less regressive than their counterpart hydrocarbon characteristic taxes.

Table B.7 shows the costs and incidence of the hypothetical fleet average hydrocarbon output tax. The costs <u>per household</u> increase as money income rises from $23.36 at the less than $3,000 class to $133.82 at the $15,000 and above category. The pattern of incidence is mildly progressive through income category $5,000-$5,999 (exclusive of the lowest income category) and increasingly regressive for incomes above $6,000. The implicit tax rate rises from 1.124% at income $3,000-$3,999 to 1.252% at income category $5,000-$5,999 and then declines rapidly to 0.602% at the uppermost income category. The heaviest burden of the tax is borne by the $5,000-$5,999 income class, where the implicit tax rate is twice that borne by the uppermost income class. The cost per <u>car-owning household</u> rises from $54.20 to $139.15 as incomes rise from low to high. The pattern is mildly regressive through income category $5,000-$5,999 whereupon the pattern becomes increasingly regressive. The heaviest burden of the tax is borne by the lowest income classes where the implicit tax rates of 3.095% and 1.764% imposed on the lowest two income classes represent a relative burden 4.94 times and 2.82 times the burden borne by the $15,000 and above category.

Table B.8 presents the results of a hypothetical HC tax based on the quantity of annual hydrocarbon emissions. The costs per household and per car-owning household increase as money income rises. The patterns of incidence per household and per car-owning household are progressive through income category $5,000-$5,999 and increasingly regressive thereafter, and regressive throughout, respectively. The relative burden of the per unit output tax falls

TABLE B.7.--The Cost and Incidence of a Fleet Average Hydrocarbon Output Tax.

Household Money Income	All Households				Car Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $3,000	1,751	10,739	23.36	1.334	4,630	54.20	3.095
$3,000-$ 3,999	3,478	5,095	39.11	1.124	3,245	61.36	1.764
$4,000-$ 4,999	4,502	4,505	56.01	1.244	3,426	73.60	1.634
$5,000-$ 5,999	5,466	4,805	68.47	1.252	3,906	84.22	1.540
$6,000-$ 7,499	6,710	6,646	80.17	1.194	5,808	91.76	1.367
$7,500-$ 9,999	8,561	9,346	95.22	1.112	8,517	104.49	1.220
$10,000-$14,999	12,106	12,769	102.25	0.844	12,082	108.07	0.892
$15,000 and over	22,210	8,706	133.82	0.602	8,373	139.15	0.626

[a]Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

TABLE B.8.--The Cost and Incidence of an Annual Hydrocarbon Emission Output Tax.

Household Money Income	All Households				Car Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $3,000	1,751	10,739	23.06	1.316	4,630	53.48	3.054
$3,000-$ 3,999	3,478	5,095	38.81	1.115	3,245	60.97	1.753
$4,000-$ 4,999	4,502	4,505	55.94	1.242	3,426	73.51	1.632
$5,000-$ 5,999	5,466	4,805	72.80	1.331	3,906	89.60	1.639
$6,000-$ 7,499	6,710	6,646	80.04	1.192	5,808	91.53	1.364
$7,500-$ 9,999	8,561	9,346	95.89	1.120	8,517	105.41	1.231
$10,000-$14,999	12,106	12,769	103.33	0.853	12,082	109.31	0.902
$15,000 and over	22,210	8,706	141.52	0.637	8,373	147.59	0.664

[a]Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

heaviest on the less than $3,000 class when costs are distributed across car-owning households, heaviest on the $5,000-$5,999 class when costs are distributed across all households in the income group.

The costs and incidence of the hypothetical tax whose tax rate rises as the index of emissions rise is presented in Table B.9. The cost per household and per car-owning household rises as income rises with a range of $127.62-$682.71 and $296.01-$709.87, respectively. The pattern of incidence is identical to those described above for both methods of cost distribution over households. The relative burden per household borne by the $5,000-$5,999 class is 2.3 times as great as that borne by the $15,000 and above category. The heaviest burden, on a per car-owning household basis, is borne by the lowest two income categories whose implicit tax rates are 5.29 times and 3.00 times the implicit rates of the uppermost class, respectively.

The costs per household and per owner of the exponential level of output tax, Table B.10, range from $1,555.76 and $3,796.61 to $7,609.07 and $7,911.69, respectively, as income rises from the lowest income category to the highest. The pattern of incidence per household is mildly progressive through income category $5,000-$5,999 (exclusive of the lowest category) and increasingly regressive thereafter. The pattern of incidence per owner is regressive throughout with the regressivity increasing as income rises.

TABLE B.9.--The Cost and Incidence of a Level of Hydrocarbon Output Tax.

Household Money Income	All Households				Car Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $3,000	1,751	10,739	127.62	7.289	4,630	296.01	16.905
$3,000-$ 3,999	3,478	5,095	212.52	6.110	3,245	333.72	9.595
$4,000-$ 4,999	4,502	4,505	301.21	6.690	3,426	396.06	8.797
$5,000-$ 5,999	5,466	4,805	386.96	7.070	3,906	476.00	8.708
$6,000-$ 7,499	6,710	6,646	423.07	6.305	5,808	484.09	7.214
$7,500-$ 9,999	8,561	9,346	501.18	5.854	8,517	549.97	6.424
$10,000-$14,999	12,106	12,769	525.21	4.338	12,082	555.10	4.850
$15,000 and over	22,210	8,706	682.71	3.073	8,373	709.87	3.196

[a] Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

TABLE B.10.--The Cost and Incidence of an Exponential Level of Hydrocarbon Output Tax.

Household Money Income	All Households				Car Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $3,000	1,751	10,739	1,555.76	88.56	4,630	3,596.91	205.00
$3,000-$ 3,999	3,478	5,095	2,555.78	73.48	3,245	4,012.77	115.40
$4,000-$ 4,999	4,502	4,505	3,584.78	79.63	3,426	4,713.71	104.70
$5,000-$ 5,999	5,466	4,805	4,560.86	83.44	3,906	5,610.52	102.60
$6,000-$ 7,499	6,710	6,646	4,983.63	74.27	5,808	5,702.54	84.99
$7,500-$ 9,999	8,561	9,346	5,854.53	68.38	8,517	6,424.39	75.04
$10,000-$14,999	12,106	12,769	6,062.66	50.08	12,082	6,407.44	52.93
$15,000 and over	22,210	8,706	7,609.07	34.26	8,373	7,911.69	35.62

[a] Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

Carbon Monoxide Results

Tables B.11-B.15 show the estimated cost and short run incidence of the various hypothetical taxes imposed on carbon monoxide emissions characteristics of polluting automobiles. In general, the cost per household rises as money income rises. The pattern of incidence of each of the taxes is regressive throughout all income categories with the implicit tax rates declining rapidly over the first three income categories, declining at a fairly constant rate over the middle income categories, and declining rapidly over the upper income categories. The cost per car-owning household generally increases as money income rises, but the pattern is not as consistent as was the per household pattern. The pattern of incidence is regressive throughout with a heavier burden of the tax falling on the lower income categories than is the case when incidence is measured per household. This is due primarily to the smaller proportion of car owners who must bear the cost of the tax in the lower income categories.[9] Although the pattern of incidence of all hypothesized carbon monoxide (CO) characteristic taxes is regressive, it is interesting to note that the pattern is less regressive than was the pattern of hydrocarbon emission characteristic taxes. This can be explained in part by reference to Tables 4.1, 4.2, 4.3, and 4.4, Chapter IV of this study, which show that high carbon monoxide polluting automobiles

---

[9]Compare the number of car-owning households to the number of households by income group in the tables.

are more evenly distributed among the income classes than are high hydrocarbon polluting automobiles.

Table B.11 displays the cost and short run incidence of a lump sum tax on carbon monoxide emissions in excess of the acceptability standard. The cost per household ranges from $.32 to $1.29 as income rises from the lowest income class to the highest. The pattern of incidence is mildly regressive throughout most of the income distribution, becoming increasingly regressive at the uppermost income categories. The implicit tax rate of the lowest two income classes, 0.059% and 0.024%, respectively, reflect burdens which are 15.95 times and 6.48 times as great as that imposed on the uppermost income class. The costs per owner range from a low of $.94 at the $1,000-$1,999 income class to $1.36 at the $25,000 and above income class, with costs generally rising as income rises. The pattern of incidence is more regressive than the per household pattern, with the implicit tax rate falling rapidly from 0.195% at the less than $1,000 class to 0.004% at the uppermost class. The burden of the tax falls heaviest on the lowest income categories, where the implicit tax rates range upwards of 15 times greater than the implicit rates at the highest income categories.

The cost per household of the fleet average emissions tax, Table B.12, generally increases with money income. The pattern of incidence is quite regressive at the lowest income classes and increasingly regressive throughout the remainder of the distribution. The implicit tax rate is 18 times as great for the lowest income as it is for the higher income classes. Although the implicit tax rate

TABLE B.11.--The Cost and Incidence of a Lump Sum Tax on Carbon Monoxide.

Household Money Income	All Households				Car-Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $1,000	547	1,924	0.32	0.059	580	1.07	0.195
$1,000- $1,999	1,505	4,252	0.37	0.024	1,661	0.94	0.062
$2,000- $2,999	2,487	4,563	0.51	0.020	2,389	0.98	0.039
$3,000- $3,999	3,478	5,095	0.62	0.018	3,245	0.97	0.028
$4,000- $4,999	4,502	4,505	0.76	0.017	3,426	1.00	0.022
$5,000- $5,999	5,466	4,805	0.83	0.015	3,906	1.02	0.019
$6,000- $7,499	6,710	6,646	0.92	0.014	5,808	1.06	0.016
$7,500- $9,999	8,561	9,346	1.03	0.012	8,517	1.13	0.013
$10,000-$14,999	12,106	12,769	1.15	0.009	12,082	1.22	0.010
$15,000-$24,999	18,514	6,792	1.30	0.007	6,561	1.35	0.007
$25,000 and over	35,326	1,914	1.29	0.004	1,812	1.36	0.004

[a]Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

TABLE B.12.--The Cost and Incidence of a Fleet Average Carbon Monoxide Emission Tax.

Household Money Income	All Households				Car-Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $1,000	547	1,924	2.56	0.468	580	8.48	1.550
$1,000- $1,999	1,505	4,252	2.96	0.197	1,661	7.59	0.500
$2,000- $2,999	2,487	4,563	4.06	0.163	2,389	7.77	0.310
$3,000- $3,999	3,478	5,095	4.89	0.141	3,245	7.68	0.220
$4,000- $4,999	4,502	4,505	5.94	0.132	3,426	7.81	0.173
$5,000- $5,999	5,466	4,805	6.38	0.117	3,906	7.85	0.144
$6,000- $7,499	6,710	6,646	7.06	0.105	5,808	8.07	0.120
$7,500- $9,999	8,561	9,346	7.77	0.091	8,517	8.53	0.100
$10,000-$14,999	12,106	12,769	8.54	0.071	12,082	9.03	0.075
$15,000-$24,999	18,514	6,792	9.47	0.051	6,561	9.81	0.053
$25,000 and over	35,326	1,914	8.85	0.025	1,812	9.34	0.026

[a]Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

at the $1,000-$1,999 category falls to 8 times that of the $25,000 and above class, the tax burden borne by this group is still disproportionately large. The cost per owner ranges from $7.59 to $9.81, and is significantly larger at the lower income classes than was the per household cost. The implicit tax rate of the lowest two income classes, 1.55% and 0.50%, respectively, represents a burden 60 times and 19 times as great as that borne by the uppermost income class. The overall pattern of incidence is quite regressive throughout all income categories.

Table B.13 exhibits the estimated cost and incidence of a tax on actual CO emission characteristics. The cost per household and per car-owning household range from $2.85 and $8.45 to $10.97 and $11.36, respectively, with the cost generally rising as money income rises. The patterns of incidence are both regressive throughout the income distribution, with a more extreme regressivity at the lower ends of the distribution exhibited by the per car-owning household pattern. The implicit tax rate ranges upward to 0.521% at the per household under $1,000 class and up to 1.73% at the per car-owning household under $1,000 class. These implicit tax rates represent tax burdens 17.37 and 57.7 times as great as that imposed on the uppermost income class.

The cost per household of the level of CO emissions tax, Table B.14, ranges upwards to $63.89 at the $15,000-$24,999 class. The pattern of incidence is one of increasing regressivity as income rises. The implicit tax rate of the lower two income categories, 3.179% and 1.397%, respectively, represent burdens of

TABLE B.13.--The Cost and Incidence of a Tax on Measured Carbon Monoxide Emissions.

Household Money Income	All Households				Car-Owning Households		
	Mean[a] Income ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $1,000	547	1,924	2.85	0.521	580	9.44	1.730
$1,000- $1,999	1,505	4,252	3.30	0.219	1,661	8.45	0.561
$2,000- $2,999	2,487	4,563	4.56	0.183	2,389	8.72	0.351
$3,000- $3,999	3,478	5,095	5.48	0.158	3,245	8.60	0.247
$4,000- $4,999	4,502	4,505	6.59	0.146	3,426	8.67	0.193
$5,000- $5,999	5,466	4,805	7.24	0.132	3,906	8.90	0.163
$6,000- $7,499	6,710	6,646	8.12	0.121	5,808	9.29	0.138
$7,500- $9,999	8,561	9,346	8.87	0.104	8,517	9.73	0.114
$10,000-$14,999	12,106	12,769	9.77	0.081	12,082	10.32	0.085
$15,000-$24,999	18,514	6,792	10.97	0.059	6,561	11.36	0.061
$25,000 and over	35,326	1,914	10.43	0.030	1,812	11.02	0.031

[a] Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

TABLE B.14.--The Cost and Incidence of a Level of Carbon Monoxide Emissions Tax.

Household Money Income	All Households				Car-Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $1,000	547	1,924	17.39	3.179	580	57.71	10.550
$1,000- $1,999	1,505	4,252	21.02	1.397	1,661	53.83	3.580
$2,000- $2,999	2,487	4,563	28.35	1.140	2,389	54.14	2.180
$3,000- $3,999	3,478	5,095	33.83	0.973	3,245	53.12	1.530
$4,000- $4,999	4,502	4,505	40.84	0.907	3,426	53.70	1.190
$5,000- $5,999	5,466	4,805	43.91	0.803	3,906	54.02	0.990
$6,000- $7,499	6,710	6,646	49.43	0.737	5,808	56.57	0.840
$7,500- $9,999	8,561	9,346	53.19	0.621	8,517	58.37	0.680
$10,000-$14,999	12,106	12,769	57.52	0.475	12,082	60.79	0.500
$15,000-$24,999	18,514	6,792	63.89	0.345	6,561	66.14	0.360
$25,000 and over	35,326	1,914	57.83	0.164	1,812	61.08	0.170

[a] Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

19.38 and 8.52 relative to the burden borne by the $25,000 and above class. The pattern of incidence per car-owning household is more regressive at lower income categories than was the per household pattern. The implicit tax rate and relative burden increase from 0.17% to 10.55% and from 1.00 to 62.05 as money income declines from above $25,000 to under $1,000. The cost per car owner is relatively constant throughout all income classes.

Table B.15 shows the cost and incidence of the hypothetical exponential CO emissions characteristic tax. As was the case with this tax when based on hydrocarbon emissions, the pattern of incidence per household and per car-owning household is only slightly more regressive than the pattern exhibited by the other tax schemes.

Tables B.16-B.19 present the estimated costs and short run incidence of the various hypothetical taxes imposed on the annual output in grams of CO.[10] In general, the cost per household and per car-owning household increases as money income rises for all hypothetical taxes. All hypothetical taxes on the annual output of CO exhibit a pattern of incidence which is progressive through the middle income categories (exclusive of the lowest category) and becomes increasingly regressive at income levels above $6,000. These patterns of incidence are found to be less regressive than the corresponding patterns of the HC output taxes, because CO

---

[10]The transformation of the tax base and the scalars used in that transformation have been described in the section on hydrocarbon taxation.

TABLE B.15.--The Cost and Incidence of an Exponential Level of Emissions Tax on Carbon Monoxide.

Household Money Income	All Households				Car-Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $1,000	547	1,924	382.19	69.90	580	1,267.83	231.80
$1,000- $1,999	1,505	4,252	554.71	36.80	1,661	1,420.00	94.40
$2,000- $2,999	2,487	4,563	783.51	31.50	2,389	1,496.50	60.15
$3,000- $3,999	3,478	5,095	923.70	26.60	3,245	1,450.31	41.69
$4,000- $4,999	4,502	4,505	1,115.68	24.78	3,426	1,467.06	32.56
$5,000- $5,999	5,466	4,805	1,214.10	22.20	3,906	1,493.54	27.32
$6,000- $7,499	6,710	6,646	1,433.46	21.40	5,808	1,640.28	24.40
$7,500- $9,999	8,561	9,346	1,469.69	17.20	8,517	1,612.74	18.80
$10,000-$14,999	12,106	12,769	1,570.33	12.90	12,082	1,659.62	13.71
$15,000-$24,999	18,514	6,792	1,770.31	9.60	6,561	1,832.64	9.90
$25,000 and over	35,326	1,914	1,521.76	4.30	1,812	1,607.43	4.55

[a]Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

polluting automobiles are more evenly distributed across income classes than are HC polluting automobiles.[11]

Table B.16 shows that the cost per household and per owner of the fleet average output tax increases as money income rises to a maximum of $140.03 and $145.59, respectively. The pattern of incidence per household is progressive up through incomes below $6,000, and increasingly regressive thereafter. The implicit tax rate rises to 1.31% at $5,000-$5,999 and then declines to 0.63% at incomes greater than $15,000. The burden falls heaviest on income category $5,000-$5,999 where the implicit tax rate is 2.08 times as great as that of the highest income class. The pattern of incidence per owner is generally regressive throughout, with regressivity increasing moderately through income $5,000-$5,999 and increasing rapidly thereafter. The implicit tax rate of the lowest income class, 2.937%, represents a burden which is 4.48 times as great as that borne by the uppermost income class.

Table B.17, the measured output tax table, shows that cost per household and per owner again increases as money income rises, with the costs per owner falling within a narrower range than the costs per household. The pattern of incidence is similar to that of the average fleet output, but more progressive. The implicit tax rate per household rises from 1.21% at income $3,000-$3,999 to 1.49% at income $5,000-$5,999 and then declines rapidly to 0.733% at the uppermost income category. The relative burdens implied by

[11]See Tables 4.2 and 4.4, Chapter IV of this study.

TABLE B.16.--The Cost and Incidence of a Fleet Average Output Tax on Carbon Monoxide.

Household Money Income	All Households				Car Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $3,000	1,751	10,739	22.17	1.266	4,630	51.43	2.937
$3,000-$ 3,999	3,478	5,095	37.67	1.080	3,245	59.13	1.700
$4,000-$ 4,999	4,502	4,505	54.64	1.210	3,426	71.85	1.590
$5,000-$ 5,999	5,466	4,805	71.46	1.310	3,906	87.92	1.610
$6,000-$ 7,499	6,710	6,646	79.78	1.190	5,808	91.19	1.360
$7,500-$ 9,999	8,561	9,346	94.79	1.110	8,517	104.07	1.220
$10,000-$14,999	12,106	12,769	104.19	0.860	12,082	111.17	0.910
$15,000 and over	22,210	8,706	140.03	0.630	8,373	145.59	0.655

[a]Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

TABLE B.17.--The Cost and Incidence of a Measured Output Tax on Carbon Monoxide.

Household Money Income	All Households				Car Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $3,000	1,751	10,739	24.78	1.415	4,630	57.48	3.280
$3,000-$ 3,999	3,478	5,095	42.20	1.210	3,245	66.22	1.900
$4,000-$ 4,999	4,502	4,505	60.62	1.350	3,426	79.76	1.770
$5,000-$ 5,999	5,466	4,805	81.88	1.490	3,906	99.68	1.820
$6,000-$ 7,499	6,710	6,646	91.76	1.370	5,808	104.97	1.560
$7,500-$ 9,999	8,561	9,346	108.21	1.260	8,517	118.71	1.390
$10,000-$14,999	12,106	12,769	119.19	0.980	12,082	124.81	1.030
$15,000 and over	22,210	8,706	162.81	0.733	8,373	169.28	0.762

[a]Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

these implicit rates are 1.93, 2.03 and 1.00, respectively.[12] The implicit tax rate per owner declines from 3.28% to 0.762% as income rises from low to high. This implies a relative incidence of 4.30 to 1.00.

Table B.18 presents the level of CO output tax cost and incidence measured per household and per car-owning household. The costs per household and per car-owning household vary from $155.02 to $938.37 and from $359.57 to $975.69, respectively, as income rises. The pattern of incidence per household is identical to that of the previously discussed taxes. The burden borne by the $5,000-$5,999 income class is found to be 2.13 times the burden borne by the upper income class. The pattern of incidence when the tax cost is spread across only car-owning households is generally regressive, with the heaviest burden falling on the lowest income classes. The implicit tax rate declines from 20.45% to 4.39% as income rises, indicating that a tax burden 4.68 times as great as that imposed on the uppermost income class is borne by the lowest income category. The patterns of incidence of the exponential level of CO emissions tax are nearly identical to those of the previous tax. This can be confirmed by reference to Table B.19.

Oxides of Nitrogen Results

Tables B.20-B.24 present the estimated costs and short run incidence of the various hypothetical taxes imposed on oxide of

---

[12]Although the relative burdens are greater, the implicit marginal tax rates are more progressive.

TABLE B.18.--The Cost and Incidence of a Level of Output Tax on Carbon Monoxide.

Household Money Income	All Households				Car Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $3,000	1,751	10,739	155.02	8.85	4,630	359.57	20.54
$3,000-$ 3,999	3,478	5,095	260.49	7.49	3,245	409.02	11.76
$4,000-$ 4,999	4,502	4,505	375.73	8.35	3,426	494.02	10.97
$5,000-$ 5,999	5,466	4,805	491.79	8.99	3,906	605.02	11.07
$6,000-$ 7,499	6,710	6,646	558.56	8.32	5,808	639.24	9.54
$7,500-$ 9,999	8,561	9,346	648.92	7.58	8,517	712.11	8.29
$10,000-$14,999	12,106	12,769	701.74	5.80	12,082	741.64	6.13
$15,000 and over	22,210	8,706	938.37	4.22	8,373	975.69	4.39

[a] Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

TABLE B.19.--The Cost and Incidence of an Exponential Level of Carbon Monoxide Output Tax.

Household Money Income	All Households				Car Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $3,000	1,751	10,739	4,098.73	234.00	4,630	9,506.75	543.00
$3,000-$ 3,999	3,478	5,095	7,112.49	204.50	3,245	11,167.30	321.00
$4,000-$ 4,999	4,502	4,505	10,264.42	227.90	3,426	13,496.90	299.80
$5,000-$ 5,999	5,466	4,805	13,597.90	248.70	3,906	16,727.60	306.00
$6,000-$ 7,499	6,710	6,646	16,198.00	241.40	5,808	18,535.10	276.00
$7,500-$ 9,999	8,561	9,346	17,930.22	209.40	8,517	19,675.43	229.00
$10,000-$14,999	12,106	12,769	19,158.00	158.20	12,082	20,247.30	167.20
$15,000 and over	22,210	8,706	25,735.00	115.80	8,373	26,810.00	115.90

[a] Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

nitrogen emission characteristics. In general, the costs per household and per car-owning household rise as money income rises, due primarily to the expansion of the tax base through the addition of a greater number of polluting units as income rises. The pattern of incidence of each of the taxes is mildly regressive throughout the lower and middle income categories, becoming increasingly regressive at incomes above $6,000. The pattern of incidence, when calculated per car-owning household, is regressive throughout all income categories with a heavier burden falling on the lower income categories than is the case when incidence is measured per household. Although the pattern of incidence of all NO_X characteristic taxes is regressive, the pattern is much less regressive than the pattern of incidence exhibited by the HC and CO taxes. This result is expected, since the composition of the fleet NO_X emissions, i.e., the proportion of the fleet with low versus high emissions, is more progressive than is the case for the other two pollutants. Referring to Tables 4.2, 4.4, and 4.6 in Chapter IV of this study, one observes that the proportion of the fleet with low (high) NO_X emission characteristics is slightly more (less) at low income classes, whereas the proportion of the fleet with low (high) HC and CO characteristics increases (decreases) as money income rises. Therefore, one expects that the tax cost based on NO_X emissions will be more evenly distributed and less regressive than the tax cost based on HC or CO emissions.

Table B.20 shows that the cost per household of the lump sum NO_X characteristic tax ranges from $.29 at the lowest income class

TABLE B.20.--The Cost and Incidence of a Lump Sum Tax on Oxides of Nitrogen.

Household Money Income	All Households				Car-Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $1,000	547	1,924	0.29	0.0538	580	0.98	0.178
$1,000- $1,999	1,505	4,252	0.33	0.0217	1,661	0.84	0.055
$2,000- $2,999	2,487	4,563	0.47	0.0189	2,389	0.89	0.036
$3,000- $3,999	3,478	5,095	0.57	0.0163	3,245	0.89	0.025
$4,000- $4,999	4,502	4,505	0.72	0.0160	3,426	0.95	0.021
$5,000- $5,999	5,466	4,805	0.81	0.0148	3,906	1.00	0.0018
$6,000- $7,499	6,710	6,646	0.91	0.0136	5,808	1.04	0.015
$7,500- $9,999	8,561	9,346	1.03	0.0120	8,517	1.13	0.013
$10,000-$14,999	12,106	12,769	1.20	0.0099	12,082	1.27	0.010
$15,000-$24,999	18,514	6,792	1.40	0.0076	6,561	1.45	0.008
$25,000 and over	35,326	1,914	1.50	0.0042	1,812	1.58	0.005

[a]Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

to $1.50 at the above $25,000 class. The pattern of incidence is mildly regressive throughout the income distribution. The implicit tax rate declines continuously from 0.0538% at the lowest income class to 0.0042% at the uppermost category. The burden of the tax falls most heavily on the lowest income category, where the implicit tax rate is 12 times as great as that of the uppermost income category. The cost per car-owning household falls in a narrow range bounded by $.84 and $1.58 and generally increases as incomes rise. The pattern of incidence is more regressive than that exhibited by the per household pattern at the lower end of the income distribution, the implicit tax rate of the lowest two income categories being 39.55 and 12.22 times, respectively, as great as that of the uppermost income class.

Table B.21, the fleet average emissions characteristic tax, exhibits costs per household and per car-owning household which generally increase with money income. The pattern of incidence is mildly regressive throughout the distribution when costs are spread over all households in the income classes. The implicit tax rate is at most 11 times that of the highest income class, and, if we exclude the lowest income class where the incidence is likely to be overstated, the implicit tax rate is at most 4.1 times that of the highest income class. Although the relative burden falls heaviest on low income categories, this burden is less than that calculated for the other pollutants. The pattern of incidence per car owner is more regressive at the lower end of the distribution than was the case for calculations on a per household basis, with the

TABLE B.21.--The Cost and Incidence of a Fleet Average Oxides of Nitrogen Emissions Tax.

Household Money Income	All Households				Car-Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $1,000	547	1,924	1.16	0.2125	580	3.86	0.710
$1,000- $1,999	1,505	4,252	1.19	0.0788	1,661	3.03	0.200
$2,000- $2,999	2,487	4,563	1.83	0.0734	2,389	3.49	0.140
$3,000- $3,999	3,478	5,095	2.23	0.0640	3,245	3.49	0.100
$4,000- $4,999	4,502	4,505	2.90	0.0643	3,426	3.81	0.084
$5,000- $5,999	5,466	4,805	3.31	0.0605	3,906	4.07	0.074
$6,000- $7,499	6,710	6,646	3.77	0.0561	5,808	4.31	0.064
$7,500- $9,999	8,561	9,346	4.30	0.0502	8,517	4.72	0.055
$10,000-$14,999	12,106	12,769	5.10	0.0421	12,082	5.39	0.045
$15,000-$24,999	18,514	6,792	6.11	0.0330	6,561	6.32	0.034
$25,000 and over	35,326	1,914	6.70	0.0192	1,812	7.18	0.020

[a]Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

implicit tax rate declining as income rises from 0.710% to 0.02%.

The costs per household and per owner of the measured emissions tax, Table B.22, increase as money income rises. The pattern of incidence per <u>household</u> is mildly regressive. The implicit tax rate declines from 0.394% to 0.155% at the lowest two classes to 0.028% at the uppermost income class. The pattern of incidence per <u>car-owning household</u> is more regressive, with implicit tax rates falling from 1.3% and 0.4% at the lowest income classes to 0.029% at the highest income class. The burden of the tax falls most heavily on the lowest income classes regardless of how the tax cost is calculated.

Table B.23 indicates that the level of emissions tax cost rises moderately with money income. The incidence per <u>household</u> ranges from 1.99% to 0.13% representing a mildly regressive pattern. The pattern of incidence per <u>car-owning</u> <u>household</u> is more regressive at the lower end of the distribution than was the per household pattern. The implicit tax rate of the lowest two income categories, 6.57% and 2.0%, respectively, represent a burden which is 50 times and 15 times greater than the burden imposed on the uppermost income category.

Table B.24 shows that the cost per household and per car owner of the exponential level of emissions tax rises with money income, although the pattern per car owner is less pronounced. The pattern of incidence per household and per car-owning household is regressive throughout the income distribution, with the burden of

TABLE B.22.--The Cost and Incidence of a Measured Oxides of Nitrogen Emissions Tax.

Household Money Income	All Households				Car-Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $1,000	547	1,924	2.15	0.394	580	7.14	1.300
$1,000- $1,999	1,505	4,252	2.34	0.155	1,661	5.99	0.400
$2,000- $2,999	2,487	4,563	3.45	0.139	2,389	6.58	0.260
$3,000- $3,999	3,478	5,095	4.16	0.119	3,245	6.53	0.190
$4,000- $4,999	4,502	4,505	5.30	0.118	3,426	6.97	0.150
$5,000- $5,999	5,466	4,805	5.79	0.106	3,906	7.12	0.130
$6,000- $7,499	6,710	6,646	6.50	0.096	5,808	7.43	0.110
$7,500- $9,999	8,561	9,346	7.29	0.085	8,517	8.00	0.093
$10,000-$14,999	12,106	12,769	8.33	0.069	12,082	8.81	0.073
$15,000-$24,999	18,514	6,792	9.65	0.052	6,561	9.99	0.053
$25,000 and over	35,326	1,914	9.89	0.028	1,812	10.45	0.029

[a]Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

TABLE B.23.--The Cost and Incidence of a Level of Emission Tax on Oxides of Nitrogen.

Household Money Income	All Households				Car-Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $1,000	547	1,924	10.84	1.990	580	35.95	6.57
$1,000- $1,999	1,505	4,252	11.77	0.78	1,661	30.15	2.00
$2,000- $2,999	2,487	4,563	17.41	0.70	2,389	33.26	1.33
$3,000- $3,999	3,478	5,095	23.42	0.67	3,245	32.93	0.95
$4,000- $4,999	4,502	4,505	26.38	0.59	3,426	34.69	0.77
$5,000- $5,999	5,466	4,805	28.44	0.52	3,906	34.99	0.64
$6,000- $7,499	6,710	6,646	31.72	0.47	5,808	36.29	0.54
$7,500- $9,999	8,561	9,346	35.37	0.41	8,517	38.81	0.45
$10,000-$14,999	12,106	12,769	39.72	0.33	12,082	41.98	0.35
$15,000-$24,999	18,514	6,792	45.31	0.24	6,561	46.91	0.25
$25,000 and over	35,326	1,914	44.59	0.13	1,812	47.10	0.13

[a]Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

TABLE B.24.--The Cost and Incidence of an Exponential Level of Oxides of Nitrogen Emissions.

Household Money Income	All Households				Car-Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $1,000	547	1,924	77.95	14.25	580	258.59	47.30
$1,000- $1,999	1,505	4,252	85.34	5.67	1,661	218.47	14.52
$2,000- $2,999	2,487	4,563	126.25	5.08	2,389	241.13	9.69
$3,000- $3,999	3,478	5,095	151.34	4.35	3,245	237.62	6.83
$4,000- $4,999	4,502	4,505	185.05	4.11	3,426	243.33	5.40
$5,000- $5,999	5,466	4,805	197.93	3.62	3,906	243.49	4.45
$6,000- $7,499	6,710	6,646	218.59	3.26	5,808	250.13	3.72
$7,500- $9,999	8,561	9,346	241.10	2.82	8,517	264.57	3.09
$10,000-$14,999	12,106	12,769	264.05	2.18	12,082	279.06	2.31
$15,000-$24,999	18,514	6,792	293.53	1.59	6,561	303.87	1.64
$25,000 and over	35,326	1,914	358.31	1.01	1,812	378.49	1.07

[a] Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

the tax falling heaviest on the low income categories. The burden borne by the lowest income group relative to the highest group ranges upwards to 14 times when costs are distributed over all households and upwards of 44 times when costs are distributed per car-owning household. It is interesting to note that, whereas this form of the tax was most regressive when based on HC and CO, it is nearly the least regressive of the NO_X taxes (the relative burdens are distributed more evenly). Since the distribution of NO_X emissions has a slightly progressive nature--lower NO_X emissions from low income owned cars--heavy taxation of high NO_X automobiles which are owned in proportionately greater quantities by high income classes than low will produce the above result.

Tables B.25-B.28 present information on the costs and patterns of incidence of the various hypothetical NO_X output taxes.[13] In general, although costs per household for all taxes rise as money income rises, the patterns of incidence are increasingly progressive for incomes less than $6,000, where mileage driven increases rapidly with income, and only mildly regressive for incomes above $6,000, where the progressive impact of mileage driven becomes less pronounced. Further, although costs per car owner also increase as money income rises, the spreading of these costs among proportionately fewer households at the lower end of the income distribution substantially eliminates the previously

---

[13]The transformation of the tax base and the scalars used in that transformation have been described in the section on hydrocarbon taxation.

measured progressivity. The burden of the taxes fall more heavily on the lower income classes when the total tax cost is distributed across car-owning households only, and falls heavily on the middle income classes when the total costs are distributed across all households.

Table B.25, the average fleet output of NO_X tax, shows that costs calculated on both bases increase as money income rises. The pattern of incidence (exclusive of the lowest income class) is progressive through income category $5,000-$5,999 and increasingly regressive thereafter when costs are distributed per household. This pattern prevails when costs are distributed across car-owning households only, primarily because the progressive impact of the average fleet NO_X emissions, which are lower at lower income levels, combined with the progressive nature of annual miles driven per vehicle is sufficient to overcome the regressivity of distributing a similar tax cost over a smaller proportion of owners at low income categories. The relative burden of the tax per household falls most heavily on the $5,000-$5,999 category while the relative burden per car-owning household falls heavily on low income categories.

Table B.26, the measured output tax, reveals a pattern of incidence per household similar to that of the other taxes, although the implicit tax rates are higher. The pattern of incidence per car-owning household is mildly regressive, although the implicit tax rate is fairly constant over the $3,000-$3,999 to $5,000-$5,999 income range, declining rapidly only at incomes above $6,000. The burden of the tax at the two lowest income categories

TABLE B.25.--The Cost and Incidence of a Fleet Average Output of Oxides of Nitrogen Tax.

Household Money Income	All Households				Car Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $3,000	1,751	10,739	9.59	0.547	4,630	22.25	1.270
$3,000-$ 3,999	3,478	5,095	17.13	0.492	3,245	26.87	0.772
$4,000-$ 4,999	4,502	4,505	26.65	0.591	3,426	35.02	0.777
$5,000-$ 5,999	5,466	4,805	37.03	0.677	3,906	45.58	0.833
$6,000-$ 7,499	6,710	6,646	42.54	0.633	5,808	48.70	0.725
$7,500-$ 9,999	8,561	9,346	52.45	0.612	8,517	57.58	0.672
$10,000-$14,999	12,106	12,769	62.20	0.513	12,082	64.75	0.534
$15,000 and over	22,210	8,706	93.88	0.422	8,373	97.62	0.439

[a]<u>Source</u>: U.S. Department of Commerce, Bureau of the Census, <u>Consumer Income in 1971</u>, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

TABLE B.26.--The Cost and Incidence of a Measured Oxides of Nitrogen Output Tax.

Household Money Income	All Households				Car Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $3,000	1,751	10,739	18.32	1.046	4,630	42.45	2.427
$3,000-$ 3,999	3,478	5,095	32.03	0.921	3,245	50.29	1.445
$4,000-$ 4,999	4,502	4,505	48.78	1.083	3,426	64.14	1.424
$5,000-$ 5,999	5,466	4,805	64.89	1.187	3,906	72.83	1.460
$6,000-$ 7,499	6,710	6,646	73.40	1.093	5,808	83.99	1.251
$7,500-$ 9,999	8,561	9,346	88.94	1.038	8,517	97.60	1.140
$10,000-$14,999	12,106	12,769	101.66	0.839	12,082	107.44	0.887
$15,000 and over	22,210	8,706	145.51	0.655	8,373	151.30	0.681

[a]Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

is 3.56 times and 2.12 times the burden at the uppermost income class.

Table B.27, the level of emissions tax, shows that costs per household range from $92.42 at the lowest income level to $677.36 at the uppermost level. The pattern of incidence is generally progressive through the lower-middle income classes, becoming increasingly regressive at incomes in excess of $6,000. The implicit tax rate is 5.28% at the less than $3,000 class, declines to 4.64% at $3,000-$3,999, rises to 5.83% at income class $5,000-$5,999 and falls rapidly to 3.05% at the uppermost class. The costs per car-owning households follow the pattern of the other taxes. The pattern of incidence is identical to that of the other taxes, although implicit tax rates and relative burdens are higher.

The results of the exponential level of NO_X output tax are presented in Table B.28. As was the case for the previous oxide of nitrogen taxes, costs per household and per car owner increase with money income. The pattern of incidence per household is identical to that exhibited by the other hypothetical tax incidence patterns, although the tax burdens borne by the lower-middle income categories are increased. The implicit tax rates are quite high for a specific tax, ranging from 40.56% of household income to 20.79% of household income. The magnitude of these implicit tax rates suggests a tax rate in other than dollar per gram terms should be applied if this form of the tax is to be considered for public policy implementation. The pattern of incidence per car-owning household is generally regressive throughout, although the lower-middle income categories

TABLE B.27.--The Cost and Incidence of a Level of Oxides of Nitrogen Output Tax.

Household Money Income	All Households				Car Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $3,000	1,751	10,739	92.42	5.28	4,630	214.36	12.24
$3,000-$ 3,999	3,478	5,095	161.50	4.64	3,245	253.57	7.29
$4,000-$ 4,999	4,502	4,505	242.71	5.39	3,426	319.15	7.09
$5,000-$ 5,999	5,466	4,805	318.58	5.83	3,906	391.90	7.17
$6,000-$ 7,499	6,710	6,646	358.38	5.34	5,808	410.10	6.11
$7,500-$ 9,999	8,561	9,346	431.46	5.04	8,517	473.45	5.53
$10,000-$14,999	12,106	12,769	484.60	4.00	12,082	512.16	4.23
$15,000 and over	22,210	8,706	677.36	3.05	8,373	704.30	3.17

[a] Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

TABLE B.28.--The Cost and Incidence of an Exponential Level of Oxides of Nitrogen Output Tax.

Household Money Income	All Households				Car Owning Households		
	Mean Income[a] ($)	No. of Households (000)	Cost per Household ($)	Incidence (%)	No. of Households (000)	Cost per Household ($)	Incidence (%)
Under $3,000	1,751	10,739	669.25	38.22	4,630	1,552.28	88.65
$3,000-$ 3,999	3,478	5,095	1,165.31	33.51	3,245	1,829.67	52.61
$4,000-$ 4,999	4,502	4,505	1,702.49	37.82	3,426	2,238.69	49.73
$5,000-$ 5,999	5,466	4,805	2,216.90	40.56	3,906	2,727.14	49.89
$6,000-$ 7,499	6,710	6,646	2,470.05	36.81	5,808	2,826.44	42.12
$7,500-$ 9,999	8,561	9,346	2,941.51	34.36	8,517	3,227.82	37.70
$10,000-$14,999	12,106	12,769	3,221.41	26.61	12,082	3,404.58	28.12
$15,000 and over	22,210	8,706	4,616.66	20.79	8,373	4,800.26	21.61

[a] Source: U.S. Department of Commerce, Bureau of the Census, Consumer Income in 1971, P-60 Series, No. 85 (December 1972), Table 64, p. 145.

bear the tax in a manner which is nearly proportional to their money incomes. The implicit tax rate falls from 88.65% at the lowest income class to 21.16% at the highest, indicating that a burden 4.1 times as great as that borne by the uppermost income category is borne by the lowest category. Although the relative burdens are only slightly greater and spread more evenly among the income classes, the magnitude of the incidence suggests that an appropriate rate level should be set in less than dollar terms.