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The Incidence of the Costs of Controlling Automotive Air Pollution

I. INTRODUCTION

The automobile is a major source of air pollution in the United States. It is responsible for approximately two-thirds of all man-made emissions of carbon monoxide, and approximately half of the emissions of nitrogen oxides and hydrocarbons. In the Clean Air Act of 1970, Congress undertook a major revamping of federal policy toward air pollution control. Although there were major changes in the policy aimed at controlling emissions from stationary sources, these changes were overshadowed by the new strategy regarding the automobile and its contribution to air pollution. For the first time, Congress itself specified emission standards to be met by all new cars produced in the 1975 and subsequent model years.

Specifically, the Clean Air Act required that all new cars produced for the 1975 and later model years meet emission standards (maximum emissions per vehicle mile) which were no more than 10 percent of the standards in effect when the law was passed. These standards were to

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apply to emissions of carbon monoxide and hydrocarbons. A similar requirement was imposed on emissions of nitrogen oxides with the standard to be met in the 1976 model year. The law permitted the administrator of the Environmental Protection Agency (EPA) to grant a one-year delay in the deadline for meeting these standards if auto manufacturers requested the delay and showed that meeting the original deadline was not technically feasible. Manufacturers have requested and received one-year extensions of the 1975 deadline for carbon monoxide and hydrocarbons emissions and the 1976 deadline for nitrogen oxides.

The costs of meeting these standards will be substantial. EPA has estimated that design and equipment changes will increase the cost of new cars by between $200 and $300 over the 1970 models (Environmental Protection Agency, 1972). In addition, emission control devices decrease the fuel efficiency of new cars, resulting in an expected increase in fuel consumption of about 15 percent in comparison with the 1970 models. EPA estimates the total cost of installing emission control devices will be about $4 billion per year by 1976. Furthermore, annual operating and maintenance costs will be higher by 1976 by about $2.5 billion per year, and this figure will rise in subsequent years as the total number of cars equipped with emission control devices rises from year to year.[1]

The federal strategy for controlling automotive air pollution, as embodied in the Clean Air Act of 1970, raises several major issues which have become the focus of sharp debate in recent months. One issue concerns the technical feasibility of meeting the standards. In requesting an extension of the deadline, the auto companies argued that standards could not be met with existing technology.

A more fundamental issue is the effectiveness of the chosen strategy. The emission standards for automobiles were meant to contribute to the attainment of ambient air quality standards throughout the country. The Clean Air Act of 1970 requires that these ambient air quality standards be attained no later than 1977. Since the emission standards apply only to new cars starting with the 1975 model year (1976 with the extension), and since new car production replaces only about 10 percent of the total stock of cars each year, only about 10 to 20 percent of the cars being driven in 1977 will be meeting the emission control standards. For a number of cities, it appears that this reduction in emissions will not be sufficient to attain the ambient air quality standards (New York *Times*, 1973). These cities must find some supplementary means of reducing total automotive emissions if the ambient air quality standards are to be met by the deadline. In fact, some cities are faced with the problem that even after all the cars being driven in those urban areas are complying with the new emission standards, total emissions will still be too high, and ambient air quality standards will not be met.

As these problems become more visible, attention is being turned to alternative strategies toward the automobile, either as a replacement for, or as a supplement to, the emission standards approach. These alternatives would attempt to deal with one or more of the following problems:

1. The congressionally mandated emission standards control emissions per mile driven, but do not control or influence the number of miles driven.
2. The emission standards apply only to newly manufactured cars, so that the impact of the standards on total emissions depends on the rate at which present high-pollution vehicles are retired from the fleet and replaced by new low-pollution vehicles. Policy alternatives would consider controlling emissions from the existing fleet as well as from new cars.
3. Since many parts of the country do not presently have significant automotive air pollution problems, the present emission standards impose costs on car buyers in some areas for which there is little or no compensating benefit through reduction in air pollution damages. This is not only in some sense inequitable, but may represent a substantial resource misallocation.

In addition to the questions of technical feasibility and the effectiveness of the present strategy and possible alternatives, another issue being discussed is that of the income distribution effects, or incidence, of the costs of controlling automotive pollution. As society undertakes a significant reallocation of resources, such as represented by the move toward a cleaner environment, we should be concerned not only with the magnitude of costs and benefits, but also with questions involving who gains and who loses.

On the benefit side, there have been some preliminary attempts to determine the incidence of the damages due to air pollution. These studies suggest that lower-income families experience higher pollution levels and, therefore, are likely to benefit relatively more from pollution reduction (Freeman 1972; Zupan 1973).[2] However, these studies have been limited by the difficulty in placing dollar values on damages due to pollution or on benefits of pollution control.

Turning to the incidence of the costs of pollution control, economic theory, a priori reasoning, and some bits of evidence suggest that the costs of pollution control will be distributed in a regressive manner, i.e., that the cost per family will be a higher percentage of income for lower-income families (Freeman 1972). There are some data available to support this hypothesis. In a major study of the costs of air pollution control, EPA estimated the costs of meeting the present pollution control standards for the major classes of stationary sources of air pollution (Environmental Protection Agency 1972). These estimates of pollution control costs were then used to project likely price increases by industrial categories. An input-output model was used to trace through these price increases to twelve categories of personal consumption expenditures. Finally, for each personal consumption expenditure category, the relationship between family income and expenditure was determined from the 1961 Bureau of Labor Statistics, *Survey of Consumer Expenditures.* EPA concluded, "Since the percentage of income spent on food, tobacco, personal care, housing, household operation, and medical care generally declines with increases in family income, price increases in these categories would weigh most heavily on families in the lower income brackets" (Environmental Protection Agency 1972, p. 5-9). Since these are the largest categories of personal consumption expenditure, the net effect is likely to be a mildly regressive pattern of incidence.

EPA's study suggests, however, that automotive pollution control is a special case, and that these costs are distributed in a largely progressive pattern. The Agency estimated the total annual costs of achieving the automotive emission standards and allocated these costs to each income class according to the *Survey of Consumer Expenditures* data on expenditures for transportation. EPA concluded:

> Expenditures for transportation are largest for the middle income groups on a percentage basis; the lower 24 percent of families and the upper 2 percent of these groups spend about three-fifths and four-fifths respectively of the middle income group's percentage of transportation expenditures. Because transportation costs are projected to increase the most (4.3 percent) and because they are a significant share of all income groups' PCE, the differential impacts of the price increases by income groups tend to be dominated by the distribution of transportation expenditures. For this reason, the middle and upper income groups would probably be affected to a greater extent on a percentage basis than those families in the lower and the very highest income group (Environmental Protection Agency 1972, pp. 5-9, 5-10).

There are several reasons to be cautious about this conclusion, however. First, pollution control costs were allocated by income class according to estimates of total transportation expenditures by households. However, this total lumps together spending on purchases of both new and used cars, as well as operating expenses and spending on other modes of transport. The present strategy imposes costs directly only on new-car purchasers. A second reservation concerns the interrelationship between new- and used-car prices, and the possibility that the price mechanism may shift some part of the pollution control costs on to other than new-car buyers. Finally, there is the phenomenon of multi-car ownership by families and the large number of used cars owned by upper-income families. These all make it more difficult to draw inferences about the actual incidence of automotive pollution control costs from data on such a broad aggregate as transportation expenditures by income class.

More recently, Nancy Dorfman has completed a study of the distribution of the overall costs of federal air and water pollution control policies (Dorfman 1973). Considering both air and water pollution control together, and taking account of different possible assumptions about the incidence of taxes to finance the public share of costs, Dorfman found a more or less proportional incidence for 1972 but increasingly regressive patterns of incidence for 1976 and 1980. Her analysis of automotive pollution control costs was based on auto purchase and ownership data from the *Consumer Buying Indicators* (Department of Commerce). Actual costs for meeting 1972 automobile emissions standards and estimates of expected costs for 1976 and 1980 were distributed by income class on the assumption that used-car prices would adjust to changes in new-car prices so as to maintain the same relative prices and rates of price depreciation of cars of different ages. Costs per family were found to be approximately proportional to income over the lower- and middle-income range, but with the lowest income class (under $2,000 per year) bearing a much higher burden relative to income, and the cost relative to income declining for families with income over $15,000 per year. Dorfman's results are different from those reached in this study in that we find the pattern of incidence to be unambiguously regressive.

This paper has three major purposes. The first is to present an analysis of the distribution of automotive pollution control costs under the present strategy (the Clean Air Act of 1970). This estimate of incidence will be based on an explicit model of new-car and used-car demand, prices, and user costs; and it will utilize data on the purchases and ownership of new and used cars according to income level. The second purpose is to consider the incidence of alternative strategies for controlling air pollution. Specifically, we shall investigate policy alternatives which will impose pollution control requirements on all owners of cars rather than only on new-car buyers. Alternative strategies will include costs which are imposed uniformly on all cars, costs which vary systematically with the age of the car, and costs which are related to car usage. The third purpose is to utilize the incidence data developed here to assess the target efficiency of proposals to mitigate the possible regressive impact of pollution control costs through subsidies.

The patterns of car ownership and purchase by income level are discussed in the next section. These data form the basis for the incidence analysis. In Section III, the concept of target efficiency is discussed. The analyses of the incidence of the present program and several alternative strategies are presented in Sections IV and V.

II. CAR OWNERSHIP AND PURCHASES BY INCOME

The conventional wisdom is that the rich own mostly new cars and purchase new cars while the poor buy used cars and own mostly older cars. While this picture of car ownership and purchase patterns by income is basically correct, it is an oversimplification which obscures more complex patterns of multiple car ownership and substantial purchases of used cars and ownership of older cars by upper-income multi-car families.

The Current Population Survey has gathered quarterly data on purchases of new and used automobiles by income class and ownership of automobiles broken down by model year of car and numbers of cars per family by income class as of July of each year. The Current Population Survey data are enumerated by household. The income concept is family income defined to include: money wages and salaries, net income from business or farm, dividends and interest, rent, and any other money income received by members of the household, before deductions for taxes, social security, and so forth.

It should be noted that the income measure used is a form of current income. Ideally, one would rather work with some measure of permanent income. For example, the real significance of an increase in the price of new cars for new car buyers with less than $3,000 per year current income will be less if a substantial portion of those buyers had permanent incomes which were well above $3,000 per year. In fact, it seems plausible that a significant number of car buyers, especially new-car buyers, in the lowest income class would be classified as "temporary poor" if their permanent incomes were known.

TABLE 1 Household Car Ownership by Number of Cars Owned, July 1971

Income Class	Number of Households (000)	Percent Owning: One or More Cars	Percent Owning: One Car	Percent Owning: Two Cars	Percent Owning: Three or More Cars
Under $3,000	10,700	43.6	38.0	5.1	0.5
$ 3,000–4,999	9,600	70.2	58.9	10.8	0.5
5,000–7,499	11,500	85.2	62.8	20.3	2.1
7,500–9,999	9,300	91.3	58.4	28.1	4.8
10,000–14,999	12,800	94.9	48.6	38.7	7.6
15,000 and over	8,700	96.6	33.9	47.9	14.8

SOURCE: U.S. Department of Commerce, Bureau of the Census, *Consumer Buying Indicators*, P-65, No. 40, May 1972.

With this in mind, let us first consider ownership by income class. Table 1 shows the percentage of households involved in car ownership, as well as a breakdown of the number of cars owned by each household. Over 90 percent of households with income over $7,500 own cars, and even in the $3,000 to $5,000 income class, 70 percent of households own at least one car. Multiple car ownership is a major characteristic of middle- and upper-income households. In fact, a majority of households with incomes over $10,000 own two or more cars.

Table 2 contains data on ownership of cars by households by model year or age of car. Since the survey was taken in July of 1971, the 1971 model cars are "new." As the last column of the table shows, the median age of cars declines with increasing family income. However, there are stili substantial numbers of older cars owned by upper-income households.

In Table 3 this becomes more apparent. The table shows how cars of each vintage are distributed across income levels. The percentage of each age group owned by the lowest income class increases with age of car; but the percentage decreases with age for the highest income class. Nevertheless, while households with incomes over $10,000 represent only about 33 percent of all households, they own over 36 percent of all five-year-old and older automobiles.

Table 4 shows ownership patterns from a different perspective. For each income class, the table shows the percentage of households in that income class owning a car of a given vintage. For the $5,000 per year and over income classes, the rows sum to more than 100 percent because of multiple car ownership. The table confirms the fact that the rich own new cars and the poor own old cars. For example, barely 5 percent of households with under $5,000 a year income own a 1970 or 1971 model car, while close to 45 percent of $15,000 and over households are in this category. But, again, what is of interest is the lower right-hand corner of the table, and the substantial ownership of older cars by upper-income households. While only about 45 percent of the under $5,000 per year households own a car aged five years or older, over 60 percent of the households in the over $5,000 a year category own cars of this older vintage. With the exception of the highest income and oldest age category, not only do upper-income families own more new cars per family, but they own more old cars per family as well.

Data on car purchases by income level are consistent with the observed patterns of ownership. Table 5 shows household car purchases by income level for 1971. As expected, the percentage of households which purchased a new car in 1971 rises with income. But the percentage of households which purchased a used car also rises with income up to the $10,000 a year level.

TABLE 2 Household Car Ownership by Model Year, July 1971 (Thousands)

Income Class	Number of Households	Total Cars Owned	Cars per Household	Model Year: 1971	1970	1969	1968	1967	1966 and Earlier	Median Age of Car
Under $5,000	20,300	13,200	.65	400	700	900	1,000	1,100	9,100	≫4
$ 5,000–9,999	20,800	24,600	1.18	1,400	2,400	2,600	2,800	2,300	13,100	>4
10,000–14,999	12,800	19,000	1.48	1,500	2,400	2,500	2,300	2,000	8,300	14
15,000 and over	8,700	15,200	1.75	1,600	2,200	2,500	2,100	1,600	5,200	3
Not reported	2,200	2,300	1.05	200	200	300	200	200	1,200	>4
All households	64,800	74,300	1.15	5,100	7,900	8,600	8,400	7,300	37,000	4

SOURCE: U.S. Department of Commerce, Bureau of the Census, *Consumer Buying Indicators*, P-65, No. 40, May 1972.

TABLE 3 Household Ownership of Cars by Model Year and Income Class, July 1971

		Percentage of Cars of Given Age Owned by Income Class				
Age (years)	Model Year	Under $5,000	$5,000–9,999	$10,000–14,999	$15,000 and Over	Income Not Reported
0	1971	7.8	27.5	29.4	31.4	3.9
1	1970	8.9	30.4	30.4	27.8	2.5
2	1969	10.5	30.2	29.1	29.1	3.5
3	1968	11.9	33.3	27.4	25.0	2.4
4	1967	15.1	31.5	27.4	21.9	2.7
5 or older	1966 or before	24.6	35.4	22.4	14.1	3.2
		Percentage of Households in Income Class				
		31.3	32.9	19.8	13.4	3.4

SOURCE: U.S. Department of Commerce, Bureau of the Census, *Consumer Buying Indicators*, P-65, No. 40, May 1972.

TABLE 4 Household Ownership of Cars by Model Year and Income Class, July 1971

	Percent of Households Owning Car of Model Year					
Household Income Level	1971	1970	1969	1968	1967	1966 or Before
Under $5,000	2.0	3.4	4.4	4.9	5.4	44.8
$ 5,000–9,999	6.7	11.5	12.5	13.5	11.1	63.0
10,000–14,999	11.7	18.8	19.5	18.0	15.6	64.8
15,000 and over	18.4	25.3	28.7	24.1	18.4	59.8
Not reported	9.1	9.1	13.6	9.1	9.1	54.5
All households	7.9	12.2	13.3	13.0	11.3	57.1

SOURCE: U.S. Department of Commerce, Bureau of the Census, *Consumer Buying Indicators*, P-65, No. 40, May 1972.

TABLE 5 Household Car Purchases by Income Level, 1971 (Percent)

Income Class	Households Purchasing a Car	Households Purchasing a New Car	Households Purchasing a Used Car	Buyers Who Choose a New Car
Under $3,000	15.0	2.3	12.7	15.3
$ 3,000–4,999	24.5	5.6	18.9	22.9
5,000–7,499	34.5	10.3	24.2	29.9
7,500–9,999	38.5	11.4	27.1	29.8
10,000 and over	48.0	22.4	25.6	46.7
All households	34.9	12.6	22.3	36.1

SOURCE: U.S. Department of Commerce, Bureau of the Census, *Consumer Buying Indicators*, P-65, No. 43, December 1972.

III. TARGET EFFICIENCY

One reason for examining the incidence of automotive pollution control costs is that we (society) may decide that the pattern of incidence is inequitable; and we may wish to alter the pattern of incidence through some kind of subsidy scheme. Another reason for interest is that as the costs of meeting the 1976 automotive standards become more visible to consumers, and as costs of transportation controls and other policies necessary to meet ambient air quality standards in some areas become known, there may be considerable political reaction against the air pollution controls. It has been suggested that this kind of political backlash might be blunted by an appropriate program of subsidy. For example, A. Alan Post, the legislative analyst for the State of California, has said:

> Thus, if a disincentive or a direct regulatory action is to make the cost of essential transportation for low income workers and students prohibitively expensive, we will be confronted with the need to provide some form of exemption or subsidy for these people. Our experience to date has shown that disincentives or controls that make the cost of essential mobility prohibitive for any significant number of people are not politically acceptable (Post 1973, p. 9).

Also, the Environmental Quality Laboratory at the California Institute of Technology, in outlining their proposed strategies for meeting the air quality standards in the Los Angeles basin, included the following among their recommendations: "Mandatory installation of an evaporative control device on gasoline-powered 1966–69 vehicles . . . . Since this device is estimated to cost approximately $150 to purchase and install, some subsidy or cost sharing would be required" (Lees 1972, p. 23).

Subsidies of this sort are among several possible strategies for changing the distribution of income. Subsidies will have effects on resource allocation and economic efficiency which must be weighed when considering their use. However, our concern here is only with their evaluation in the context of redistributive or equity criteria. A number of criteria for judging income redistribution policies have been proposed and discussed in the literature. One such criterion has been proposed by Weisbrod—the target efficiency of the redistributive process (Weisbrod 1969).

Target efficiency refers to the extent to which the actual distribution of the benefits of some redistributive program coincides with the desired distribution of benefits. Where some target population has been identified as the desired beneficiary, one measure of target efficiency is the percentage of total program benefits which are delivered to the target population. This measure is termed "vertical efficiency."

"Horizontal efficiency" can be measured in two ways. The first is the percentage of members of the target group which actually receive benefits. Alternatively, where the redistributive program has the aim of meeting some target level of need (e.g., minimum income, full subsidy of specified costs), a second measure of horizontal efficiency is the dollar value of benefits received by the target group as a percentage of the total benefit *needs* of that target group.

Any subsidy of automotive pollution control costs for all households will have a lower vertical efficiency, the greater the percentage of the overall burden of pollution control costs actually borne by upper-income groups. A subsidy of pollution control costs for all households will have a virtually 100 percent horizontal efficiency in terms of coverage if the target class is defined as car-owning (or car-purchasing) households with income below some minimum. However, if the target group is defined to include all households with less than the minimum income, i.e., if the pollution control subsidy program is seen as part of a larger general income redistribution plan, the subsidy will have a relatively lower horizontal efficiency, since it will not provide benefits to non-car-owning households.

Because of our interest in equity considerations, and because of the possibility that subsidy proposals will be seriously discussed, we shall test the horizontal and vertical efficiencies of strategies to subsidize pollution control costs for automobiles. It will be assumed, for illustrative purposes, that the target group of desired beneficiaries consists of households with less than $5,000 income per year. This definition of the target group is dictated, in part, by the available data.

IV. MEETING THE 1976 NEW CAR STANDARDS

In this section, a user-cost model of the demand for cars is developed and used to analyze the relationships among prices and user costs for new and used cars. The model shows that when the price of new cars is increased; for example, becäuse pollution control equipment is installed on new cars; there is an induced increase in both the prices and the user costs of used cars. The model is used to determine the magnitude and the incidence of these changes: (a) during the first year, when only new cars have pollution control equipment; and (b) at the end of the transition period, when the uncontrolled stock of cars has been fully replaced by cars meeting the 1976 standards. After this transition, the user costs of cars of all ages fully reflect the real resource cost of pollution control; and the incidence of these costs can be found by relating user cost as a function of age of car to the income of the owners. However, the model shows that during the transition period, changes in the prices of used cars without pollution control produce both capital gains and higher user costs to owners. The pattern of these pecuniary effects is also important for a full understanding of the impact on the distribution of income of introducing a pollution control program for new cars.

The empirical analysis uses 1971 as a base year. Car purchase and car ownership data for 1971 are combined with the projected incremental cost of moving from 1971 emission levels to the 1976 standards. The period of transition between 1971 and 1976 is ignored. In other words, the analysis is based on the assumption that new cars meeting the 1976 standards were available beginning with the 1972 model year.

This study, like many analyses of incidence or burden, does not attempt to take into account the effects of price changes on demand, or other second-order effects. Although changes in the relative prices of new and used cars are explicitly incorporated in the model, the empirical analysis assumes that consumers do not respond to these price changes by altering purchase patterns of new and used cars.[3]

A. The Costs of Control

There is considerable controversy over what will be the true costs of equipping 1976 model cars with the appropriate equipment to meet the emission standards. Auto manufacturers and oil companies in advertisements and public statements have cited figures far higher than those mentioned by independent sources and used by government officials in their analysis of the problem. Fortunately, since the concern of this study is with the relative burden of control costs among income classes, the accuracy of estimates of control costs per car is of only secondary importance. The estimates of control costs used here were published by EPA (Environmental Protection Agency 1972).

The 1971 model cars already must meet certain emission control standards. EPA estimates that the cost of meeting these standards amounts to $32.50 per car. EPA has identified three technological alternatives for achieving the 1976 emission control standards. The additional costs per car for manufacturing and installing additional devices and making certain design changes to reduce emissions below the 1971 level are estimated to range between $196.50 and $318.50. The auto manufacturers have committed themselves to the most costly of these alternatives. Therefore, it is assumed here that the manufacturing costs are increased by $320, and that this cost is fully passed on to consumers in the price of new cars.

EPA also estimates that emission control devices will reduce fuel efficiency, leading to increased operating costs. In addition there will be incremental maintenance costs associated with these devices. Increased fuel consumption costs are estimated at $24.70 per year, and maintenance costs are estimated to increase by $11.40—all at 1970 prices. The total increase in operating and maintenance costs is $36.10 per year.[4]

B. A Naive Model of Incidence

Before turning to the more sophisticated user-cost model, this section presents estimates of incidence based on the assumption that pollution control costs affect only new-car purchase prices, and the price increases are borne fully by the purchasers of new cars.

Two modifications of the data presented in earlier sections are utilized here. First, to take into account the increased operating and maintenance costs, this cost stream is discounted over a five-year period at 10 percent, and the present value is added to the equipment costs of pollution control. Hence it is assumed that the total impact of pollution control on new car purchasers is equal to $320 plus $135, or $455 per car. Second, since there is considerable variation in car-purchase behavior from year to year, both in aggregate and with respect to income levels, the three-year period 1970–72 was used to determine the average number of purchases per year per income level for both new and used cars.

Table 6 shows number of households, income per household, and percent purchasing new cars for each income class. The next column shows the costs per buyer ($455) as a percentage of family income for each income class. The impact of the pollution control costs is sharply regressive, with the implicit tax rate falling from 26.5 percent at the lowest income level to only 2.5 percent at the highest income level.

TABLE 6 The Incidence of the 1976 Standards, the Naive Model

Income Class	Number of Households (thousands)	Income per Household (dollars)	Percent Purchasing a New Car[a]	Cost per Buyer as a Percent of Family Income	Cost per Household as a Percent of Family Income
Under $3,000	10,800	1,714	2.6	26.5	.69
$ 3,000–4,999	9,425	3,964	5.3	11.5	.61
5,000–7,499	11,475	6,215	10.0	7.3	.73
7,500–9,999	9,475	8,696	12.4	5.2	.65
10,000 and over	21,600	18,444	21.3	2.5	.53

SOURCE: Calculated from U.S. Department of Commerce, Bureau of the Census, *Consumer Buying Indicators*, P-65 Series.
[a]Average for three years: 1970–72.

The final column shows average cost per household as a percentage of family income. In this case, the total costs incurred by members of an income class are averaged over all members of that class whether or not they purchased a car. This measure is not as useful for welfare purposes because it obscures the differences between the impact on those who purchase cars and those who do not. However, this is a widely used measure of incidence in other situations. Moreover, it will be useful in making comparisons with the incidence as determined by the user-cost approach taken below. The incidence per household is mildly regressive overall, but it shows some degree of progressivity in the lower- to middle-income range. In this respect, the results are similar to those of EPA cited in the introduction.

Suppose that some fraction of the purchase price were subsidized by the government. How efficient would this subsidy be in delivering benefits to the assumed target group of under $5,000 per year households? Approximately 10 percent of the total cost of pollution control devices on new cars would be borne by the target group. Hence the vertical efficiency of a subsidy of the purchase price would be only 10 percent, i.e., 10 percent of the total cost of the subsidy would go to the target group. If the purpose of the subsidy is to distribute benefits to all households of under $5,000 per year, the horizontal efficiency is also quite low. Only 3.9 percent of households in the target income class purchase new cars, thus horizontal efficiency is only 3.9 percent.

C. A User-Cost Approach

The basic postulate of the user-cost theory of the demand for capital goods is that the user's demand for a durable asset is derived from the flow of services provided by the good, and that it is the price of these services or rental cost of the durable, rather than its purchase price, which governs the demand to hold that asset for a given period of time.[5] For our purposes, user cost can be defined as the cost of owning an automobile for one year and is equal to the reduction in market value of the automobile during the year plus the implicit interest cost of capital tied up in car ownership

(1) $$c_{(i,t)} = P_{(i,t)} - P_{(i+1,t+1)} + rP_{(i,t)}$$

where $c_{(i,t)}$ is the user cost of an i-year-old car in year t, P represents market price, and r is the relevant interest rate or cost of capital.

The user-cost approach is valuable for at least three reasons. First, it permits the expression of the pollution control costs in annualized terms as an increase in user cost per year rather than as an increase in purchase price as in the naive model above. Second, the user-cost approach provides a method for expressing the total stock of used cars of all ages in terms of one-year-old equivalents.[6] And third, as will be shown below, the user-cost approach permits the development of a demand model for determining relative price effects and the way in which they alter the incidence of pollution control costs.

Let us first consider the pattern of incidence in the first year of the new pollution control program, i.e., when only new cars have pollution control. The introduction of pollution control requirements which raise the purchase price of new cars will have two kinds of effects which are partly offsetting in terms of incidence. First, because used cars are close substitutes for new cars, there will be an induced increase in the price of used cars. This results in a once-and-for-all capital gain for all present owners of used cars, i.e., cars of ages $i = 1, \ldots, n$. Second, the changes in purchase prices of new and used cars will result in increases in the user costs to all present car owners and to new-car purchasers. In addition, those who purchase new cars will experience higher operating and maintenance costs for their cars. The task now is to create a model expressing these effects, and to utilize available data and reasonable assumptions to estimate their magnitude by income class.

First, a model of new- and used-car demand is required to determine the magnitude and incidence of the capital gains resulting from the increase in the price of new cars. Abstracting from the effects of income and prices of all other goods, assume that in year t the quantity demanded of new cars, $D_{(0,t)}$, depends upon the purchase price of new cars, $P_{(0,t)}$, and the purchase price of one year used-car equivalents, $P_{(1,t)}$.[7] Further assume a constant elasticity relationship

(2) $$D_{(0,t)} = P^{a}_{(0,t)} P^{b}_{(1,t)} \qquad a<0; b>0$$

In the used-car market, the stock of used cars is exogenously determined by past investment decisions. The price of used cars must be such as to make individuals willing to hold the existing stock. The used-car demand function takes the form

(3) $$P_{(1,t)} = S^{d}_{(t)} P^{f}_{(0,t)} \qquad d<0; f>0$$

where the purchase price and stock of used cars are expressed in terms of one-year-old equivalents. To obtain the change in used-car purchase prices resulting from any autonomous change in new-car purchase prices, differentiate equation (3) with respect to new-car prices, or

(4) $$\partial P_{(1,t)}/\partial P_{(0,t)} = f \frac{P_{(1,t)}}{P_{(0,t)}}$$

This expression will be referred to as the price shifter, or "s".

A reasonable magnitude for s can be assumed on the basis of available empirical studies. Wykoff has estimated a form of equation 3 where the independent variables were user costs for new and used cars, rather than purchase prices. Although he concluded that "used-car prices remain largely unexplained," because of low $\bar{R}^2$ and low t-statistics, the elasticities calculated from the estimated coefficients seemed reasonable. The elasticity for the user cost of new cars was estimated to be .34 (Wykoff 1973, pp. 384–385). It can be shown that under some reasonable assumptions, including those made in equation 8 below, the elasticity (f) of used-car *price* with respect to new-car *price* will be of the same magnitude. Accordingly, it is assumed here that $f = 1/3$. Dorfman has gathered data on new- and used-car prices from published sources (Dorfman 1973). Her data showed that on a weighted average basis, the prices of one-year-old cars in 1973 were approximately 74 percent of new-car purchase prices. Combining these estimates, equation 4 shows that for every \$4 increase in the purchase price of new cars, the price of one-year equivalent used cars can be expected to rise by \$1, i.e., $s = 1/4$.

This model of price shifting and estimated values for s can be used to determine the capital gain for each used-car owner in the following way. The capital gain to the owner of a one-year-old equivalent used car is

(5) $$g_{(1,t)} = s \, \Delta P_{(0,t)}$$

Furthermore, if it can be assumed that the price structure for used cars remains constant, i.e., there are no changes in the relative prices of used cars of different ages, the capital gain for a car of age i is

(6) $$g_{(i,t)} = s\,\Delta P_{(0,t)}(P_{(i,t)}/P_{(1,t)})$$

The same price increases that produce capital gains for used-car owners also lead to increases in user costs for both used-car owners and new-car purchasers. The increase in user cost for a purchaser of a new car with pollution control is

(7) $$\Delta c_{(0,t)} = (P'_{(0,t)} - P_{(0,t)}) - (P'_{(1,t+1)} - P_{(1,t+1)}) + r(P'_{(0,t)} - P_{(0,t)})$$

where the primes indicate purchase prices of cars with pollution control. Assume that the rate of depreciation of purchase price for cars with pollution control is the same as has been observed for cars without pollution control. Then

(8) $$P'_{(1,t+1)}/P'_{(0,t)} = P_{(1,t+1)}/P_{(0,t)} = h$$

and by substitution

(9) $$\Delta c_{(0,t)} = (1 - h + r)\,\Delta P_{(0,t)}$$

This is the increase in the user cost to a buyer of a new car.[8]

To determine the changes in user costs imposed on owners of used cars, it is necessary to determine how user costs are affected by the changes in prices of used cars in the model above. Wykoff developed models of new- and used-car demands where user-cost variables replaced the price variables in the demand equation (Wykoff 1973). He found that the user-cost model explained new-car demand as well as a model based on purchase price variables. If this is the case, the price shifting model of equations 3 and 4 can be reformulated in terms of user cost and a shifter, s', can be derived

(3a) $$c_{(1,t)} = S^{d'}_{(t)} c^{f'}_{(0,t)}$$

and

(4a) $$s' \equiv \partial c_{(1,t)}/\partial c_{(0,t)} = f' \frac{c_{(1,t)}}{c_{(0,t)}}$$

This permits the derivation of the changes in user costs for one-year-old used cars for any given increase in the price of new cars. The change in user cost is

(10) $$\Delta c_{(1,t)} = s' \, \Delta c_{(0,t)}$$

Wykoff has also analyzed how user costs for automobiles depreciated with age during the 1960s (Wykoff 1970). He found that after the first year of car life, user costs tended to decline at a constant rate such that

(11) $$c_{(i,t)}/c_{(1,t)} = e^{-d(i-1)}$$

Estimates of d, the constant depreciation rate, varied from .17 to .23 for standard and smaller models and were as high as .27 for expensive domestic cars. Accordingly, changes in user costs for older used cars are given by

(12) $$\Delta c_{(i,t)} = s' \, \Delta c_{(0,t)} \, e^{-d(i-1)}$$

The models of price changes, capital gains distribution, and changes in user costs are now complete. With assumptions as to the magnitudes of parameters, the models can be combined with data on purchase and ownership of cars to estimate the distribution of the cost of imposing pollution control standards during the first year.

The reasons for assuming $s = 1/4$ have been described above. The value for s' is also assumed to be 1/4.[9] On the basis of data from Dorfman (1973), the relative purchase price of one-year-old and new cars, h, is assumed to be equal to .74. The cost of capital, r, is assumed to be 10 percent. And finally, on the basis of data reported by Wykoff (1970), the rate of depreciation of user costs, d, is assumed to be equal to .2.

Assuming that pollution control requirements raised the price of new cars in 1972 by $320, the capital gains and user cost changes for owners of the existing stock of cars will be distributed among households as shown in Table 7. The holders of the existing stock of cars are made better off by the pollution control requirements, since the induced capital gain is roughly two and one-half times larger than the increase in user costs.[10] Although the net gain rises with income, the gain as a percentage of family income is highest for the lowest income class. The net gains are distributed in a progressive, or propoor, manner.[11]

It must be emphasized that the net gain shown in Table 7 is the result of a once-and-for-all capital gain experienced by used-car owners in the first year following the imposition of pollution controls on new cars. While user costs to used-car owners will continue to rise, there will be no further offsetting capital gains in subsequent years. Furthermore, the gain can only be realized by selling the car—either to purchase an older model or to forgo ownership altogether. If an individual retains his present car to the end of its useful life, the gain is just offset by an equal annual

TABLE 7 Incidence of the Capital Gains and User-Cost Changes for Used-Car Owners: the First Year

Income Class	Income per Household (dollars)	Capital Gain per Household (dollars)	Change in User Cost per Household (dollars)	Capital Gain as Percent of Family Income (percent)	Change in User Cost as Percent of Family Income (percent)	Net Change as Percent of Family Income (percent)
Under $5,000	2,674	+16.87	6.57	+.63	−.25	+.38
$ 5,000–9,999	7,473	+38.14	14.62	+.51	−.20	+.31
10,000–14,999	12,151	+53.91	20.52	+.44	−.17	+.27
15,000 and over	25,404	+70.71	26.75	+.28	−.11	+.17

SOURCE: Calculated from U.S. Department of Commerce, Bureau of the Census, *Consumer Buying Indicators*, P-65 Series.

equivalent flow of higher user costs. And if an individual trades in each year so as to maintain ownership at the same age level, the higher resale value of the original car is offset by a higher purchase price for the replacement.

The welfare significance of the capital gains should not be overemphasized. In terms of conventional indifference curve analysis, households experience both an increase in money income and an increase in the money price of one good such that the new budget line intersects the old one. Households could be better off, worse off, or indifferent depending on initial endowments and preferences.

In addition to the capital gains and changes in user costs of used cars, those who choose to purchase new cars will bear a burden in the form of higher user costs. Equation 9 was used to translate the change in purchase price into a change in user costs for new-car buyers. This increase in user costs was allocated by income class in accordance with the new-car purchase data summarized in Table 5. The increase in operating and maintenance costs of $36 per year was added to the increase in user charges calculated by equation 9. See Table 8. The pattern of incidence is

TABLE 8 The Incidence of User Costs for Buyers of New Cars

Income Class	Cost per Household[a] (dollars)	Cost per Household as a Percent of Family Income[a]
Under $3,000	3.90	.23
$ 3,000–4,999	7.95	.20
5,000–7,499	15.00	.24
7,500–9,999	18.60	.21
10,000 and over	31.95	.17

SOURCE: Calculated from U.S. Department of Commerce, Bureau of the Census, *Consumer Buying Indicators*, P-65 Series.

[a]Includes increased operating and maintenance costs of $36 per year per new car.

very similar to that of the naive purchase price model in Table 6. The incidence is approximately proportional up to the $10,000 income level. This is because although the burden per buyer is regressive, the proportion of households buying new cars declines as income falls.

Although the purchase data and car ownership data are tabulated on the basis of different income classifications, it is possible to merge the gain and cost data to get at least a rough idea of the overall incidence of the combined first-year gains to used-car owners and costs to new-car buyers. Because the stock of cars in existence at any point in time is far larger than the new-car purchases in a given year, the gains calculated in Table 7 outweigh the costs shown in Table 8. The net gains distributed by three broad income categories are as follows:

Income Class	As a Percentage of Family Income Gain	Loss	Net
Under $5,000	+.38	−.21	+.17
$ 5,000–9,999	+.31	−.22	+.09
10,000 and over	+.22	−.17	+.05

The overall incidence is dominated by the gains to used-car owners. This offsets the proportional or slightly regressive distribution of user costs to new-car buyers; and the net result is a propoor distribution of gains. Both the gains and costs are lowest for the high-income group, but since the purchase of new cars is more skewed by income level than is the ownership of cars, the highest income group bears a relatively larger share of the costs than it receives of the gains.

We now turn to the structure of user costs in the new equilibrium, when the stock of cars has been replaced by newer vintage cars with pollution control. It is assumed that throughout the period of transition there were no further changes in pollution control requirements or costs. Thus the user cost of new cars is the same as that given by equation 9. Further, it is assumed that the structure of user costs by age is the same as that which prevailed before the introduction of pollution control, and which was investigated by Wykoff (1970). Wykoff found that the depreciation rate in the first year was substantially higher than in subsequent years. He found a two-step depreciation schedule which is described as follows

(13) $$c_{(1,t)}/c_{(0,t)} = e^{-\hat{d}}$$

where $\hat{d} \simeq .35$, and

(14) $$c_{(i,t)}/c_{(1,t)} = e^{-d(i-1)}$$

where $i \geqq 1$, $d \simeq 2$.

Equations 13 and 14 were used to allocate user costs by income level on the assumption that the structure of ownership by age of car and income level was the same as that actually prevailing in 1971 and shown in Table 2. This allocation of costs is shown in Table 9.

There are several things to note about this distribution. First, the costs per household are substantially higher than those shown in Tables 6 through 8. In part, this is because there are no offsetting capital gains, and in part because by now all of the cars in the used-car stock have pollution control. Hence families cannot avoid the cost of pollution control in the

TABLE 9 The Incidence of User Costs, Used-Car Owners, All Cars Controlled

Income Level	Cost per Household (dollars)	Cost per Household as a Percent of Family Income
Under $5,000	43.17	1.61
$ 5,000–9,999	85.41	1.14
10,000–14,999	112.81	.93
15,000 and over	139.54	.55

SOURCE: Calculated from U.S. Department of Commerce, Bureau of the Census, *Consumer Buying Indicators*, P-65 Series.

long run by owning or purchasing a used car. Second, the incidence pattern is unambiguously regressive. The implicit tax rate on the under $5,000 per year income group is almost three times the tax rate on the $15,000 and over group.[12] In other words, when account is taken of the fact that ultimately all car-owning households will bear part of the costs of pollution control, the incidence pattern becomes much more regressive than when one investigates only the incidence of new-car purchase costs.

Again, the new-car purchase data can be merged with the user-cost data to obtain a rough picture of the incidence in the new equilibrium. See Table 10. Again, the overall pattern is regressive. However, the merging of the $15,000 and over income class with the $10,000–$15,000 class obscures the low implicit tax rate on the highest-income families.

TABLE 10 Overall Incidence, New and Used-Car Owners, All Cars Controlled

Income Class	Cost per Household (dollars)	Cost per Household as a Percent of Family Income
Under $5,000	48.94	1.83
$ 5,000–9,999	102.16	1.37
10,000 and over	155.73	.89

SOURCE: Calculated from U.S. Department of Commerce, Bureau of the Census, *Consumer Buying Indicators*, P-65 Series.

The total increase in user cost in the new equilibrium is $6,466 million per year. Of this amount, approximately $1,000 or 15 percent is borne by the under $5,000 per year income group. Hence the vertical efficiency of an across-the-board subsidization of user costs would be about 15 percent. Also, since only about 56 percent of households in the under $5,000 per year income group own cars, the horizontal efficiency of an across-the-board subsidy of user costs would be about 56 percent.

Alternatively, the subsidy could be directed at the purchase price of new cars. Since this subsidy would not cover the increased operating costs, it would have a slightly different distribution of its benefits than a full user-cost subsidy. However, the vertical efficiency of such a purchase price subsidy would not be substantially different from the 15 percent cited here.

V. THE INCIDENCE OF ALTERNATIVE CONTROL STRATEGIES

In the introduction, it was suggested that the present strategy directed at achieving pollution control standards for new cars produced after 1976 may not be the most appropriate. It will be approximately five years before normal replacement of the existing stock of cars results in the majority of cars on the road having been designed and manufactured to meet the 1976 standards. Furthermore, there are major unsolved problems concerning the durability and effectiveness of the technology which American manufacturers have apparently chosen to meet these standards. Finally, the federal standards do not take into account regional differences in the severity of the automotive air pollution problem. Some urban areas will probably have to take more severe action to control automotive emissions in order to meet the established ambient air quality standards (*New York Times* 1973; Lees 1972).

These factors have led some students of the problem to consider alternative control strategies which would be directed at controlling the emissions of all cars within the relevant jurisdiction. In this section, the incidence of the costs of three alternative strategies of this type are examined. In each case, the costs are purely hypothetical. No attempt has been made to relate costs to the achievement of actual air quality standards, nor was there any attempt made to utilize engineering data to determine a "realistic" cost. However, given the postulated hypothetical cost figures, the imputation of these costs among income groups appears valid. For other control schemes which have the same distributional impact but different total cost levels, the incidence patterns portrayed here would still be relevant, since the alternative programs would be proportional to those shown here.

Three kinds of control programs are considered:

1. Uniform control costs per car. It is assumed that every car on the road is required to install or retrofit the same emission control package, i.e., the increase in user costs is the same for all models and ages of cars.
2. Uniform emissions standards for all cars. It was assumed that all cars must meet the same emissions standards, but that the costs of meeting these standards was a rising function of age of car.
3. Costs related to use. The preceding strategies focus on emissions per mile, without attempting to control miles driven. A surcharge on gasoline purchases is one way of attempting to curtail automobile use as part of an overall air pollution control strategy.

A. Uniform Control Costs per Car

It was postulated that all cars would be required to incur the same level of control costs, and that the effect of these requirements would be to raise the user cost per car by $100 per year. The car ownership data were used to impute a control cost per owner and a control cost per household for each income level. The dollar amounts of these costs and costs as a percentage of family income are tabulated in Table 11.

TABLE 11 Incidence of Uniform Control Cost per Car

		Control Cost per Owner		Control Cost per Household	
Income Class	Income per Household (dollars)	Dollars	As a Percent of Family Income	Dollars	As a Percent of Family Income
Under $3,000	1,714	114	6.65	49.70	2.90
$ 3,000–4,999	3,964	117	2.95	82.00	2.07
5,000–7,499	6,215	129	2.08	109.70	1.77
7,500–9,999	8,696	141	1.62	129.20	1.49
10,000-14,999	12,151	157	1.29	148.79	1.22
15,000 and over	25,404	180	.71	174.10	.69

SOURCE: Calculated from U.S. Department of Commerce, Bureau of the Census, *Consumer Buying Indicators*, P-65 Series.

The pattern of incidence is highly regressive. For the under $3,000 income class, the implicit tax rate per car owner is more than nine times the corresponding tax rate on the highest income level. Even neglecting the under $3,000 per year class, which may include a high proportion of students and other voluntary temporary poor, the implicit tax rate per owner and per household is still more highly regressive than that found for the federal policy.

The vertical efficiency of an across-the-board subsidy of pollution control costs can be measured by the percentage of total control costs which is borne by the target group, i.e., the under $5,000 per year income class. Under the uniform control cost scheme, since the under $5,000 income class owns 18 percent of all cars owned by the household sector, it bears 18 percent of the total cost of the control imposed on the household sector. Hence, the vertical efficiency of an across-the-board subsidy scheme would be 18 percent. Since 56 percent of households in the under $5,000 per year income class own one or more cars, the horizontal efficiency of a subsidy scheme is 56 percent.

B. Control Costs Rise with Age of Car

For this section, it was postulated that the cost of controlling emissions for 1971 model cars resulted in an increase in user cost of $40 per car per year, and that user costs increased linearly with age to a level of $140 per year for 1966 and earlier model cars. This pattern of user cost results in a total cost of control per year approximately the same as the uniform control cost per car strategy analyzed above.

Table 12 contains control costs per household in dollar magnitude and as a percentage of family income. Again the pattern of incidence is regressive. However, this strategy does not impose absolutely larger costs on lower-income households, as one might have thought. This is because

TABLE 12 Incidence of Rising Control Costs with Age of Car

	Control Cost per Household	
Income Class	Dollars	As a Percent of Family Income
Under $5,000	80.59	3.01
$ 5,000–9,999	134.52	1.80
10,000–14,999	159.06	1.31
15,000 and over	175.40	.69

SOURCE: Calculated from U.S. Department of Commerce, Bureau of the Census, *Consumer Buying Indicators*, P-65 Series.

although low-income households tend to concentrate their ownership in the older age bracket, middle- and upper-income households own a larger number of the older vintage cars. The overall pattern of incidence is remarkably similar to that of the uniform control cost policy analyzed above. The implicit tax rate is slightly higher for the rising control cost strategy at the lowest income levels; but the tax rate is identical for both strategies at the highest-income class.

A subsidy plan which subsidizes the same percentage of control costs for all car owners would have a vertical efficiency of 20 percent. In other words, 20 percent of the subsidy would reach households in the $5,000 and under income class; and since 56 percent of the households in this income group own cars, the horizontal efficiency of such a subsidy program would be 56 percent.

An alternative subsidy scheme might cover only control costs for older vintage cars. For example, the subsidy might cover some fraction of the increase in user costs for 1967 and earlier vintage cars only. The vertical efficiency of that plan is somewhat higher, but is still a surprisingly low 24 percent. In other words, 76 percent of the benefits of such a subsidy would go outside the target income class. Moreover, of the 20.3 million households in the under $5,000 per year class, only 10.2 million or just over 50 percent would receive benefits from such a subsidy.

C. A Gasoline Tax

Gasoline purchase data by income class were available from the Brookings MERGE File for 1972.[13] A gasoline surtax was taken as representative of the several possible emissions control strategies directed at auto usage (miles driven) rather than auto ownership. A surtax of twenty cents per gallon was assumed in calculating Table 13; but the pattern of incidence would be the same for any strategy imposing costs on users in proportion to gasoline purchases.

Table 13 shows a pattern of incidence which is slightly progressive except at the extremes of the income distribution. The implicit tax rate rises from .84 percent for the $2,000–$3,999 per year class to 1.09 percent for the $15,000–$19,999 class. This contrasts with other control strategies analyzed here, all of which were regressive overall.

The data of Tables 11 and 13 are also relevant to the recent discussion of the distributional effects of alternative means of allocating scarce gasoline supplies. Allowing the price of gasoline to rise or imposing a surtax to control demand would not apparently have the regressive impact cited by opponents of price or tax policies. However, as Table 11 shows, the most commonly mentioned alternative, issuance of equal

TABLE 13 Incidence of Gasoline Surtax, Twenty Cents per Gallon

Income Class	Mean Income (dollars)	Tax Cost per Household: Dollars	Tax Cost per Household: As a Percent of Family Income
Under $2,000	1,062	13.72	1.29
$ 2,000–3,999	3,061	25.66	.84
4,000–5,999	5,000	41.44	.83
6,000–7,999	7,143	66.58	.93
8,000–9,999	9,000	90.12	1.00
10,000–14,999	12,000	128.60	1.07
15,000–19,999	17,500	190.28	1.09
20,000–25,999	22,250	236.16	1.06
26,000–49,999	33,684	305.16	.91
50,000 and over	95,484	296.16	.31

SOURCE: From data supplied by Nancy Dorfman from the Brookings MERGE File.

quantities of salable rationing coupons to each car owner, would have far more favorable distributional effects. The coupon scheme would involve a substantial transfer of income from the government (in the case of the surtax alternative) or oil producers (where the alternative was a price increase) to car owners, with the value of the transfer being a larger percentage of income for lower-income households.

VI. SUMMARY AND CONCLUSIONS

In this paper, we have developed a user-cost model of demand for new and used automobiles, and have used this model to trace out the effects of an increase in the price of new automobiles caused by the imposition of automotive emissions standards. In addition, we have compared the pattern of incidence that results from the present strategy with those which might result from alternative policies imposing requirements on all cars. EPA suggests that, relatively, the burden of the 1976 emissions standards will fall most heavily on middle-income groups. While this result is confirmed by the application of the naive model of new-car purchases, the more comprehensive user-cost model shows that the final result will be an unambiguously regressive distribution of the burden.

This conclusion is in contrast to Dorfman's finding of slight progressivity over the middle-income range (Dorfman 1973). It is difficult to pinpoint the reasons for our differences, but they appear to stem from different assumptions about the patterns of price changes for used cars, and different treatments of increased operating costs. Resolution of these differences probably requires more theoretical and empirical work to refine models of the structure of asset prices and rentals in the car market and the dynamics of the interaction between new- and used-car prices.

There are several limitations to the analysis presented here. First, there is considerable uncertainty as to what will be the costs of meeting the new-car standards by 1976. While most of the uncertainty regarding what technologies will be used has been resolved, there are still widely varying estimates as to the costs of utilizing these technologies. It is even difficult to reconcile estimates of control costs published by EPA at different times. Hence, all of the estimates of incidence presented here must be construed as indicating the *relative* distribution of the burden more accurately than the absolute levels of the burden.

Second, it should be noted that the incidence analysis assumes no changes in the patterns of automobile purchases and ownership in response to changes in the price of automobiles relative to other goods, or changes in the relative user costs of different models and vintages of automobiles. To the extent that consumers respond to changes in relative prices and user costs, the incidence patterns will be modified. Not only might the total quantity of automobiles demanded change, but there are likely to be changes in the model mix as well. This will be both because of changes in the relative prices of models and because of different own-price and cross-elasticities of demand among models and vintages. Also, the analysis abstracts from the possible effects of other forces such as rising fuel costs and rising costs of safety features, both of which are likely to compound the effects of pollution control requirements on the patterns of ownership and purchase.

Finally, the analysis considers only the effects of emission control costs borne directly by households as they purchase cars for private use. About 30 percent of each year's new-car production goes into commercial or governmental use. It is assumed that the emission control costs associated with these cars are passed on to consumers in a pattern similar to all other governmental and industrial pollution control costs.[14]

All of the strategies imposing direct control requirements on cars are regressive. The gasoline tax is the only exception revealed by our analysis, and that tax would be only slightly progressive through the middle-income range. The federal new-car strategy is substantially less regressive than the two alternative policies imposing requirements on all cars. With the federal strategy, after the transition the burden as a percentage of income for the under $5,000 group was about twice the burden on the over $10,000 group. However, for the two alternative strategies analyzed, the relative burden on the under $5,000 group was closer to three times the burden on the over $10,000 group. The analysis of target efficiency showed that the vertical efficiency of any across-the-board or general subsidy of pollution control costs would be quite low. The vertical efficiency of a subsidization of the costs of meeting the 1976 standards would direct only about 15 percent of its benefits to the under $5,000 per year income group. The vertical efficiencies of the uniform control costs and rising control costs with age strategies were 18 percent and 24 percent, respectively.

Finally, it is important to look specifically at the burdens placed upon households in the lowest income class by each of these strategies. In the first year, the 1976 new-car standards result in a net gain per household of approximately $10 for the under $5,000 per year class; and since only about 56 percent of the households in this income class own cars, this works out to a gain of approximately $18 per owner of a used car. On the other hand, each of the households in this income group purchasing a new car in the first year will experience an increase in user cost of approximately $170. While this would be a large burden relative to income, households in this situation could avoid, or at least reduce, the burden by retaining their old car or purchasing a used car rather than a new one.

After the effects of the new-car controls have been fully worked out, used-car owners in the under $5,000 class would be experiencing a $43 increase in user cost per household, or a $77 increase in user cost per owner. During the transition period between the first imposition of controls and the final equilibrium, the burden per household or per owner would be gradually rising to this level.

If control costs are imposed on all cars, the only way a low-income family can avoid the increase in user cost is to become a nonowner. The impact on low-income households could be substantial. As Table 11 showed, in the uniform control cost case, car owners in the under $3,000 per year income class had control costs of $114 per household or 6.65 percent of family income. The incidence patterns are roughly similar for the case of rising control costs with age of car.

Of major concern is the question of economic dependence on automotive transportation. If a control program prices a household out of the car market, will its members lose access to jobs? Morgan has reported some data on miles driven to work by income level (Morgan 1974). In general, as incomes per family rise, a greater percentage of family heads drive to work, and the average length of the trip rises. Over 40 percent of all families are not dependent on cars for travel to work (this includes families without a working head); and the percentage is almost 70 percent for the bottom two-fifths of the income scale. However, of those family heads who do drive at least ten miles to work and return, only about 30 percent report the availability of any public transportation alternative.

NOTES

1. These calculations do not take into account the rise in oil prices during 1974 associated with the Organization of Petroleum Exporting Countries (OPEC).
2. But for somewhat different results based on a different set of data and methods, see Gianessi, Peskin, and Wolff, Chapter 6, below.
3. For an analysis of the aggregate impact of meeting the 1976 standards which does consider changes in the pattern of purchases, see (Council on Environmental Quality 1972).
4. More recently, EPA has concluded that one catalyst replacement will be required during the first 50,000 miles of use. Catalyst replacement costs are estimated at between $50 and $155 per car (Environmental Protection Agency 1973, p. 4-8). These costs are not included in this study. Although this exclusion biases the estimated level of control cost, it does not materially affect the pattern of incidence of these costs.
5. Wykoff has developed the user-cost approach to create a model of the demand for automobiles. See (Wykoff 1970, 1973).
6. Briefly, the stock of used cars, measured in terms of one year old equivalents is given by

   $$S_{(t)} = \sum_{i=1}^{n} S_{(i,t)}(c_{(i,t)}/c_{(1,t)})$$

   S_t is a weighted index, where the number of cars in each year group is weighted by the ratio of the user cost of cars of that age to the user cost of the one-year equivalent. The definition can be expanded to take into account different models of the same vintage. See (Wykoff 1973).
7. This is Wykoff's "superior good" model in which new cars are qualitatively different from used cars by virtue of their newness alone. He found that this model explained new-car purchases better than the alternative "stock adjustment" model which treats new cars simply as additions to the total stock of cars. See (Wykoff 1973).
8. In addition, new-car buyers incur increased operating and maintenance costs as described earlier. These are added to the change in user cost measured by equation 9.
9. Wykoff's best estimate of f is .34. See (Wykoff 1973, pp. 384–385). He also estimates

   $$c_{(1,t)}/c_{(0,t)} = e^{-\hat{d}}$$
   $$= .7047$$

   where

   $$\hat{d} = .35$$

   See (Wykoff 1970).
10. In actuality, this gain will be spread out over several years between 1972 and 1976 as emission standards gradually become more stringent and new-car prices gradually rise.
11. This surprising result that owners of used cars benefit in the first year from the imposition of pollution control is not particularly sensitive to the choice of values for the parameters and does not depend on s. The net gain to the owner of an i year old car is

    $$g_{(i,t)} - \Delta c_{(i,t)} = s\,\Delta P_{(0,t)}\left\{\frac{P_{(i,t)}}{P_{(1,t)}} - [(1+r-h)\,e^{-d(i-1)}]\right\}$$

    which will be greater than zero if

    $$\frac{P_{(i,t)}}{P_{(1,t)}} > (1+r-h)\,e^{-d(i-1)}$$

and

$s > 0, \Delta P_{(0,t)} > 0$

The first inequality will hold for any reasonable set of values for the variables. The exponential term on the right side of this second equation is the ratio of user costs while the term on the left is the ratio of purchase prices. With the assumed values of r and h, the term in parentheses is substantially less than 1 (.36). Since the depreciation patterns for purchase price and user cost are likely to be similar, the inequality should hold in general.

12. As noted above, the data in the lowest income class may overstate the true degree of regressivity if it includes the "temporary poor," whose car purchases and ownership reflect a higher permanent income level.
13. I am indebted to Nancy Dorfman for making these data available to me. For some further interesting data on car use by income level, see (Morgan 1974).
14. See (Environmental Protection Agency 1972) and (Dorfman 1973).

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5 COMMENTS

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I. SUMMARY

A. Myrick Freeman's paper has three major purposes: (a) analysis of the distribution of automotive pollution control costs imposed by government regulations embodied in the Federal Clean Air Act of 1967 and Amendments of 1970; (b) analysis of the incidence of costs imposed by alternative strategies for controlling air pollution from private motor vehicles; (c) evaluation of the effectiveness of an across-the-board subsidy to neutralize the regressive impact of costs imposed by different strategies to control automotive pollution emissions. The paper is organized in four sections: patterns of car ownership and purchases, target efficiency measures, proposed user-cost model, and alternative strategies.

Patterns of Car Ownership and Purchases

The notion that the rich buy new cars and own mostly new cars while the poor buy used cars and own mostly used cars was tested against automobile purchase and ownership data enumerated in the July 1971 Current Population Survey. The data base of this study treats 1971 model cars as new. Examination of the household data that includes *purchases* of new and used cars by income class and *ownership* according to model of car and number owned per family indicated that upper-income households own a substantial inventory of cars older than the 1971 vintage. Table 3 shows that about 33 percent of all households have incomes over $10,000 but own over 36 percent of all automobiles that are five or more years old. Table 4 shows a similar pattern from a different perspective. It shows that 60 percent of the households reporting over $5,000 annual income own five-year-old and older cars, while only about 45 percent of households with annual incomes under $5,000 own cars in this vintage range.

Target Efficiency Measures

In this section, the possible need for a subsidy is introduced for two reasons: inequitable distributions of automotive pollution control costs may arise, and

NOTE: The views expressed are those of the discussant and do not purport to represent the views of the Environmental Studies Staff, the Bureau of Economic Analysis, or the U.S. Department of Commerce.

increased recognition that pollution control costs may be prohibitively high and thus may result in a reaction against such controls.

A subsidy, or cost sharing, of pollution control costs affects income distribution. Weisbrod (1969) proposed target efficiency of the redistributive process as a criterion for evaluation of income redistribution policies. Two measures of target efficiency were used in this paper. The first, "vertical efficiency," measures the percentage of total subsidy program benefits that are delivered to a predetermined target population. Coverage by a redistributive program is measured by "horizontal efficiency," which indicates the percentage of members of the target group that actually receive benefits.

As the incidence of pollution control costs upon upper-income groups increases, the vertical efficiency of an across-the-board subsidy of control costs decreases. The horizontal efficiency of such a subsidy is 100 percent if the target group is defined on the basis of car-owning (or car purchasing) households with a given level of annual income, and less than 100 percent if the target group includes all households in the given income category, those owning and those not owning automobiles.

The target group selected for this study is all households with yearly income less than $5,000.

Proposed User-Cost Model

A model based on annualized user costs is proposed for testing different strategies for meeting the 1976 new car antipollution standards. The present federal strategy of imposing emission controls only on new cars was analyzed first through a naive model of cost incidence and then through the user-cost model.

The assumptions of the naive model are that only new-car purchase prices are increased by pollution control costs and that these increases are borne fully by the buyers of new cars. It was estimated that the emission control device (presumably, a catalytic converter) elected by the automotive industry to meet 1976 standards will increase the price of new cars by $320 and increase associated annual operating and maintenance costs by $36. The operating and maintenance cost stream was discounted over a five-year period at a 10 percent discount rate to arrive at a total cost burden per new car of $455 present value. Application of this model to data on new-car purchases revealed an extremely regressive impact of control costs. Table 6 shows that the cost per buyer as a percentage of family income is 26.5 percent for incomes under $3,000 and 2.5 percent for income levels $10,000 and over. On the basis of costs per household, the result ranges from 0.69 percent to 0.53 percent. The naive model that is based on capital-cost increases on new cars yields a mildly regressive distribution of costs per household.

If the total cost were to be subsidized, the target group of under $5,000 per year households would receive only 10 percent of the total subsidy. In other words, the subsidy would have a vertical efficiency of 10 percent. Since only 3.9

percent of the target group buys new cars, this percentage represents the horizontal efficiency.

Freeman developed a "user-cost" model based on a model that Wykoff (1970) used to measure demand for automobiles. User costs are estimated on the basis of demand for, and purchase prices of, new and used cars.

Freeman states that the user-cost model has the advantages of measuring increases in annualized user costs in contrast to measuring increase in capital cost, measuring the total stock of used cars of all ages in terms of a one-year-old equivalent, and permitting development of a demand model to ascertain relative price effects on used cars.

A price-shifting factor was derived to measure the induced change in used-car purchase prices as a function of an autonomous change in new-car purchase prices. This induced change in used-car prices depends on the assumption that used cars are close substitutes for new cars. Further, used cars without pollution control can be assumed to be close substitutes for new cars with pollution control devices. It was estimated that a $4 increase in the purchase price of a new car generates an increase of $1 in the price of one-year-equivalent used cars. The analysis shows that this induced change results in a capital gain only in the first year of operation because of the price differential caused by pollution control devices. Further, used-car owners experience increases in user costs because of the same new-car purchase price increases that led to the capital gains. Increases in user costs for used cars are less than those for new cars. This difference is attributable to used cars not being perfect substitutes for new cars (Wykoff 1973). Increases in user costs to new- and used-car owners were augmented by associated increases in operating and maintenance costs.

The main thrust of this paper is an examination of the distribution of emission control costs resulting from the use of a user-cost model. This model was used to determine the pattern of incidence in the first year of the new pollution control program and in the subsequent equilibrium year, when the stock of noncontrolled cars has been completely replaced by emission-controlled cars.

In the first year, the user-cost model shows a net gain, or negative user cost, for new- and used-car owners because of the capital gain effect on used-car owners. This effect has a pro-poor distribution of 0.17 percent of family income for the target group, diminishing to an extreme of 0.05 percent for households in the $10,000 and over class.

After reaching a steady state wherein all cars are controlled, the user-cost model shows a regressive distribution ranging from 1.83 percent of family income of target households to 0.89 percent for households with $10,000 and over. If subsidized, the vertical efficiency is 15 percent and horizontal efficiency is 56 percent. Ownership patterns indicate that 56 percent of households with yearly incomes less than $5,000 own automobiles. It is assumed that purchase and ownership patterns are stable over the adjustment period.

Alternative Strategies

Two alternative strategies requiring control devices were examined. One involved uniform control costs per car through installation of the same emission control package across all cars. The other involved uniform emissions standards for all cars, where the cost of the emission control device increases with the age of the car in which it is to be installed.

The two alternatives were each regressive. Table 11 shows a range of 2.90 percent to 0.69 percent for uniform cost alternative. Table 12 shows a range of 3.01 percent to 0.69 percent for the uniform emission level alternative. If subsidized, their vertical efficiencies would be 18 to 20 percent, while their horizontal efficiencies would still be 56 percent.

In contrast to control strategies dependent upon automobile ownership, a third alternative based on automobile usage was examined. The third strategy is a tax on gasoline purchases that would impose pollution costs as a function of usage. This approach yields a slightly progressive distribution of the cost burden.

According to Freeman, the distribution of control costs shown by the naive model confirms EPA's suggestion that the burden of 1976 emission standards falls mostly on the middle-income group. In steady-state equilibrium, his user-cost model shows the federal strategy to be the least regressive relative to the other two approaches based on the use of an antipollution device.

II. CRITIQUE

Distributions of costs that would be imposed by the Federal Clean Air Act of 1967 and Amendments of 1970 and two alternative strategies for controlling automotive air pollutant emissions through control devices have been evaluated according to two criteria: (1) the impact of cost by income level (progressive, proportional, or regressive) and (2) the efficiency with which a particular strategy would distribute the benefits of an across-the-board subsidy aimed at lessening the cost impact.

No mention was made of the manner of financing any subsidization of a share of the purchase price of a new car with the antipollution device. Consequently, the impact of cost by income level was not compared against the tax increment by income level that would be imposed by the financing of the across-the-board subsidy. It is possible that the subsidy-financing tax burden may result in greater regressivity than the emission control cost burden.

Considering that the intent of a subsidy is to benefit a predetermined target group, it appears that a more direct mechanism can be used to reach a narrowly defined target group. The more appropriate target group should be only those households in a given income category that are actually affected by pollution control costs. Based on the car ownership patterns presented in the paper, only 56 percent of the households in the under $5,000 yearly income category comprise the appropriate target group. This group owns new and used cars. Further, this means-test constraint should not be limited to an income criterion but should include an appropriate wealth test. A wealth test should eliminate those for whom income is not an accurate measure of economic strength.

Because the proposed across-the-board subsidy does not conform to the vertical and horizontal tenets of an equitable system of taxation, it is proposed that only the affected target group should have their pollution control costs mitigated through the mechanism of a tax credit applicable to the federal income tax system. The suggested tax credit can be treated as equivalent to a negative income tax that is sufficient to neutralize the pollution control cost burden imposed on low-income households by government regulations. This approach assures 100 percent vertical target efficiency and 100 percent horizontal efficiency. That is, only the selected target group would benefit from a subsidy. An across-the-board subsidy is too diffused in its distributive effect to achieve a sharply focused stream of benefits that impinge only on the unduly burdened target group.

An important facet that has not been discussed is the effect of a subsidy upon the decision making of the automobile manufacturer. It was pointed out in the paper that the automobile industry has elected the most expensive of three possible methods to reduce emissions from an automobile engine to achieve 1976 government standards. No mention was made of alternative engine designs such as diesel, stratified-charge, Wankel, or electric designs. Because 1980 standards restrict permissible automobile emission to half of those that will be permitted in 1976, a long-run perspective should consider a least-cost solution possibility through manufacture of an engine that generates fewer pollutants. It is essential to compare a catalytic converter as an end-of-line method of abating air pollutants with a completely redesigned automobile engine as a change-in-propulsion-process method that generates fewer pollutants that have to be abated.

The latter approach requires the automobile manufacturer to assume more risk by investment in capital equipment necessary for production of less-pollutant-generating engines that would yield long-term benefits to society. Any subsidy of the difference in the new car purchase price resulting from pollution control devices would serve as an incentive to the manufacturer to be a risk averter by concentrating on the production of converters.

Changing the design of the engine to reduce generation of pollutants would probably lead to an increase in car prices relative to other goods and services, whereas a 100 percent subsidization of an end-of-line catalytic converter would tend to protect the prevailing car prices. In effect, such a subsidy benefits the seller of an automobile as well as the buyer. In the long run, the subsidy may lead to other than a least-cost method of reducing air pollutant emissions and would probably reduce the impact that relative price changes might have in reducing automobile use. Further, a subsidy applied to the catalytic-converter price differential still allows the manufacturer to obtain a profit through an administered pricing formula and to retain his share of the market.

It is paradoxical that price increases due to optional accessories such as air conditioners, power brakes, power steering, and power whatever are not viewed as undue burdens on the low-income household. The pressures of advertising and emulation have probably changed a relatively income-elastic demand for these accessories to a relatively inelastic demand. Higher automobile purchase prices in this case did not raise the subsidy issue. Even though government regulations will force the automotive industry to increase production costs owing to the installation of automobile pollution control devices, the effect on automobile supply and demand by the resulting increase in the purchase price and subsequent operating and maintenance costs of a new car should still be managed by the conventional market forces. People will either have to forgo other goods and services to own an expensive and an allegedly socially detrimental mode of transportation or make their preferences for improved mass transportation known to their legislative representatives.

Since the private automobile contributes over 50 percent by weight of all air pollution in the United States, the air pollution problem requires examination of the whole transportation system, not just one of its components. It is evident that a subsidy scheme aimed at neutralizing the burden of pollution control costs does not contribute to the reduction of demand for automobiles. Consideration of the alleged wasteful deployment of increasingly scarce resources to the production and use of the private car and all associated ancillary goods and services necessitates a careful study of the incidence of costs of pollution control and policies to lighten their burdens in the frame of reference of a total system, not a subsystem alone.

A minor matter that requires some comment is that of capital gains and user costs applicable to used-car owners. Their connection with a real benefit or burden to the used-car owner seems weak. Even if the assumption that an increase in the new-car purchase price will induce relative increase in the purchase prices of used cars is valid, there is no realized capital gain to a used-car owner until he sells. Furthermore, the individual seller of a used car has virtually no market power through which he could realize his potential capital gain. If a used-car owner trades his car for another more recent vintage used car, his capital gain from the "sale" aspect of the transaction is offset by the capital gain embodied in the price of the purchased used car. Only by selling without replacement can the owner of a used car realize the capital gain.

This reasoning leads to an interesting observation that increases in new-car purchase prices because of antipollution devices bestow capital gains upon the used-car dealer. That is, he obtains potential capital gains on his whole inventory of used cars and realizes these inventory gains as taxable ordinary income through sales.

A similar argument applies to the increased user cost for the used-car owner resulting from the upward change in the purchase prices of used cars. The real-cost burden is derivable only from the purchase of new cars with antipollution devices or from the installation of retrofit antipollution devices on all cars, new and used, as defined by the alternative strategies: that of uniform control costs per car and that of uniform emissions for all cars.

A real cost that some used-car owners are likely to face is that of increased fuel costs when new cars are equipped with a catalytic converter. Owners of pre-catalytic-converter cars equipped with high performance engines that operate more efficiently and economically with leaded gasoline will in all likelihood bear increased costs because the petroleum industry will shift more of its resources to the production of nonleaded gasoline. The nonleaded gasoline requirement by cars equipped with catalytic converters may very well shift the pricing structure of leaded as well as nonleaded gasoline upward.