Distributional Impacts of an Environmental Tax Shift: The Case of Motor Vehicle Emissions Taxes

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Abstract

One of the most common criticisms of pollution taxes is that they are often believed to be inequitable -- i.e., low income households are thought to be disproportionately harmed. In this paper, we assess the distributional impacts of three taxes aimed at reducing emissions from motor vehicles: (i) a tax on total annual emissions, (ii) a tax on emissions rates (in grams per mile), and (iii) a tax on annual miles traveled. We use two alternative measures of economic well-being, annual household income and a constructed measure of lifetime income. We find that all three fees look regressive, both on the basis of annual and lifetime income -- though much less so on a lifetime income basis. However, if one of these fees is used to substitute for existing vehicle registration fees, the differential impacts over existing fees are quite small: on a lifetime income basis, the mileage-based fee looks almost identical to the current system, while the total emissions fee is a little more regressive and the emissions rate-based fee slightly more regressive still than the current system. These results highlight the importance of tax *shifting* to help the environment.

Key Words: motor vehicle emissions, tax incidence, lifetime income

JEL Classification Numbers: H22, H23

Table of Contents

List of Tables

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I. INTRODUCTION

Regulation of emissions from motor vehicles has relied for the most part on traditional "command and control" approaches, with new car tailpipe emissions standards the dominant strategy. These approaches have been criticized by many observers as inflexible, poorly targeted to actual in-use emissions, not compatible with motorists' incentives, and ultimately very costly ways to reduce pollution (see Harrington, Walls, and McConnell, 1995; Kessler and Schroeer, 1993). These observers have suggested several economic incentive approaches as alternatives. One such approach that looks particularly promising is making vehicle owners pay fees based on an estimate of their vehicles' annual emissions.

Emissions fees give motorists the incentive to drive their vehicles less and to scrap or repair particularly dirty vehicles. In contrast, new car emissions standards, as well as inspection and maintenance (I&M) programs -- currently the primary means of controlling in-use emissions -- give no incentive to reduce driving.[2] And other economic incentive

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[2] Moreover, because most I&M programs have a very small penalty for failure, they also provide little incentive to scrap or repair dirty vehicles.

approaches have some drawbacks. Accelerated vehicle scrappage programs, in which older, dirty vehicles are bought and scrapped, give no incentive to reduce driving and no incentive to repair vehicles.[3] Gasoline taxes reduce driving in the short run, but in the long run lead to purchase of more fuel-efficient vehicles and more driving -- and thus more pollution.[4] In addition, they do not distinguish between dirty and clean vehicles.

Vehicle emissions fees have another advantage as well. Because they could be used to replace *existing* motor vehicle taxes, they could provide environmental benefits with no net increase in an average household's tax payments. In fact, in addition to improving efficiency in the market for emissions, they might produce a "double dividend" by reducing deadweight losses generated by existing taxes.[5] Such a tax shift rather than a tax increase might also make the policy more politically palatable. Vehicle owners already pay fees and taxes to register their vehicles; under a new but *revenue-neutral* policy, they would simply pay fees in a different way.

Of course, this means that there would be winners and losers -- some vehicle owners would pay more under an emissions-based system and some less. If the poor end up paying more, this might doom the policy -- or at least lead policymakers to search for ways to

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[3] In fact, these programs could have some perverse incentives if the vehicle "bounty" is high enough: vehicle owners could hold onto their vehicles longer or let their vehicles deteriorate enough so that they qualify for the payment; they could also try to falsely register their vehicles in jurisdictions where such programs exist (see Alberini, et al., 1994, for more).

[4] Conventional pollutant emissions such as carbon monoxide (CO), hydrocarbons (HCs), and nitrogen oxides (NOx) are proportional to mileage because standards are set on a grams per mile, not grams per gallon, basis. In other words, cars of the same model year and thus subject to the same standards should have the same emissions rates, all else equal, regardless of their fuel efficiencies.

[5] See Goulder (1994) for a general discussion of the "double dividend."

redistribute tax revenues. One of the most common criticisms of pollution taxes in general is that they are often believed to be inequitable -- i.e., low income households are thought to be disproportionately harmed. In this study, we assess the distributional impacts of revenue-neutral mileage-based and emissions-based vehicle registration fees. We do this using a household-level dataset that contains information on the make, model, and model year, along with annual mileage, of each vehicle in each of 1,018 California households. We look at the incidence of moving from the status quo in California, a registration fee system based on vehicle values, to an environmentally motivated registration fee system.

To assess the distributional impacts, we use two measures of economic well-being, annual household income and lifetime income, a variable that we construct from information on households' education levels and other socioeconomic and demographic data. Economists have long criticized the use of annual income as a measure of economic well-being since annual income depends heavily on where an individual is in his/her earnings life-cycle. Studies of gasoline taxes and carbon taxes have found those taxes to look much less regressive on a lifetime income basis than on an annual income basis.[6] We calculate current registration fees as a fraction of annual income and of lifetime income; we then look at three alternative revenue-neutral fees, a fee based on annual vehicle-miles-traveled (VMT), a fee based on emissions rates in grams per mile (g/mi), and a fee based on total emissions (g/mi multiplied by VMT).

In the following section, we discuss existing registration fee systems in the U.S. These systems vary greatly by state, with some states applying uniform assessments across vehicles,

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[6] Poterba (1991a; 1991b) uses annual consumption as a proxy for lifetime income. Rogers (1993) uses a constructed lifetime income variable. We discuss the two approaches in more detail below.

some using fees that vary with vehicle age, weight, horsepower, and most often, some measure of vehicle value, and some states relying on property taxes that vary by county. We choose to focus our empirical work on California because its registration fee system is straight-forward and has a feature typical of many states in that fees vary with vehicle values.

In section III, we discuss alternative approaches to assessing tax incidence. We present the different ways of categorizing households: annual income, annual total consumption expenditures, and a constructed measure of lifetime income. We then discuss some findings in the literature using these different approaches. We end section III showing our constructed lifetime income variable and how it compares with annual income.

In section IV, we describe the household-level dataset that we use to calculate registration fee payments by household, the U.S. Department of Transportation's 1990 Nationwide Personal Transportation Survey (NPTS). We also discuss our data on vehicle emissions which we merge with the NPTS data.

In section V, we show our distributional findings. First, we show the incidence of existing vehicle registration fees in California. We then discuss the efficiency rationale for controlling emissions by assessing an emissions fee for each vehicle. We compare fees based on emissions rates, in grams per mile, total annual emissions (grams/mile multiplied by annual miles traveled), and annual mileage. We compute the average fees for California that would generate approximately the same amount of registration fee revenues that California currently earns; we then redo our incidence analysis under the new proposed systems. In section VI, we draw some overall conclusions from our work.

II. MOTOR VEHICLE REGISTRATION FEES[7]

States collected approximately $14.7 billion in taxes and fees to register and title private motor vehicles in 1990, an average of about $80 per vehicle (U.S. DOT/FHWA, 1990). Some of these revenues go for general, non-highway purposes, law enforcement, and administrative costs, but most go to fund the construction and maintenance of state highways, county roads, and city streets. On average, across all states, revenues from registration fees account for 18 percent of all state government spending on roads. This percentage varies widely across states: in Louisiana, revenues from registration fees account for only 3 percent of state highway spending, while in Kentucky, they account for 34 percent (U.S. DOT/FHWA, 1990). Registration fees provide the second-largest source of highway funds for most states, after motor fuels taxes, but this too varies a great deal across states. In Kentucky, about as much revenue is generated from registration fees as is generated from the state gasoline tax ($352 million in 1990). In Colorado, on the other hand, six times as much revenue is generated from the state gasoline tax as from registration fees. And in Louisiana, state gasoline tax revenues are 14 times registration fees (U.S. DOT/FHWA, 1990).

In addition to state-level fees, 17 states have counties that levy personal property taxes on vehicles. In some states -- Virginia and Connecticut are two good examples -- these taxes are quite substantial. In 1990, for example, the annual property tax paid on a 1988 Honda Accord DX in Fairfax County, Virginia, amounted to approximately $334; in New Haven,

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[7] Most of the discussion in this section is based on a Resources for the Future (RFF) computer program that computes registration fees and taxes by individual vehicle for each state. The program was developed using information gathered from contacting each state directly and from several counties in states that had county-level fees and taxes and also from a publication by Commerce Clearing House, Inc. (1991) on state taxes.

Connecticut, the tax was $354. That same Honda Accord could have been registered in Ohio for an annual fee of only $23.

Vehicle taxes and fees in most states depend in one way or another on the value of the vehicle. Most often, fees are calculated as a percentage of either the National Automobile Dealers' Association (NADA) published trade-in, loan, or retail values for used vehicles, or as a percentage of the actual purchase price of the vehicle, or the vehicle's "list price" or "manufacturer's suggested retail price (MSRP)" when the vehicle was new. In some states, the fees vary with vehicle age -- i.e., older vehicles pay less than newer vehicles.[8] In several states, fees are based on vehicle weight and in a few states, fees are based on horsepower or other vehicle characteristics. In most states, there is an initial fee for first-time registrations, a fee for titling the vehicle, and an annual fee. In some cases, the initial fee is low (in California and Colorado, it is zero) but the annual fee quite high. In other cases (Texas, for example), the initial fee is high but the annual fee rather modest.

For our analysis, we choose California. In California, the annual fee is equal to 2 percent of a vehicle's value plus a flat fee of $25; there is no initial or title fee.[9] We have performed the same analyses for Illinois and Ohio. In Illinois, vehicles pay a flat annual fee of $48, a $3 title charge, and an initial fee that varies with the vehicle's purchase price and with age.[10] In Ohio, vehicles pay a flat fee of $23 per year regardless of vehicle value or age. Our

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[8] In states where the list price or MSRP is used, the age of the vehicle is always taken into account in one way or another.

[9] Vehicles brought into California from another state are assessed an additional fee when they do not meet California emissions standards; the fee ranges from $50 to $300 depending on the engine compression ratio. We ignore that component of the fee structure here.

[10] If the vehicle price falls between $15,000 and $20,000, the owner pays $750 regardless of vehicle age;

estimated incidence across income groups in Illinois did not differ in any significant way from those of California, and Ohio's fee is so small that there were no interesting findings to report for that state. For the remainder of the paper, we focus on California for our empirical results. However, in our discussion of the California findings, we highlight the difference in incidence of a flat fee system such as Ohio's versus one based on vehicle value.

III. MEASURING INCIDENCE

Economists have long argued that using annual income as a basis for determining tax incidence is problematic because of the tendency for individuals to consume based on permanent income, or earnings over their life-cycle (Friedman, 1957; Modigliani and Brumberg, 1954). Since earnings for most people vary a great deal over their life-cycles, using an income figure for one year will usually present a biased estimate of the true potential to consume. Most people tend to earn their highest incomes around middle age and their lowest incomes when they are young or old. Grouping people by annual income using cross-section data will lead to some young and old people in the lower income groups who may not belong there on the basis of lifetime income. Likewise, higher income groups will include some middle-aged people who may belong in a lower category if grouped by lifetime income.

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between $20,000 and $25,000, $1000; between $25,000 and $30,000, $1250; and over $30,000, the fee is $1500. For vehicles purchased for less than $15,000, the initial fee depends on age according to the following schedule:

1-year-old or less	$390	5-years-old	$115	9-years-old	$50
2-years-old	$290	6-years-old	$90	10-years-old	$40
3-years-old	$215	7-years-old	$80	over 10-years-old	$25
4-years-old	$165	8-years-old	$65		

Poterba (1989, 1991a, 1991b) has proposed using annual total consumption expenditures as a proxy for lifetime income, arguing that since consumption tends to be smoothed over the life-cycle, it is a more accurate estimate of true lifetime well-being. He shows that taxes on gasoline, alcohol, and tobacco appear to be much less regressive when viewed as a percentage of total consumption expenditures rather than as a percentage of annual income. Metcalf (1993) uses a similar approach to analyze state and local taxes. He finds that sales taxes, when viewed as a percentage of annual consumption rather than annual income, appear to be equally as progressive as income taxes and property taxes appear to be approximately proportional to consumption.

Using consumption expenditures as a proxy for lifetime income is less than ideal. If capital markets function imperfectly and there are constraints on the amounts that individuals can borrow and lend, then consumption might actually follow annual income more than the life-cycle or permanent income models would suggest. In this case, annual consumption expenditures would also misrepresent an individual's lifetime well-being and misrepresent the incidence of any given tax (Zeldes, 1989).

Fullerton and Rogers (1993) use an 18-year span of data from the Panel Study of Income Dynamics (PSID) and estimate a model explaining individuals' wage rates as a function of various demographic variables and several age terms. With the results of the estimation, they can describe how a person's earnings move over that person's life-cycle. This allows them to then calculate lifetime income for each individual in the dataset by taking the present discounted value of the areas under each of the estimated age-wage profiles. They then categorize households based on lifetime income and use a computable general equilibrium

(CGE) model to analyze several different taxes. Their measure of incidence is then a *lifetime* tax burden as a fraction of lifetime income.

The Fullerton and Rogers approach is an elegant one but is only feasible with panel data. One cannot calculate either lifetime income or lifetime tax payments for individual households without information on income and consumption patterns over time. Moreover, use of a CGE model is probably overkill for small taxes such as our vehicle registration fee. Rogers (1993) and Casperson and Metcalf (1994) present interesting alternatives when data are limited to cross-sections. Both studies use the PSID to estimate relationships between various demographic variables and lifetime income. They then use those estimated relationships in a cross-section dataset: they apply the estimated PSID coefficients to demographic variables in their cross-section datasets (both studies use the Consumer Expenditure Survey, CES) and then create a lifetime income variable for the households in the CES. Both studies compute incidence by assessing *annual* tax payments as a fraction of lifetime income. In other words, they use their calculated lifetime incomes to better categorize each household's ability to pay, but they still calculate an annual rather than a lifetime tax burden.

Casperson and Metcalf estimate annual earnings as a function of various age terms and other demographic variables, then calculate the present discounted value of estimated lifetime earnings for each individual in the CES. Rogers relies on her earlier work with Fullerton and takes a somewhat simpler approach: she uses Fullerton and Rogers' calculated lifetime incomes for each household in the PSID and estimates lifetime income as a function of education level, education squared, and interactions between education level and dummy variables for whether the household is married, white, or female-headed.[11] Rogers computes the incidence of gasoline, alcohol, and tobacco taxes; Casperson and Metcalf look at a value-added tax. In both studies, the taxes appear much less regressive when viewed on a lifetime income basis than on an annual income basis. Casperson and Metcalf, in fact, find the VAT as a fraction of income to be approximately the same across lifetime income groups. Both studies also find that the taxes appear to be *more* regressive than when viewed as a fraction of total consumption expenditures.[12]

Table 1. Rogers' (1993) Estimated Lifetime Income Equation Using PSID Data
(sample size = 500 households; t-stats in parentheses)

Independent Variable	Estimated Coefficient
Constant	733120.72 (6.137)
Education	-47863.01 (-2.038)
$Education^2$	4697.85 (4.734)
Married * Education	-4150.51 (-1.121)
White * Education	-1629.20 (-.332)
Female * Education	-18847.91 (-4.108)
Adjusted R^2 = .28369; F = 40.525	

[11] She uses the education and race of the head of the household only, stating that these are very highly correlated with the education and race of the spouse. The PSID defines the head of the household as male, thus the female-headed household dummy will pick up *single*, female-headed households. For married households, her measure of household income is the average of the income of the husband and wife.

[12] Casperson and Metcalf find that the VAT actually looks progressive when measured as a fraction of consumption. Rogers, consistent with results of Poterba (1991b), finds that gasoline expenditures as a fraction of total consumption expenditures are approximately the same across quintiles. She finds similar results for alcohol; utilities and tobacco taxes still appear regressive, however, even when viewed as a fraction of consumption.

In our study, we use Rogers' approach. We take her estimated regression results, reprinted in Table 1, and apply them to the NPTS data for California households. We then predict lifetime income for each household and put it on an annual basis by computing a 60-year constant annuity using a 4 percent real interest rate.

Although having a lifetime income measure is desirable for all the reasons we laid out above, it is important to understand the limitations of our approach. First, unlike the PSID, the NPTS dataset does not identify a household "head," only a "reference person." We assume the reference person is the head unless it is a married household and the reference person is female; in this case, we use information on the male spouse (to be consistent with the PSID which always assumes that the male is the head of the household). Second, we have a number of unmarried group households in our sample. As we stated in footnote 11 above, Rogers uses the average income of the husband and wife in a married household, thus we must double our calculated lifetime incomes for married households to get a more accurate measure of household income. Although it is less than ideal, we do the same for group households. Third, Rogers' lifetime income variable is a *potential* lifetime income, calculated assuming everyone works the total number of hours available in each year (see Fullerton and Rogers, 1993, Chapter 4, for an explanation). Since we want to directly compare results using our calculated annualized lifetime income variable with results using annual income, we adjust the predictions we get from her regression. Specifically, we multiply each predicted value by the ratio of the sum of annual incomes to the sum of the predicted lifetime incomes from the Rogers regression. This ensures that the mean adjusted annualized lifetime income is equal to the mean annual income for our sample. The adjustment does not affect the relative position of the households and thus does not affect our Suits Index calculations and other regressivity results, but it is a rather ad hoc adjustment that is necessary because we do not know the number of hours worked by our households. Fourth, Fullerton and Rogers (1993) find that individual fixed effects are extremely important in earning regressions. Unfortunately, since these fixed effects cannot be carried over to households in the cross-section dataset, one cannot include them in earnings regressions used to generate lifetime incomes. The result is that our calculated lifetime incomes probably do not have the variability across households that true lifetime incomes would have. Finally, there is a general problem faced by anyone calculating lifetime incomes for a cross-section of households: one has virtually no choice but to assume that the status of the household in the cross-section has held and will continue to hold throughout its lifetime. In other words, a recently widowed elderly person will mistakenly be counted as single and a sophomore in college who eventually earns a degree will mistakenly be assigned 13 years of education. Without panel data, there is no good solution to this problem.

Table 2. Summary Statistics for Annual and Lifetime Income for California Households in 1990

	Annual Income	Annualized Potential Lifetime Income[1]	Adjusted Annualized Lifetime Income[2]
Mean	40,791	77,988	40,791
Median	37,500	80,827	42,276
Standard deviation	28,198	29,929	15,654
25th percentile	18,000	56,959	29,792
75th percentile	57,500	95,285	49,839

[1] Potential income is income calculated assuming each household works the total number of hours available in a year, 4000 hours (see Fullerton and Rogers, 1993, chapter 4).

[2] We adjust the potential lifetime income figures downward so that the mean equals the mean of annual income. See text for explanation.

Despite these shortcomings, our measure of lifetime income seems reasonable. Most of the differences across households are explained by differences in education which is plausible. Table 2 shows summary statistics for annual and the calculated annualized lifetime income for our California households. The table shows both the annualized *potential* lifetime income as defined by Fullerton and Rogers (1993) and used by Rogers (1993) and the adjusted annualized lifetime income variable that we use in our distributional analysis below. The adjusted lifetime income has a mean identical to the mean of annual income, but the standard deviation is much smaller than the standard deviation of annual income. This is expected and is similar to the findings in Casperson and Metcalf and in Rogers. Somewhat surprisingly, our mean of lifetime income is less than the median. This may be a result of underestimating the lifetime income of household at the high end of the distribution.

Table 3. Joint Distribution of Annual Income and Lifetime Income Quintiles

	Annual Income				
	1	*2*	*3*	*4*	*5*
Lifetime Income					
1	46	27	18	7	2
2	25	24	25	17	10
3	17	20	21	19	22
4	8	19	21	28	25
5	4	10	15	30	42
	100	100	100	100	100

Only 32 percent of our households fall into the same lifetime income quintile as annual income quintile. Table 3 shows the joint distribution of annual income and lifetime income quintiles for California. The entries in the table show the percentage of households in each annual income quintile that falls into each of the lifetime income quintiles. For example, 46 percent of households that fall into the bottom annual income quintile also fall into the bottom lifetime income quintile; 25 percent move to quintile 2; 17 to quintile 3 and so forth. The columns of the table sum to 100 percent.

IV. THE CALIFORNIA DATA

We use the U.S. Department of Transportation's 1990 NPTS dataset as the basis of our analysis. The NPTS is a survey of 22,000 randomly selected U.S. households; it contains information on the make, model, and model year of each vehicle in each household, as well as a host of socioeconomic and demographic information about each household.[13] There are 2,037 California households in the NPTS, but because of missing information on income and other unreliable data, we had to omit several observations. Our final California dataset includes 1,018 households who own 1,813 vehicles.

Table 4 shows some summary information about the California households and their vehicles. In our sample of 1,018 households, there are an average of 1.79 vehicles per household. This includes some households -- 6.2 percent -- who own no vehicles (22 percent of the lowest annual income quintile own no vehicles; all households in the richest quintile own at least one vehicle). Average registration fees in 1990 amounted to about 0.68 percent of annual income and about the same fraction of lifetime income, 0.56 percent. This is a small fraction of income but registration fees in California are still a fairly sizable fraction of the cost of owning and operating a vehicle. The average vehicle in California cost $126 to register in

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[13] See U.S. DOT/FHWA (1993) for general description of the NPTS and summary of information from it.

1990. As a comparison, fuel costs amounted to about $700 per vehicle per year and insurance costs in California averaged about $870,[14] thus registration fees amounted to about 7 percent of annual vehicle operating costs, excluding maintenance costs in 1990. Table 4 also shows that the average vehicle in California is driven 13,409 miles per year, slightly more than the national average of 12,700.[15]

Table 4. Vehicles, Annual Mileage, Emissions and Registration Fees in California in 1990

Number of households in sample	1,018[1]
Average number of vehicles per household	1.79
Average annual miles per vehicle	13,409
Average exhaust HC emissions[2]	2.49 g/mi
Percentage of households with zero vehicles	6.2%
Average annual registration fee per vehicle	$126
Average annual registration fee per household	$226
Median household annual income	$37,500
Average registration fee as percent of annual income	0.68%
Median household annualized lifetime income	$42,276
Average registration fee as percent of annualized lifetime income	0.56%

[1]Although the NPTS has a total of 2037 California households, we lose observations because of missing income, missing annual mileage, and erroneous or missing information on make, model, and model year of vehicles in the household.

[2]This is a weighted average based on miles traveled; the unweighted average emissions rate is 2.80 g/mi

[14] The national average for insurance costs in 1990 was $658 (Insurance Information Institute, 1991).

[15] Some analysts have suggested that the NPTS, which relies on reported annual mileage figures from survey respondents rather than odometer readings, overestimates annual mileage (Lave, 1994). The 1995 NPTS, which is "in the field" at the date of this writing, is reportedly obtaining odometer readings (Liss, 1995).

Table 5. Share of Income, Vehicles, Mileage, Emissions and Registration Fees by Annual Income and Lifetime Income Quintile in California in 1990

Quintile	Income		Vehicles		Annual Miles		Emissions	
	Annual	Lifetime	Annual	Lifetime	Annual	Lifetime	Annual	Lifetime
1	4	9	12	11	11	8	16	9
2	11	15	16	18	14	18	16	20
3	18	20	20	22	19	23	18	23
4	26	24	24	25	24	27	23	27
5	41	32	28	25	32	24	28	22
Total	100%	100%	100%	100%	100%	100%	100%	100%

Note: Quintiles are defined by either annual income or lifetime income where lifetime income is calculated as described in the te

The NPTS does not contain information on vehicle emissions. Our emissions data come from a California dataset of over 90,000 vehicles that were subjected to remote sensing in 1991 (Stedman, et al., 1994). Remote sensing is a technology that combines roadside monitors that send infrared beams from one side of the road to a detector on the other side, measuring a vehicle's emissions, with a video camera that obtains a photograph or electronic identification of the license plate. This dataset contains information on vehicles that were sensed at various times during the day and year and at various locations in the network of roads and highways in Southern and Northern California. Variables of use to us in the dataset include vehicle make, model, and model year, along with the zip code where the vehicle is registered, and various types of emissions information.

The primary systematic way in which emissions vary across vehicles is by model year. Older vehicles were subject to less strict standards when they came off the assembly lines. More importantly, emissions systems deteriorate over time and sometimes break down completely; even vehicles that were very clean when new can be very high polluters after a few years, particularly if they are not well-maintained. We use the remote sensing data to compute average hydrocarbon (HC) emissions rates by vehicle age for cars and light-duty trucks.[16] We assign these averages to our NPTS vehicles.[17] We also carried out our analysis using

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[16] Cars and trucks must be treated separately because until the 1994 model year, the standards for light-duty trucks were less stringent than those for cars. Minivans and sport-utility vehicles are classified as trucks. Carbon monoxide emissions are also available but since ozone is a more serious air quality problem, we focus on HCs (HCs and NOx combine in the atmosphere to form ozone). NOx emissions are not available from the remote sensing dataset.

[17] The remote sensing data were obtained in 1991; since the NPTS data are from 1990, we assign the average remote sensing emissions for model year *t* vehicles to NPTS vehicles of model year *t-1* -- e.g., the average for 1990 vehicles is assigned to 1989 vehicles in the NPTS dataset. Because there were relatively few pre-1965 vehicles in the remote sensing data set, we use the 1965 average for any pre-1965 vehicles in the NPTS.

emissions data from the U.S. Environmental Protection Agency's MOBILE computer simulation model, which also provides model year average emissions rates. Our general findings are the same with either emissions data, but the virtue of the remote sensing data is that they tell us something about the variability of emissions within model year; the MOBILE model reports only averages by model year. We return to this issue below by exploring an alternative to using simple model year average emissions rates.

V. DISTRIBUTIONAL FINDINGS

A. California's Existing Registration Fee System

Table 6 shows average annual registration fee payments by quintile under the current fee system. Each quintile contains 20 percent of California households; quintile 1 is the poorest quintile and quintile 5 the richest. Quintiles are defined on both an annual income and a lifetime income basis.

Table 6. 1990 Registration Fees in California by Quintile

Quintile	Annual Income		Lifetime Income	
	Average Annual Fee in $	Fee as % of Annual Income	Average Annual Fee in $	Fee as % of Lifetime Income
1	90	1.13	97	0.50
2	146	0.67	198	0.64
3	222	0.61	240	0.58
4	284	0.55	280	0.58
5	384	0.47	310	0.49
Average	$226	0.68%	$226	0.56%

Note: Quintiles are defined by either annual income or lifetime income where lifetime income is calculated as described in the text.

On the basis of annual income, the system appears regressive. Households in the bottom annual income quintile pay 1.13 percent of their income in registration fees, on average, compared to an average for all households of 0.68 percent, while households in the top annual income quintile pay only 0.47 percent. Thus, even though higher income households own more valuable vehicles and more of them per household, their incomes are so much above the lowest quintile households, that they pay less as a fraction of income. On a lifetime income basis, however, the fee no longer looks markedly regressive. As a fraction of income, households in the bottom quintile pay less than the average household and exactly the same as households in the top quintile. The Suits Index for existing registration fees is -0.09, using annual income, and -0.03 using lifetime income.[18] Thus, on a lifetime income basis, existing registration fees are approximately proportional to our measure of annualized lifetime income.

These findings are roughly consistent with published studies of general property taxes. Metcalf (1993) finds that local property taxes are regressive on an annual income basis but approximately proportional to total consumption expenditures (used as a proxy for lifetime income). Fullerton and Rogers (1993), using lifetime income, find the property tax incidence to be U-shaped -- i.e., households in the middle deciles pay the least as a fraction of income while households in the bottom and top deciles pay the most. Fullerton and Rogers point out that property tax incidence plays out in two ways: on the one hand, a property tax reduces the rate of return on capital and since capital makes up an increasing fraction of income, this makes the tax progressive; on the other hand, a property tax increases the price of housing and since

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[18] A Suits Index is the tax analog to the Gini coefficient. Values less than zero connote regressivity and values greater than zero progressivity; a Suits Index of zero indicates a proportion tax (see Suits, 1977).

housing expenditures make up a decreasing fraction of income, this makes the tax regressive. Since motor vehicles typically do not have investment value, the price effect seems likely to dominate. In any case, we have not attempted to account for any rate of return effect so it makes sense that regressivity shows up in our results. Interestingly, Suits (1977), in sample calculations of his index for several taxes, included taxes on personal property and motor vehicles. He obtained index values of -0.12 using 1966 tax rates and income and -0.09 using 1970 tax rates and income.

B. VMT-based and Emissions-based Registration Fees in California

Various forms of emissions fees are being considered in the policy arena. The EPA, in its proposed Federal Implementation Plan (FIP) for California includes a recommendation for some type of emissions fee. In response to the FIP, California revised its State Implementation Plan (SIP), which now includes a VMT fee (Wallerstein, 1995). This SIP is awaiting EPA approval. Maricopa County in Arizona has considered fees based on emissions rates and vehicle age (see Energy and Environmental Analysis, 1993, for an analysis). The President's Federal Advisory Committee on Reducing Greenhouse Gas Emissions from Motor Vehicles seriously considered promoting VMT fees as a way of reducing carbon dioxide emissions (see Policy Dialogue Advisory Committee, 1995).

In this study, we analyze three types of alternative registration fee systems designed to reduce emissions: (i) a fee based on annual vehicle-miles-traveled (VMT); (ii) a fee based on HC emissions rates, in grams per mile (g/mi); and (iii) a fee based on total HC emissions (g/mi multiplied by VMT). Because our emissions rates are averages by vehicle age and not actual emissions for the vehicles in the NPTS dataset, we can only approximate the impacts of the two emissions-based fees. In effect, we are analyzing something more akin to vehicle age-based fees. At the end of this section, we present some results using alternative emissions estimates.

Clearly, a fee based on total emissions would be the most efficient since it would encourage both reduced driving and repair and scrappage of dirty vehicles. In fact, the most efficient fee would be one that obtained emissions readings during actual driving in areas and at times of the day and year with serious air quality problems. The most serious air quality problem, ozone, is primarily a summer-time, urban area phenomenon, and a fee based on HC (and/or NOx) emissions differentiated in these ways would be ideal.[19]

Although a fee based on total emissions is likely to be most efficient, we also look at a VMT-based fee and a fee based on emissions rates. VMT fees may be more politically acceptable initially because the public tends to believe that existing inspection programs are already "taking care of" the emissions rate problem.[20] This means that any system based on emissions may meet with some strong resistance. Also, the incidence of a VMT fee would look a lot like the incidence of a gasoline tax increase, a policy that would be administratively the easiest to carry out.

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[19] Harrington, Walls and McConnell (1995) have shown the efficiency advantages of emissions fees over "command and control" regulations such as I&M.

[20] Deakin (1995) reports that members of several focus groups that she conducted in California expressed this view and voiced "outrage" when told of I&M waivers and different I&M pass/fail "cutpoints" for vehicles of different ages. In most states, a vehicle can fail an inspection but receive a waiver and still be driven if the owner has spent a specified amount of money (very low in most states) attempting to fix the car. (The 1990 Clean Air Act Amendments raised the required waiver limit to $450 but EPA appears to be backing off from that requirement, or at a minimum, moving to allow states to phase it in over time. See *Car Lines*, 1995.) All states set different allowable emissions limits for vehicles of different ages, with older vehicles allowed to pollute at a higher rate. See Aroesty, et al. (1994) for a discussion of I&M problems in California.

On the other hand, increasing the cost of driving is never a popular policy as past resistance to gasoline tax increases suggest. Moreover, it is possible that an emissions fee would be used to substitute for existing I&M programs. In this case, a system focusing on emissions rates -- like existing I&M programs -- may be more acceptable. For these reasons, it seems important to analyze the distributional impacts of all three types of fees. Knowing their equity, as well as their efficiency, impacts should help identify the best fee.

If we divide total mileage by all passenger vehicles in California into total registration fees paid by these vehicles under the existing system, we end up with an average VMT-based registration fee of 0.94 cents per mile.[21] This amounts to approximately 16 percent of 1990 fuel costs for an average vehicle in California (equivalent to a gasoline tax of about 19 cents per gallon). If we multiply our HC emissions rates by mileage for each vehicle and divide the resulting total emissions number into total registration fees paid under the existing system, we end up with an emissions fee of 0.46 cents per gram.[22] Finally, performing a similar calculation for emissions rates, we obtain an emissions rate fee of $50.72 per g/mi. The emissions rate fee is like an emissions fee calculated with the assumption that all vehicles are driven the same number of miles per year.[23]

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[21] We use the NPTS data to perform this calculation. The NPTS has a system of weights to ensure that adding observations will lead to a total that is representative of the population at large. We compare our calculated registration fee and VMT totals for our California sample with that from U.S. DOT/FHWA (1990) and the two sources give quite close results.

[22] 0.46 cents per gram is equivalent to approximately $4,200 per ton which is probably less than the optimal emissions fee -- i.e., it is probably below the point where the marginal benefits of HC's reduced are equal to the marginal costs (see Small and Kazimi, 1994; Harrington, Walls and McConnell, 1995).

[23] One can verify using the numbers in Table 1 that the fees are revenue-neutral. The average household continues to pay approximately $218 per year in registration fees.

Table 7. VMT-Based and Emissions-Based Registration Fees in California by Annual Income Quintile

Quintile	Average Annual VMT Fee		Average Annual Emissions Fee		Average Annual Emissions Rate Fee	
	in $	as % of annual income	in $	as % of annual income	in $	as % of annual income
1	129	1.54	182	2.27	173	2.35
2	157	0.72	179	0.83	212	1.01
3	209	0.57	200	0.56	227	0.64
4	274	0.54	255	0.50	239	0.46
5	357	0.43	310	0.38	277	0.34
All households	$226	0.76	$226	0.90	$226	0.95

(i) Measuring incidence using annual income

The distributional impacts of the three fees on an annual income basis are shown in Table 7. All three fees appear more regressive, on an annual income basis, than the current system. Households in the bottom two quintiles pay more in absolute dollar terms and more as a fraction of annual income than they do under the current, value-based system, while households in quintiles 4 and 5 pay less. Under the VMT fee, households in the lowest quintile pay, as a fraction of income, over twice the average -- 1.54 percent versus an average of 0.76 percent; they pay 2.5 times the average under the two emissions fees. Not only do households in the poorest quintile pay substantially more as a fraction of annual income with the two emissions fees than their counterparts in the richest quintile, they even pay more in absolute dollar terms on a per-vehicle basis. The average household in quintile 1 pays $172 per vehicle

($182 per household divided by an average of 1.06 vehicles per household), under a fee based on total emissions, while the average household in quintile 5 pays only $124 per vehicle ($310 per household divided by an average of 2.51 vehicles per household).

The Suits Indexes for the three fees are dramatically different from the Suits Index of -0.09 that we obtained above for the current registration fee. The VMT, emissions, and emissions rate fees have Suits Indexes of -0.15, -0.24, and -0.28, respectively. The two emissions fees thus exhibit quite a bit of regressivity.

Even though these are revenue-neutral fees, on the basis of annual income, their differential impacts over the existing California registration fee are fairly substantial. Under the emissions fee, households in the bottom quintile would pay, on average, $92 more per year in registration fees, an additional 1.1 percent of their incomes. Households in the top quintile, on the other hand, would pay $74 per year less in registration fees, which as a fraction of income amounts to less than one-tenth of one percent of average income.

(ii) Measuring incidence using lifetime income

The lifetime income findings, shown in Table 8, are quite different from the annual income results. With the VMT fee, households in the poorest quintile now appear to be exactly as well off as they are under the existing registration fee system. The VMT fee appears to be very slightly regressive -- a poorest quintile household pays about 1.12 times what a household in the richest quintile pays, as a fraction of lifetime income -- but it is not noticeably different from the existing registration fee system. The Suits Index, on a lifetime income basis, for the VMT fee is -0.06, compared to -0.03 for the existing registration fee.

Table 8. VMT-Based and Emissions-Based Registration Fees in California by Lifetime Income Quintile

Quintile	Average Annual VMT Fee		Average Annual Emissions Fee		Average Annual Emissions Rate Fee	
	in $	as % of lifetime income	in $	as % of lifetime income	in $	as % of lifetime income
1	94	0.48	109	0.56	134	0.71
2	207	0.66	224	0.71	215	0.68
3	252	0.61	253	0.61	267	0.65
4	299	0.62	298	0.62	282	0.59
5	274	0.43	242	0.38	228	0.36
All households	$226	0.56%	$226	0.58%	$226	0.60%

The fee based on total emissions is slightly more regressive than the existing registration fee: households in the bottom quintile pay 0.56 percent of their annualized lifetime income, same as the average, while households in the top quintile pay only 0.38 percent. The Suits Index for the emissions fee is -0.11.

The emissions rate fee looks still more regressive. Households in the bottom quintile pay almost twice what those in the top quintile pay, as a fraction of income, and unlike with the VMT and emissions fees, they also pay a greater share than the average household pays. The Suits Index for the emissions rate fee falls to -0.14.

On a lifetime income basis, the differential impacts of VMT or emissions-based fees over the current system are very small. Under even the worst of the fees, the emissions rate-based fee, households in the poorest quintile pay only an additional $37 per year, less than one-half of one percent of their annualized lifetime income. With the VMT or total emissions fee, poorest quintile households' registration fee payments either stay the same or rise only slightly.

(iii) Measuring incidence using an alternative estimate of emissions rates

As we explained in section III, the emissions rates used to compute the two emissions-based fees are model-year averages calculated from our remote sensing dataset. Our results thus confirm a widely-held belief that poorer households -- as measured by annual income -- own older, dirtier vehicles. This holds up in the lifetime income results as well, since households in the bottom quintile are worse off under the emissions rate-based fee, though the impact is greatly diluted.

Using model year averages is less than ideal, however, since even within the same model year, vehicles can have quite different emissions.[24] An ideal dataset would contain actual in-use emissions for specific vehicles matched with income and other information on the owners of those vehicles. As we stated above, no such dataset exists. We can, however, use the remote sensing data combined with income information by zip code to explore whether there is any systematic relationship between income and emissions rates.[25] We run Ordinary Least Squares regressions of emissions rates on median household income by zip code, vehicle age (with a 1991 vehicle's age equal to zero), an interaction term between income and vehicle

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[24] According to the remote sensing data, 1975 cars, for example, have mean exhaust HC emissions of 5.2 g/mi, a standard deviation of 7.1 g/mi, and a maximum reading of 50.0 g/mi; 1990 cars have a mean of 0.9 g/mi, a standard deviation of 1.3 g/mi, and a maximum of 29.0 g/mi.

[25] The income information comes from CACI Marketing Systems' *The Sourcebook of Zip Code Demographics* (1991).

age, and a dummy variable equal to one for foreign vehicles and zero for domestic. The results are shown in Table 9.

Table 9. OLS Regression Results for HC Emissions Rates
(dependent variable is exhaust HC emissions in g/mi)

	Cars		Light Trucks	
	Estimated coefficient	t-statistic	Estimated coefficient	t-statistic
Constant term	-0.2793	-4.03	-0.0039	-0.03
Vehicle age	0.4047	45.89	0.6153	27.72
Income	$1.35x10^{-5}$	8.21	$1.63x10^{-5}$	4.32
Foreign	-0.0856	3.15	-0.3669	-5.65
Age*Income	$-3.7x10^{-6}$	-16.29	$-6.61x10^{-6}$	-11.02
No. of observations	58,584		19,220	
R^2	0.16		0.15	

The R^2's for the regressions are low, indicating that, even after controlling for vehicle age, unobserved factors explain most of the variation in emissions across individual vehicles. All of the variables are statistically significant, however, and the results are robust to model specification. As expected, emissions do increase with vehicle age -- the coefficients on the *age* terms are positive -- but the effects vary with income. Specifically, the impact of vehicle age on emissions is *lower* in zip codes that have higher median incomes than it is in zip codes with lower median incomes. According to the regression results, aging a truck by one year should increase emissions by approximately 0.45 g/mi for a household making $25,000 per year but only by 0.28 g/mi for a household making $50,000 per year. In addition, for cars and trucks more than about three-years-old, emissions decrease with increases in income and they do so at an increasing rate.

We use the results in Table 9 to form new HC emissions predictions for our California vehicles. We then recalculate the two revenue-neutral emissions fees and reassess the distributional impacts of the two fees. The new lifetime income results are shown in Table 10.[26]

Table 10. Emissions-Based Registration Fees in California with Emission Rates a Function of Income By Lifetime Income Quintile

Quintile	Average Annual Emissions Fee		Average Annual Emissions Rate Fee	
	in $	as % of lifetime income	in $	as % of lifetime income
1	135	0.70	162	0.86
2	243	0.77	226	0.72
3	260	0.63	271	0.66
4	265	0.55	256	0.53
5	223	0.35	212	0.34
All households	$226	0.60%	$226	0.62%

Both of the fees look more regressive than they did when emissions were model-year averages. Households in the bottom quintile now pay 0.70 percent of lifetime income in emissions-based registration fees, twice what the richest quintile households pay. The emissions rate-based fee looks worse still. Households in the bottom quintile pay 0.86 percent of lifetime income in fees, 2.5 times what the top quintile households pay. The new Suits

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26 We also computed the annual income results but do not show them here. Like the lifetime income results, they also exhibit more regressivity.

Indexes for the emissions and emissions rate fees are -0.16 and -0.19, respectively. Again, these number show more regressivity than the Suits Indexes calculated using model-year average emissions rates. Table 11 summarizes the Suits Indexes for each of the fees using both annual income and our annualized lifetime income variable.

Table 11. Suits Indexes for Alternative Registration Fees in California Using Annual and Lifetime Income

	Annual Income	Lifetime Income
Current registration fee	-0.09	-0.03
VMT fee	-0.15	-0.06
Emissions fee	-0.24	-0.11
Emissions rate fee	-0.28	-0.14
Emissions fee, with emissions rates a function of income*	-0.34	-0.16
Emissions rate fee, with emissions rates a function of income*	-0.41	-0.19

*Emissions rates estimated using regression results in Table 9.

The differential impacts over the existing system remain rather small for the fee based on total emissions but start to look important for the fee based on emissions rates. Households in the bottom lifetime income quintile would pay an extra $65 per year, on average, with a fee based on emissions rates, an additional 0.4 percent of their annualized lifetime income.

The finding of slightly more regressivity shows up because, according to the results in Table 9, poorer households not only own older cars but the older cars they own are dirtier than average. This makes sense since repairs and maintenance are costly. This is a potentially troubling finding from a public policy perspective, but we hesitate to draw too strong a conclusion based on the zip code level income information. What these results really indicate is the need for a micro-level dataset that contains emissions information. Such a dataset would shed more light on the important distributional impacts associated with emissions fees.

VI. CONCLUSIONS

Policymakers are currently looking more favorably on economic incentive approaches to reducing pollution, yet the enthusiasm for such approaches on efficiency grounds is usually tempered by concerns over equity. This is particularly the case with policies concerning motor vehicles. In every debate over increasing the federal gasoline tax, for example, numerous arguments have been made about the detrimental impact on the poor.

In this paper, we analyzed the distributional impacts in California of three types of vehicle emissions-based fees: (i) a fee based on annual vehicle-miles-traveled; (ii) a fee based on emissions rates (in g/mi); and (iii) a fee based on total annual emissions. We found that all three fees appear regressive, particularly on the basis of annual income, but also on the basis of a constructed lifetime income measure. Emissions rate-based fees are the most regressive because poorer households often own older, dirtier vehicles. VMT fees are the least regressive of the three -- poorer households tend to drive fewer miles than wealthier households. On the basis of annual household income, all three fees look more regressive than current vehicle registration fees in California.

Using lifetime income greatly mutes these regressivity findings, and none of the fees looks markedly different on a lifetime income basis from current vehicle registration fees in California. This means that if the fees are used to substitute in a revenue-neutral fashion for existing registration fees, there would be only a small differential impact on California households. Using lifetime income, we found that a VMT fee would look about the same as current registration fees, while the two emissions-based fees look slightly more regressive than current fees. These findings indicate the importance of tax *shifting* -- using an environmental tax to replace existing taxes can considerably lessen the negative distributional impacts arising from the environmental tax.

Using lifetime income rather than annual income is central to these results. If annual income is used as a measure of the household's economic well-being, all three fees look quite a bit more regressive than the current registration fee system.

Also important to the results is the assumption that vehicle emissions vary only by vehicle age and thus lower income households own dirtier vehicles only because they own older vehicles. We explore whether this assumption is valid using data on emissions combined with zip code level median income data. We find that even controlling for vehicle age, lower income households may own dirtier than average vehicles. This means that emissions fees might be more regressive than we found using age-based average emission rates. To more carefully address the distributional impacts of emissions fees, one needs a dataset linking household level socioeconomic information with information on emissions from the vehicles in the household. This is an important topic for future research.

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