Distribution Effects of Gasoline Taxes in the South: A Comparison of the Expenditure and Income Approaches[1]

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Abstract

Variations in the spending on gasoline and motor oil by quintiles are determined using both an income and expenditure base. Total expenditure data in relationship to expenditures on gasoline and motor oil in the Southern urban areas in 1990 are a relatively stable percent over the first four expenditure quintiles, 4.4 to 4.5 percent. Using income before taxes, depicts a continual decrease in the percent of income spent on gasoline, as expected. In the Southern states a gasoline tax loses much of its regressivity when permanent income is used as the base, and becomes markedly regressive when income before taxes becomes the basis for determining the tax burden.

Introduction

Local, state, and federal governments are interested in potential revenue from gas taxes as well as the burden and distributional effects of the taxes on households. Ecologists seeking to reduce the level of fuel use in order to lessen carbon emissions are interested in determining the principal fuel users.[2] Transportation authorities require estimates of future traffic patterns partially based on current gasoline consumption. The ample explanations regarding the amount of expenditures on gasoline for vehicles are both confusing and controversial. Research of the recent decade emphasizes the importance of permanent income represented by total expenditures as separate from current income as a more precise measure of spending on gasoline and motor oil.

Our study is a paradigm of the determinants of expenditure on gasoline and motor oil for the Southern states for the year 1990. Using the U.S. Bureau of Labor consumer expenditure data, the study estimates the impact of current income, total expenditures and select consumer unit sociological variables such as vehicle ownership on gasoline expenditures. Research of the recent decade emphasizes the importance of permanent income represented by total expenditures as separate from current income as a more precise measure of spending on gasoline and motor oil. First, the recent literature on the determinants of gasoline usage are reviewed. Second, the study methodology and sample is

explained. Third, the sample data are analyzed. This section also includes a review of the analyses of variance (ANOVA) results and the regression analyses. Four, we estimate the impact of a sales tax on gasoline and motor oil expenditures. Variations in the distributional effects by consumer unit quintiles are determined using both an income and expenditure base. The paper concludes with comments on the results.

Review of Literature

Income and Expenditures

The household, in this study represented by the consumer unit, was considered the fundamental unit of trip generation by Wootton and Pick (1967). These researchers maintain that the household characteristics that are responsible for systematic variation in trip generation are disposable income, car ownership, and family structure and size. Recent work in transportation also indicates that gasoline demand is the result of very complex, dynamic behavioral relationships, between many factors in addition to income and car ownership (Golob 1989; Golob, van Wissen and Muers 1986; Hillsman and Southworth 1990).

Breakdown of the Wootton and Pick (1967) data showed that both income and car ownership were independently important in determining trip generation.

The number of journeys generated increases both with increasing income and with increasing car ownership. Wootton and Pick (1967) indicate that the location of the household relative to other transport facilities and the ease of reaching required destinations will influence the type of trip. The researchers recognize that locational qualities have been difficult to appropriately evaluate, but regard their importance as secondary to the internal characteristics of the household.

Our approach allows the use of a permanent income variable, represented by total expenditure. Poterba (1989) reports that a randomly chosen individual has only a 41 percent chance of being in the same income quartile in 1971 and 1978, indicating that the annual income distribution is unstable from year to year. Since households move across income categories, classifying them as well-to-do or poor based on annual income data provides a noise measure of long-term economic status. The notion that households behave on the basis of long-term income underlies the life-cycle and permanent income theories of consumption (Congressional Budget Office 1990; Carroll and Summers 1991).

The life-cycle income/consumption approach, dating back to the research of Friedman (1957) and Ando and Modigliani (1963), introduces considerations which are absent in analysis of consumption based on annual income. The hypothesis recognizes predictable life-cycle patterns in earnings, asset accumulation, and consumption (Blomqvist 1981; Davies 1979; Mincer 1974). An example of this would be that elderly households may spend more than their current income, and, as a result, their low annual income provides a poor indicator of their economic status.

Tanner (1979) also maintains that the total amount of time, money and other costs spent on personal travel may be relatively constant over time. He regards varied expenditure of either time or money on travel as inconsistent with rational economic behavior and with conventional transport modeling. However, Tanner (1979) using data from a national travel survey maintains that generalized expenditures are almost directly proportional to gross income per person.[3]

Gasoline Taxes

In the case of expenditures for gasoline and motor oil, a tax on gasoline may be far less regressive than initially believed as Poterba (1990) points out. Using national data from the Consumer Expenditure Survey, Poterba concludes that annual expenditures are a more reliable indicator of household well-being than annual income. He points out that the new estimate of gasoline tax regressivity is not, per se, a feature of using expenditures rather than income as a basis for assessing incidence. The ratio of gasoline expenditure to total expenditures

will be smaller than the ratio of gasoline expenditure to income, the more traditional measure, and will be relatively more constant across all income groups (Congressional Budget Office 1986).[4]

Empirical Analysis

Data Source and Sample

To capture behavioral relationships and correlations between various economic variables, household expenditures of Southern urban consumers on gasoline and oil for motor vehicles are evaluated utilizing Consumer Expenditure Survey data from the Department of Labor. The interview data provide a continuous and comprehensive flow of information on consumer unit expenditures for goods and services used in day-to-day living, the amount of family income, and major demographic and economic characteristics of units. These interviews also provide comprehensive regional data on income and household type.[5]

All data on consumer income and expenditure patterns are drawn from the 1990 Consumer Expenditure Survey, which is a stratified national sample. The survey obtains the expenditures of consumers in five consecutive quarterly interviews. The interviewed consumer unit is selected on a rotating panel basis. After the fifth interview, the sample unit is dropped from the survey and replaced by a new consumer unit. For the survey as a whole, 20 percent of the sample is dropped and a new group added each quarter. Consumer units are interviewed four times during a period of twelve months (U.S. Department of Labor 1986). For this study, the survey provides regional data on expenditures on gasoline and motor oil, , used as a proxy for spending on gasoline, income and expenditure of consumer units, age of household heads, and number of family members. (U.S. Department of Labor 1988).

As indicated, this study focuses on the Southern region, including the states of Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia. A stratified consumer unit sample of the 1,300 Southern units was selected from the 5,000 U.S. consumer units where at least three quarters of the interviews were in 1990. Of the Southern units, 646 gave complete reporting of the items included in this study.

Numerical Results

The data collected from the sample of 646 consumer units, gives a kaleidoscopic view of the use of gasoline by urban Southern consumer units.[6] Table 1 discloses characteristics of consumer units by quintiles of income

before taxes, the lowest 20 percent in income to the highest. The gasoline and motor oil expenditures average was $1,092 for all consumer units, ranging from $533 at the lowest quintile to $1,684 at the highest. The units in the lowest quintile have an average income before taxes of $6,314. Income progressively increased to the highest quintile, where households have average income of $77,060.

We are initially concerned with the percent of income before and after taxes spent on gasoline and motor oil. The average percent of income before taxes spent on gasoline and motor oil was about 3.2 percent. As expected, consumer units in the lowest quintile spent 8.4 percent of this income on gasoline, but the percent declines to 2.2 percent for the highest quintile. All quintiles spent about the same percent of income after taxes as before taxes. With both incomes, the percentages spent are progressively smaller in the higher quintiles.

relatively constant picture. The percent of total expenditure of the average household is 4.0 percent. The percent of total expenditure spent by the lowest quintile household was 4.3 rising to 4.8 at the third quintile and then falling to 3.3 for the highest quintile household. Interestingly, the lowest quintile spent only about 1.0 percent of total expenditures more on motor oil and gasoline than highest income quintile.

In summary, if you look at percentages of expenditures spent on gasoline and motor oil in relationship to total expenditures arranged by quintiles, there were no strong differences, although the average expenditure on gasoline did increase with quintile ranks. However, for income quintiles the spending percent decreased considerably as the quintile rank increased (Table 1).

Regression Results

The ANOVA procedure was used to identify those socioeconomic characteristics which impact gasoline and motor oil in the urban South.[7] The ANOVAs showed that many factors could be used to some extent as predictors of gasoline consumption. Through use of regression analysis, it was possible to narrow down the list considerably because of the significant correlations between the various factors. An ideal solution would be a compact regression equation showing which factors best predict changes in gasoline consumption.

Table 1
Gasoline Expenditures by Quintile of Income Before Taxes, 1990 Adjusted

Consumer Unit	Total Units	Quintile				
		Lowest	Second	Third	Fourth	Highest
Gasoline and Motor Oil	$ 1,092	$ 533	$ 733	$ 1,036	$ 1,435	$ 1,684
Percent of Income before Taxes	3.2	8.4	5.0	3.8	3.3	2.2
Percent of Income after Taxes	3.6	8.5	5.2	4.2	3.7	2.5
Income before Taxes	$33,772	$ 6,314	$15,541	$27,129	$42,866	$77,060
Income after Taxes	$30,575	$ 6,285	$14,855	$24,755	$39,217	$67,816
Total Expenditures	$27,006	$12,555	$16,862	$23,284	$32,279	$50,079

Total expenditures in relationship to income before and after taxes shows an interesting pattern. When reviewing the data quintiles, it was clear that the lowest quintiles actually spend a larger amount than their incomes before and after taxes while the higher quintiles spend less. With the lowest quintile, income after taxes was $6,285 while total expenditures were $12,555. (See Table 1.) The highest quintile had $67,816 in income after taxes compared to $50,079 in total expenditures.

The percent of total expenditures spent on gasoline and motor oil by consumer units in Table 2 depicts a

In this case total expenditures (Tot Exp) was again used as the proxy for permanent income, while income after tax (IAT) was used to designate regular income. IAT was deemed to be more compatible with Tot Exp than income before tax (IBT) since the former represents available income. However, regression results using IBT or IAT would have been essentially the same.

The full regression model was of the form:

$$\ln(gas) = \text{constant} + b_1 \ln(\text{Tot Exp}) \text{ or } b_1 \ln(\text{IAT}) + b_2 \text{ Vehicles} + b_3 \text{ Age75} + \text{error}$$

Table 2
Gasoline Expenditures by Quintile of Total Expenditure, 1990 Adjusted

Consumer Unit	Total Units	Quintile				
		Lowest	Second	Third	Fourth	Highest
Gasoline and Motor oil	$ 1,092	$ 351	$ 701	$ 1,084	$ 1,464	$ 1,860
Percent of Total Expenditures	4.0	4.3	4.7	4.8	4.5	3.3
Total Expenditures	$27,006	$8,239	$14,964	$22,467	$32,422	$56,973
Average Cost Per Vehicle	$535	$450	$501	$507	$544	$579

(1967) that recognizes the importance of income and vehicle ownership is verified as is the work that includes an adjustment factor for older households. Additional household characteristics such as composition of household and status of household reference person appear to be subsumed under the income or car ownership categories. Thus, our study does not verify the position that many household characteristics in addition to income and car ownership determine gasoline expenditures as suggested by Golob (1989) Golob, van Wissen and Muers (1986) and Hillsman and Southworth (1990).

The percent of total expenditures spent on gasoline is constant for all but the first and fifth quintiles. However, when current before and after tax income is used as the relative base, the percentage spent on gasoline decreases as income increases. This substantiates that the Southern states follow the interpretation of national spending of Tanner (1979), Poterba (1989), the Congressional Budget Office (1990), and Carroll and Summers (1991).

Gasoline Taxes

Introduction

Federal policy goals may be established to meet national and international goals in the reduction of greenhouse gases, to provide for national security in energy, and to increase taxes collected for needed state and federal revenue. The economic instrument used to achieve specific policies may take the form of tariffs on imported oil, subsidies on domestically produced oil, carbon rights or permits, carbon taxes or sales tax per gallon of gasoline. This study concentrates on the last alternative. In all cases the direct impact of the tax on the consumer unit is crucial, and the indirect effects created by the ramifications of the original sales tax are not considered.[9]

The economic theory behind a tax on gasoline is tied to the concept of externalities. The consumer is not covering the full cost of production when external

where:

ln(gas)	natural log of (gasoline and motor oil expenditures + 1)
ln(Tot Exp)	natural log of total expenditures
ln(IAT)	natural log of income after taxes
Vehicles	number of vehicles owned by consumer unit. If 3 or more vehicles owned, vehicles = 3
Age75+	dummy variable equal to 1 if the reference person is 75 years or older; 0 otherwise

It can be noted in Table 3 that while both ln(Tot Exp) and ln(IAT) are significant and positive in all regressions, the explanatory power of the former is far superior. This is evident in their respective adjusted R^2s of 0.368 and 0.188 when they are used as solitary independent variables in equations (2) and (3). This lends additional support to the assumption that permanent income, proxied by Tot Exp, is a better predictor than current income (IAT or IBT).[8]

Recap

The Consumer Expenditure Survey sample of the Southern states, presents an excellent opportunity to estimate consumer unit expenditures on gasoline by current and permanent income and other socioeconomic characteristics. In 1990, gasoline and motor oil spending was positively related to both total expenditures, a proxy for permanent income, current income, and vehicle ownership and negatively affected by the elderly. Previous research, such as that of Wootton and Pick

Table 3
Regression Equations on Log of Gas & Motor Oil Expenditures*

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	4.204	-9.968	-2.494	-4.250	0.689	-2.870	1.674
	(.000)	(.000)	(.001)	(.000)	(.272)	(.002)	(.008)
ln(TotExp)		1.633		0.916		.797	
		(.000)		(.000)		(.000)	
ln(IAT)			0.882		0.379		0.311
			(.000)		(.000)		(.000)
Vehicles	1.230			0.836	1.074	0.784	0.976
	(.000)			(.000)	(.000)	(.000)	(.000)
Age75+						-0.880	-1.083
						(.000)	(.000)
Adj R sq	0.417	0.368	0.188	0.489	0.444	0.508	0.474
F	461.570	376.726	150.196	309.648	257.778	223.118	194.384
	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)
Observations	646	646	645	646	645	646	645

*p-values in ( )

societal costs arise. Present and future society may bare the cost of present emission of greenhouse gases wear and tear on highways, and other costs, not the present consumers. Thus from this concept of equity, the objective would be to force the vehicle user to cover the eternal costs generated in direct proportion to the consumer units external costs from the use of gasoline.

Elasticities

Studies of gasoline demand find significant differences between short and long term elasticities in both price and income. Dahl and Sterner (1991) conclude that between a quarter to a third of short-run adjustment comes from changes in utilization of vehicle stock. Dahl and Sterner (1991) took an average of the elasticities in all of these studies to come up with overall average elasticities for over one hundred elasticity estimates for price and income over the short-run and long-run. The average result for short-run price was -.26 and -.86 for the long-run price impact. Although the estimates included in the survey were both cross-sectional and ordinary time series data, non-lagged and lag models, and focused on the late 1970s and the decade of the 1980s, data were strikingly comparable.

Income Distribution

This study uses the distribution by income quintiles and expenditure quintiles to determine the burden of a gasoline tax of 20 percent in the Southern states. Using the percent of income spent on gasoline and motor oil by each quintile gives a picture of the initial impact of gas taxes based on income. Using a short-term price elasticity of -.26 and a long-term price elasticity of -.86, gives the burden demonstrated in Table 4. The increase in taxes slightly intensifies the regressivity of the gasoline and motor oil spending by income quintiles in the short-run. However, in the long-run, the increase in taxes ceases to effect the distribution of the spending burden. The original percent of income spent on gasoline and motor oil is reestablished in the long-run.

Expenditure Distribution

The same model is used for the expenditure data by quintiles. In this case the 20 percent tax is proportional with the exception of the first and fifth quintile which are slightly lower percents than the other three quintiles in the short-run. As mentioned, only in the highest expenditure quintile does the gas expenditure decline to 3.2 percent below the lowest quintile figure of 4.2 percent. In the long-run the percentage that each quintile spends on gasoline and motor oil is identical to pretax distribution as Table 5 shows.

Concluding Comments

For the Southern region included in this study the results of a 20 percent gasoline tax is based on the theoretical interpretation of the basis for spending on gasoline and motor oil. See Figure 1. Using income as the basis for determination, the tax increase become less regressive with time as the coefficient of price elasticity becomes larger. Thus, over time the percent of income spent for the tax by quintiles becomes similar to the

Table 4
Impact of Taxes on Gasoline Expenditures by Quintiles of Income, 1990 Adjusted

Consumer Unit Characteristics	Total Units	Quintile				
		Lowest	Second	Third	Fourth	Highest
20 Percent Gasoline Tax (Short Run Price Elasticity - .26) a						
Gasoline and Motor Oil	$1,242	$606	$834	$1,179	$1,632	$1,916
Percent of Income before Taxes	3.7	9.6	5.4	4.3	3.8	2.5
Percent of Income after Taxes	4.1	9.6	5.6	4.7	4.1	2.8
(Long Run Price Elasticity - .86) b						
Gasoline and Motor Oil	$1,085	$530	$728	$1,029	$1,426	$1,673
Percent of Income before Taxes	3.2	8.4	4.9	3.8	3.3	2.2
Percent of Income after Taxes	3.5	8.4	4.9	4.2	3.6	2.5

Notes:

a) Gasoline and Motor Oil GM^S

$$GM^S = P^S * q^S$$
$$p^S = 1.2p$$

$$\frac{\Delta q^S}{q} \Big/ \frac{\Delta p^S}{p} = -0.26$$

$$\frac{\Delta q^S}{q} = -0.26 * 0.2 = -0.052$$

$$\Delta q^S = -0.052 * q$$

$$q^S = q + \Delta q^S = q(1 - 0.052) = 0.948q$$

$$GM^S = p^S * q^S = 1.2p * 0.948q = 1.1376pq = 1.1376GM$$

Total Expenditures (E)
$$E^S = E + \Delta GM^S$$
$$= E + 0.1376GM$$

Percent of Income before Taxes
$$\frac{GM^S}{Income\ before\ Taxes}$$

Percent of Income after taxes
$$\frac{GM^S}{Income\ after\ Taxes}$$

b) Gasoline and Motor Oil (GM^L)

$$\frac{\Delta q^L}{q} \Big/ \frac{\Delta p^L}{p} = -0.86$$

$$\frac{\Delta q^L}{q} = -0.86 * 0.2 = -0.172$$

$$\Delta q^L = -0.172 * q$$

$$q^L = q(1 - 0.172) = 0.828q$$

$$GM^L = 1.2 * 0.828 * p * q = 0.9936GM$$

$$E^L = E - 0.0064GM$$

tures, the before and after gas tax distribution pattern remains essentially the same, with a limited percentage variation among quintiles.

On an expenditure basis, the proportionality remains the same. The Southern urban region studied verifies the result announced by Poterba (1990; 1991) and the Congressional Budget Office (1986). Using total expenditures as a proxy for long-term income, the distribution of the tax in the short and long-run shows only a few insignificant changes in the expenditure pattern.

Suggestions For Future Research

The distribution effects of gasoline taxes across income quintiles in the Southern region verifies conclusions from earlier national research. Future research on the other regions of the country is needed to determine if they also follow a comparable gas expenditure pattern in relationship to household income and total expenditure. While the South's pattern follows that of the nation, another region of the country may present a unique pattern.

initial percents. Thus, the impact of gasoline taxes fails to change the initial distribution of gasoline and motor oil expenditures which decrease from a high of about 8.5 percent to a low of 2.2 percent from the lowest to the highest income quintile, respectively the total expendi-

Regarding the Southern region specifically, there are a number of important variables that may affect the overall pattern substantiated by our study. The impact

Table 5
Impact of Taxes on Gasoline Expenditures by Quintiles of Total Expenditure, 1990 Adjusted

Consumer Unit Characteristics	Total Units	Quintile				
		Lowest	Second	Third	Fourth	Highest
20 Percent Gasoline Tax (Short Run Price Elasticity - .26) a						
Gasoline and Motor Oil	$1,242	$399	$797	$1,233	$1,665	$2,116
Percent of Total Expenditures	4.6	4.8	5.3	5.5	5.1	3.7
(Long Run Price Elasticity - .86) b						
Gasoline and Motor Oil	$1,085	$349	$697	$1,077	$1,455	$1,848
Percent of Total Expenditures	4.0	4.2	4.7	4.8	4.5	3.2

Notes: See Table 4 notes.

of convenient public transportation on the use of gasoline remains unclear. In addition, although the percent of income spent on gasoline declines as income levels increase, the extent that this is related to the fuel efficiency of the vehicles owned versus the number of miles traveled is a vital area of potential research. Lastly, since only urban consumer units were included in the sample used in this study, the spending patterns of the Southern rural population remains a fruitful area for future research.   ⁊⬥

✳✳✳Footnotes✳✳✳

1. Some of the data collected from an initial sample in this study were presented by Greening, Fish, and Kim (1992) at the IAEE North American Conference, October 1992. The initial version of this paper was presented at the 1993 Southern Economic Association Meetings in New Orleans.
2. Distribution impacts of environmental policies have been previously addressed in the literature (Baumol and Oates 1988). Recognition has been given to the linkage between economic and social characteristics and the distribution of air pollutants and quality changes (Asch and Seneca 1978). It has been suggested by a number of authors that these types of linkages should be recognized during the development of pollution control and abatement programs (Dorfman 1977; Gianessi, et al. 1979). Experience with previous air pollution control

programs where the initial burdens have been shared by government, the industrial sector, and households indicate that the initial financial burden of these types of programs should be shifted to the average consumer (Peskin 1978). Also see Brinner, Shelby, Yanchar, and Cristofaro (1991) for a review of federal gasoline tax policy options.

3. The characteristics of head of the household, sex, race, age and education all affect gasoline consumption according to Archibald and Gillingham (1980). These researchers arrive at several general conclusions that include the following relationships. Households headed by females consume significantly less gasoline than others. Consumption of gasoline appears to be inversely related to the age of the household. Households with more than one car consume significantly more gasoline, but gasoline consumption per car was lower for multi-car households than for one-car households. Archibald and Gillingham (1980) conclude that multi-car households with children over 17 appear to consume more, and additional full time earners increase the household's gasoline consumption.

Choices regarding the type of travel and the number of miles traveled are related to the location of the consumer unit, be it in an urban versus a rural setting, according to Hensher, Milthorpe and Smith (1990). The degree of urbanization of the location of a household is inversely related to gasoline consumption according to Archibald and Gillingham (1980). In contradiction, Wheaton's (1982) gasoline and transportation demand model estimates give a consistent picture of gasoline demand as being influenced exclusively by economic and not geographic factors. The only statistically significant difference among regions of the country was that households in the West consumed significantly less gasoline than households in the other three regions (Wheaton 1982). The nature of the consumer Expenditure Survey Sample data for the Southern States precludes any measurement of differences in the gasoline expenditure patterns of rural and urban

Figure 1. Gasoline Expenditures as a Percentage of Income Before Tax and Total Expenditures
With and Without a 20% Tax
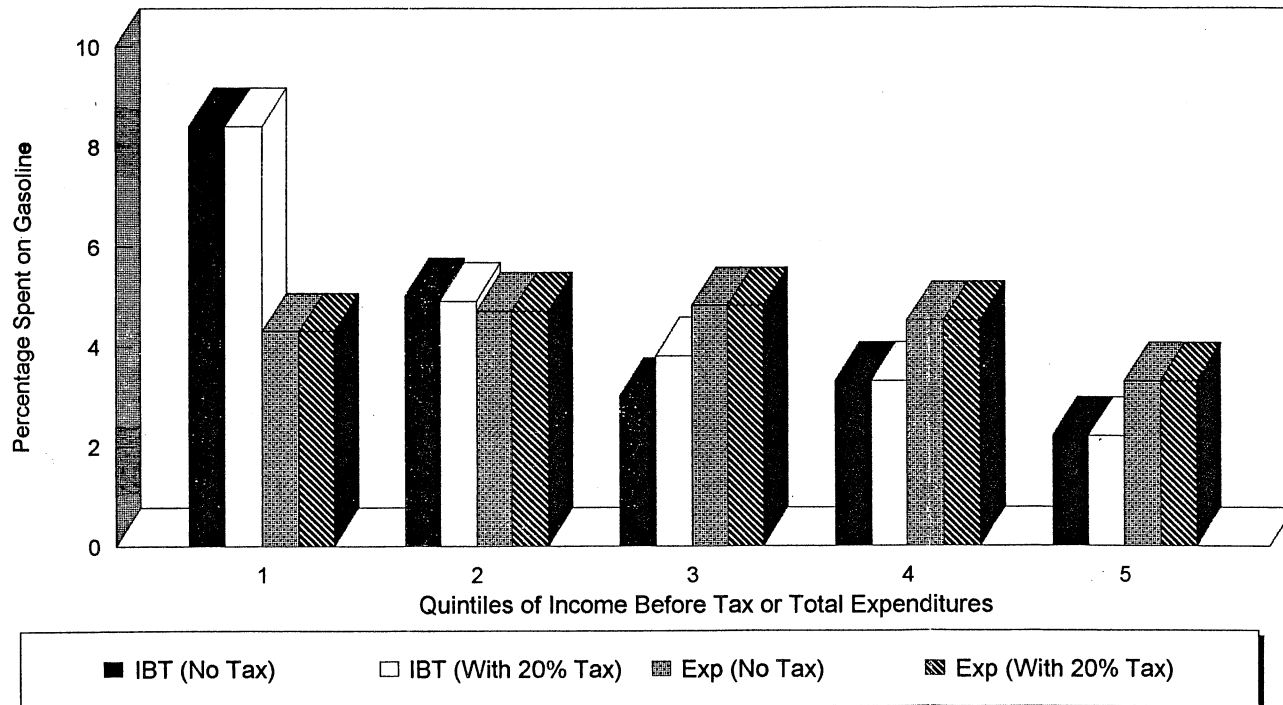
consumer units.

4. Poterba (1991) recognizes that to design a successful policy instrument, a policy maker needs to know the distributional impacts of each option. He gives an example of what would occur if a policy mandating that all cars have a certain fuel efficiency were implemented by a carbon tax. In this case higher income groups, trading cars more frequently, would benefit from this policy by buying the most advanced technology available. This is an example of a regressive policy. While a "gas-guzzler" fee would take advantage of the first-cost sensitivity of consumers in a highly progressive tax (Lashof and Tirpak 1990).

5. In addition to general demographic and income data, this data set includes a wealth of information which is useful in modeling demand for transportation, such as bus fares, the types of automobile owned by the household, and the stated purpose of travel.

6. The following definitions are provided in almost all documents presenting Consumer Expenditure Survey data (U.S. Department of Labor 1986):

CONSUMER UNIT: A single person living alone or sharing a household with others but who is financially independent, members of a sample household related by blood, marriage, adoption, or other legal arrangement, or two or more persons living together who share responsibility for at least two out of three major types of expenses--food, housing, and other expenses. The terms household or consumer are used for convenience.

TOTAL EXPENDITURES: The transaction cost, including excise and sales taxes, of goods, and services acquired during the interview period. Estimates include expenditures for gifts and contributions and payments for pensions and personal insurance.

INCOME: The combined income earned by all consumer unit members 14 years old or over during

the 12 months preceding the interview. The components of income are wages and salaries; self-employment income; social security and private and government retirement; interest, dividends, rental income, and other property income; unemployment and workers' compensation and veteran's benefits; public assistance, supplemental security income and food stamps; rent as pay and meals as pay; and regular contributions for support such as alimony and child support

7. The SAS software ANOVA procedure used on our sample data was from SAS STAT (1990). Pairwise comparisons were made using Fisher's Least Significant Difference (LSD) methodology.

$$LSD = {}^t\alpha/2\sqrt{s_w^2(\mathbin{/}\!n_i + \mathbin{/}\!n_j)}$$

with:

α = significance level of the test
n_i and n_j = respective sample sizes
s^2_w = mean square within samples.

8. The coefficient of the vehicles variable alone is positive and results in an adjusted R^2 of 0.417 as shown in equation (1). The number of vehicles is certainly an important predictor of gasoline consumption in the short-run. Using both vehicles and ln(Tot Exp) in equation (4) improves predictive power to an adjusted R^2 of 0.489. Using vehicles and ln(IAT), equation (5), results in an adjusted R^2 of 0.444. Addition of the age75+ variable yields modest improvements (R^2 of 0.508) the explanation of variability. [See equations (6) and (7) in Table 3]. The related coefficient is negative as this age group spends considerably less on gas. Several other factors not shown were statistically significant, but did little to improve the predictive power of vehicles and ln(Tot Exp) or ln(IAT).

9. Uri and Boyd (1989), using 1984 data and prices, analyzes a 15 cents increase in a gasoline sales tax using a general equilibrium model. According to their study the tax would increase federal government revenue by about $500 million for each 1 cent increase in taxes. The producing sectors would be hit by a decline in output of about $600 million per 1 cent tax, while the consumer sector would see a decline in consumption of about $640 million per 1 cent tax.

The Department of Energy (1987) develops a partial equilibrium model using 1987 data. Their study calculates the short-run effects and the long-run effects in selected industries and the economy. They forecast the decrease in fuel consumption in the short-run and the long-run with a 10 cents and 25 cents per gallon sales tax.

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