DOES VEHICLE TAXATION IMPACT VEHICLE OWNERSHIP?

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ABSTRACT

This paper is concerned with assessing the impact of vehicle taxes on vehicle ownership rates. As the debate on the appropriate levels of transport pricing has progressed, the primary concern has been to identify the externalities associated with transport and to assess their magnitude. Less visible in this literature has been an analysis of the degree to which vehicle taxes (the presumed method of internalizing transport externalities) actually impact transportation demand. The current paper assesses the degree to which current levels of vehicle taxes, which vary by country, actually impact car ownership. This study found a clear and significant relationship between vehicle taxes and levels of car ownership in a sample of 17 countries, including 15 European countries, the United States, and Japan. While the results imply that vehicle taxes can be used as an effective tool to moderate car ownership, the impact on actual vehicle miles driven would require a more detailed analysis.

INTRODUCTION

A significant portion of recent research in transportation economics has been concerned with issues of pricing. To a large extent, this interest in pricing is due to the concern that unpriced externalities exist in the transport sector. Specifically, it has been argued that both congestion costs and environmental impacts are under priced. As is well known, under or unpriced negative transportation-related externalities lead to an inefficient outcome of "too much" transportation services being consumed. The reasoning behind this proposition is the following: If the *private* cost of transportation diverges from the wider *social* cost, we are faced with a classic situation where a negative externality is being generated. At equilibrium of demand and supply in the transportation sector the externality would not be accounted for, and the private cost facing users would be below the full social cost, leading to a greater amount of travel than if the full social cost were charged.

There is a widespread view that such external costs associated with transportation exist, and may be significant in certain instances. Focusing on road transportation, a large literature has discussed the issue of unpriced congestion *(1)*. In terms of other external costs, the major pollution costs generated by road transportation are widely known and a rapidly growing literature has attempted to estimate these costs exist *(2)* and *(3)*. A study by Small and Kazimi, for example, estimated that in the Los Angeles region automobiles generated emissions whose local health impacts, on a per-mile basis, were nearly equal to $0.02 per mile in the year 2000. For heavy trucks, the corresponding figure estimated was significantly higher at $0.45 per mile.

The degree to which unpriced externalities result in inefficient outcomes is usually referred to as the deadweight loss. Vilain et. al. *(4)* estimate that the annual deadweight loss from unpriced automobile and truck emissions in the state of Pennsylvania approach approximately $71 million. This estimate accounts for pollution costs only and ignore congestion externalities.

To varying degrees, pricing policies have been implemented to address the imbalance between private and social costs. Congestion pricing, whose formalization is perhaps associated most closely with the work of William Vickerey in the 1960s, has existed in Singapore since 1975. Though other examples were scarce until the 1990s, growing congestion eventually led to adoption of various pricing schemes including France (the A1 highway), California (the SR-91), the New York and New Jersey interstate crossings and, more recently, the congestion charges for central London.

Pollution externalities have also been addressed through various charges, but here the approach has been more ad hoc *(5)*, *(6)* and *(7)*. In part, the challenge of devising user charges to reflect these external costs stems from the lack of consensus on their magnitude. Further, even if measurement were less problematic, devising an appropriate pricing tool is itself complex: For example, these costs vary by location, and are dramatically reduced in non-urban areas.

The current paper does not address the issues of accuracy in measuring external costs, nor does it suggest pricing mechanisms to achieve efficiency. Rather, the analysis herein addresses a related, and important question: *Given* pricing mechanisms, what are the responses of users? Presently varying levels of taxes are levied on car ownership and use in certain countries (hereafter, vehicle taxes or VT). VT presumably has affected the behavior of motorists in these countries, but to what degree? Specifically, what impact, if any, have existing VT had on the use of vehicles?

In order to address this important question, we estimate the impact of VT on one measure of transport demand, namely car ownership. The analysis described below assesses the degree to which varying VT in a sample of countries impacts vehicle ownership. Due to the cross-sectional nature of the data, the econometric estimation process must explicitly account for as many factors as possible that are assumed to affect vehicle ownership[1]. A priori, these factors include measures of per capita income as well as geographic factors such the country's level of urbanization. The relationship between gross domestic product (GDP) per-capita, and rates of car ownership, have been evaluated at length and are generally considered to be one of the most important predictor for overall car ownership *(8)*. Another important determinant of vehicle ownership is urban density: the more dense population settlement, the greater the presence of alternative transportation modes as well as reduced travel needs, all else being equal.

DESCRIPTIONS OF THE DATA

Data collected for this paper include various indicators compiled by the World Bank Group, geographic statistics sources, and existing research findings relative to VT *(9)*. The sample of 17 countries includes primarily European ones as well as the United States and Japan. Table 1 summarizes the various data, while Figures 1 through 3 visually display the relationship between car ownership rates and per capita GDP, VT, and urban density for the 17 sample countries.

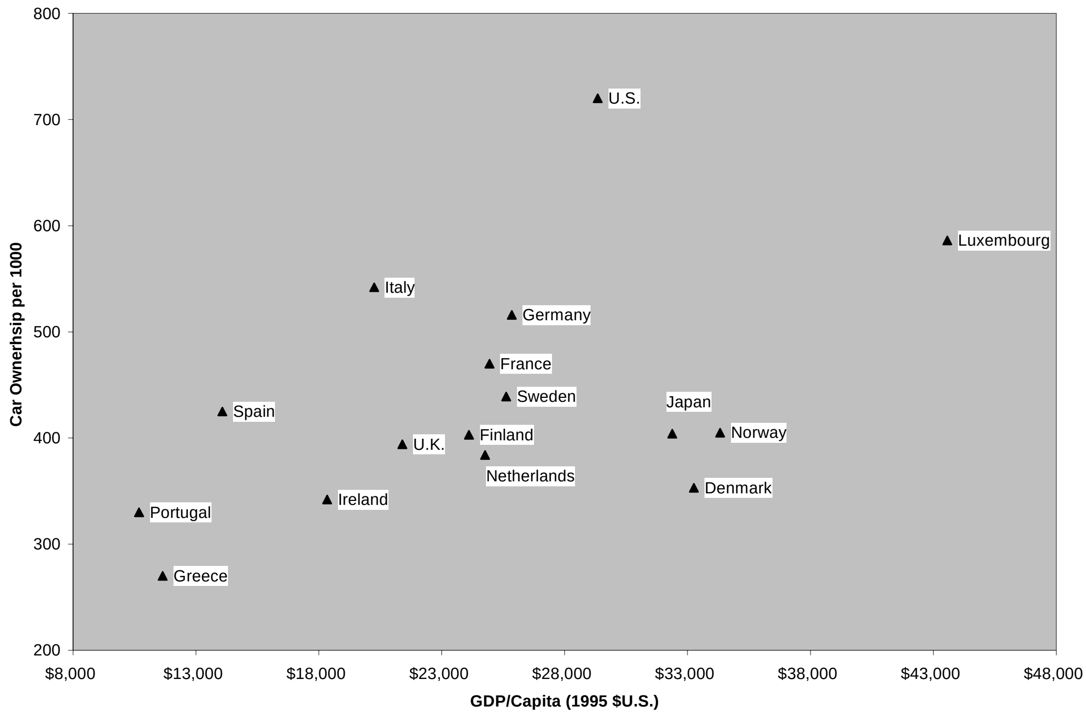
TABLE 1: Selected Data for Sample Countries

	Car Ownership per 1000[a]	GDP per Capita[a]	Urban Density[b]	Road Network[a]	Population Density[a]	Vehicle Taxes[c]	Urbanization[a] (%)
Belgium	444	$25,380	4,920	147,121	312	$966	97
Denmark	353	$33,260	4,841	71,462	125	$2,966	85
Finland	403	$24,110	4,115	77,900	17	$1,750	60
France	470	$24,940	8,419	893,500	107	$1,227	75
Germany	516	$25,850	6,380	230,735	235	$831	87
Greece	270	$11,650	18,888	117,000	82	$893	60
Ireland	342	$18,340	10,900	92,500	55	$1,380	60
Italy	542	$20,250	7,144	479,688	196	$896	67
Japan	404	$32,380	12,950	1,161,894	347	$1,100	79
Netherlands	384	$24,760	8,169	116,500	466	$1,509	89
Norway	405	$34,330	6,782	90,880	15	$1,400	74
Portugal	330	$10,690	9,000	68,732	110	$1,272	63
Spain	425	$14,080	13,075	663,795	80	$682	77
Sweden	439	$25,620	7,500	212,073	22	$1,048	83
U.K.	394	$21,400	10,800	371,913	244	$1,205	89
U.S.	720	$29,340	3,162	6,304,193	30	$353	77
Luxembourg	586	$43,570	6,100	5,189	167	$596	91

Sources: a. World Bank Development Indicators 1999; b. www.demographia.com. Wendell Cox Consultancy Site Accessed 7/1/04 Selection of largest metropolitan areas within each country. Selection of largest metropolitan areas within each country; c. and calculations of the authors; Figures for the United States car ownership include sport utility vehicles and household light trucks.

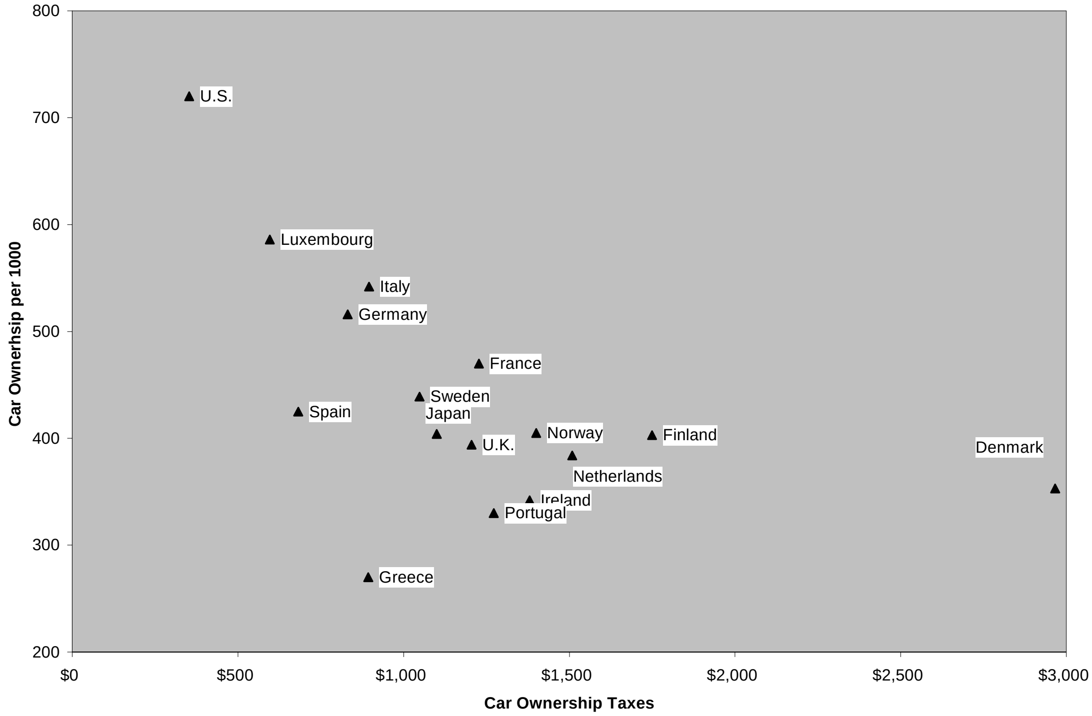
[1] The strong likelihood of country-specific heterogeneity influencing vehicle ownership would suggest the use of panel data and fixed effects techniques. Panel data is unfortunately not available here, so an alternative approach is pursued, namely to control for heterogeneity by including as many relevant explanatory variables as possible.

FIGURE 1: The Relationship Between Car Ownership and Per Capita GDP



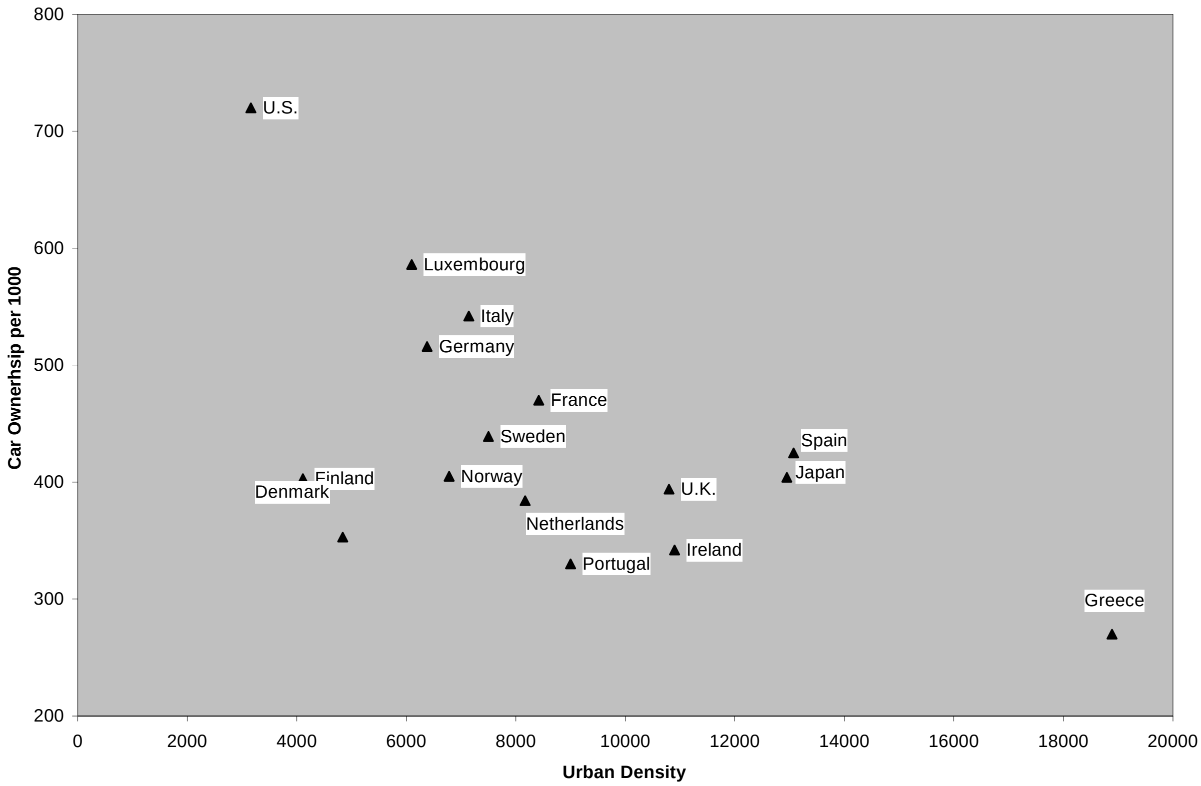
Source: Calculations of the Authors

FIGURE 2: The Relationship Between Car Ownership and Vehicle Taxes



Source: Calculations of the Authors

FIGURE 3: The Relationship Between Car Ownership and Urban Density



Source: Calculations of the Authors

Sources for the data were the following:

Macro-economic and Physical Data: The World Bank Group development indicators were used to determine various measures such as per capita GDP, car ownership rates, the extensiveness of the road network, and other physical country statistics. As shown in Table 1 and Figure 1, there is an implied strong relationship between vehicle ownership and per capita GDP. For our sample, ownership rates range from 270 for Greece to 720 for the United States.

Urban Density Data: Particular data comparing urban form amongst the sample countries was gathered. In this case, all available data on the urban density of the largest urban centers in each respective country was gathered.

Vehicle Taxes: The level of car ownership costs used here have been calculated to specifically account for taxes only. Essentially, this was due to the assumption that the principal sources of differences between costs of car ownership between countries is associated with acquisition, registration, and fuel taxes. We assume that base prices for vehicles and fuel are relatively equal across our sample of countries; other sources of ownership cost differences, such as insurance premiums, are not included in this analysis (9).

ECONOMETRIC RESULTS

The approach of the analysis is to create an econometric model of vehicle ownership that is as complete as possible in its representation of ownership determinants. We assume that a country's level of per capita GDP increases car ownership, as cars are clearly a normal good in the economic sense. The relationship between per capita GDP and car ownership often appears non-linear, as suggested in Figure 1. Some econometric work has found support for an S-shaped pattern in the relationship of income to vehicle ownership, with a tendency for some higher-income countries to approach a theoretical saturation point *(10)*. When a broad spectrum of data points representing low, middle, and high-income samples are analyzed, this relationship can be estimated using various non-linear specifications that generate non-constant elasticity of car ownership to income over the entire range of observed countries.

Several basic models were developed to estimate the impacts of a series of taxes on the demand for road transport (in this case represented by car ownership). The results of this analysis are displayed in Table 2. In general, the five models reflected the following general form;

$$CarOwnership \quad = \quad C + \beta_1 GDP\ per\ Capita + \beta_2\ Taxes + \beta_3 UrbanDensity$$

In general, as shown in Table 2, we find a clear, and significant impact of VT on vehicle ownership by country. The effect of VT in our sample is highly significant (greater than 99 percent level of confidence in all specifications reported), with VT acting to reduce car ownership in the sample of countries studied. Econometric results show that our controls for heterogeneity, urbanization rates and a measure of attraction potential, are significant and have the expected signs.

Generating a measure of VT elasticities is also estimated by specifying the relationships in logarithms. As shown in the results for equation 3 in Table 2, the implied elasticity is on the order 0f –0.3, similar to price elasticity "rules of thumb" for transit.

TABLE 2: The Effects of Vehicle Taxes on Vehicle Ownership

Independent Variable:	(1) OLS Estimator	(2) OLS Estimator	(3) OLS Estimator*	(4) TSLS Estimator**	(5) OLS Estimator
(1/Per Capita GDP)	-2214942 (-2.2)	-1343387 (-2.3)		-1357321 (-2.3)	-2762103 (-3.8)
Log (1/Per Capita GDP)			-0.2 (-2.3)		
Log Taxes		-158 (-8.8)	-0.3 (-5.3)	-163 (-7.0)	-135 (-3.8)
Urban Population Density		-0.01 (-4.5)		-0.01 (-4.5)	
Log Urban Population Density			-0.2 (-3.0)		
Roads * Population	1.39E-13 (3.2)				4.30E-14 (1.1)
Constant	505 (11.3)	1690 (13.2)	8.2 (6.7)	1730 (10.4)	1485 (5.8)
Adjusted R2	0.49	0.91	0.82	0.91	0.79

Source: Calculations of the Authors
All equations include country-level vehicle ownership as dependent variable; T-statistics in parentheses
**Vehicle ownership estimated in logs*
***Two stage least squares estimator. Instruments for taxes include various exogenous variables including the size of the country's public sector relative to its economy.*

Any model that combines variables such as income, population density and car ownership costs, to predict car ownership rates, will be confronted with issues of engogeneity. Specifically, variables that are taken as determinants of car ownership may themselves by affected by car ownership. For example, historical research has determined a clear relationship between income and the decline in residential density *(11).* Negative correlation between accessibility and income have been major determinants of trends toward dispersed and lower density urban form. Further, tax costs from state governments were found to be highly endogenous with rates of car ownership in different U.S. states.

Such potential endogeneity of independent variables is well-known to pose problems for the use of standard ordinary least squares (OLS) estimation techniques *(12).* Standard alternative approaches include the use of instrumental variable (IV) techniques, specifically the application of two-stage least squares (TSLS) estimation. TSLS estimation was carried out, where instruments for tax levels included various indicators of the relative size of the public sector in the various countries. As shown in Equation 4, the control for endogeneity using TSLS does not affect results to any significant degree

CONCLUSIONS

The analysis carried out herein confirms the notion that VT do have an impact on the observed levels of car ownership in a sample of 17 countries. The approach was to estimate a relatively complete model of vehicle ownership demand that included explicit measures of VT as independent variables. The results showed the level of VT to be highly significant factors in moderating vehicle ownership. In particular, the implied elasticity of VT to car ownership was found to be -0.3, suggesting that a 10 percent increase in VT would on average be associated with a 3 percent reduction in the rate of vehicle ownership.

Due to the limited availability of the selected data over appropriate time frames, a panel data analysis was not possible. Such a panel data set would allow the use of fixed effects estimators to account for country-specific heterogeneity. Instead, a cross-sectional data set was used, with concerted efforts to include variables that reflect country-specific heterogeneity as much as possible. For the results reported here, country-specific heterogeneity is controlled for by urbanization rates and a measure of "trip attractions" – a country's road network multiplied by its population.

Concerns over the endogeneity of the tax predictor were addressed. Potential bias from an endogenous tax variable is an inherent problem in cases where a country's tax structure has been structured in an attempt to price the externalities of car ownership itself (or more accurately, vehicle use). It is somewhat expected that the five countries that have instituted a specific carbon tax on fossil fuel consumption (Norway, Sweden, Netherlands, Denmark, and Finland) represent some of the highest overall taxes paid by car owners. In such a context, the endogeneity of the tax variable is apparent; in these countries taxes on car ownership have been introduced in *response* to rising rates of car ownership. As a consequence, an instrumental variables framework was also tested, specifically a TSLS regression that employed instrumental variables such as government expenditure. Similar results were obtained to models based on OLS methods.

While the analysis suggests that VT are a potential tool to moderate car ownership, it does not address the issue of VT and vehicle use in terms of total distance traveled. Additional research into this aspect of transport demand would represent an important next step to address the role of VT in addressing transport externalities.

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