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Distributional Effects of Environmental Taxes on Transportation
Evidence from Engel Curves in the United States

Abstract:
Indirect taxes on transportation activities that pollute can correct externalities and close the gaps between private and social costs. However, policy makers often find such Pigou taxes difficult to implement because of political resistance due to possibly adverse affects on equity. For this reason it is important to assess the distributional aspects of environmental levies. This article estimates properties of the demand for transportation in parametric and non-parametric analyses of Consumer Expenditure Surveys for the United States, 2000, and finds patterns in the resulting set of Engel curves. Private transportation using air flights and new automobiles have Engel elasticities above unity while public transportation via mass transit has Engel elasticity below unity. The findings can be interpreted in an important way since they show that a differentiated scheme of environmental taxes on transportation may function progressively. A Pigou scheme with larger taxes on modes of transportation that pollute more appears to coincide with larger levies on luxury modes preferred by richer households.

Keywords: consumption patterns, double dividend, Engel curves, environmental levies, equity, externality, indirect taxation, Pigou correction, redistribution, transportation, travel

JEL classification: D12, D31, H23, R41

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1. Introduction

Policy makers are often told by economists to separate efficiency goals from equity goals because there may be a conflict. For example, correcting an externality may require a Pigou levy that sometimes appears to hurt poor families. Distributional concerns may lead to opposition against a Pigou tax, and this is frequently observed in the political debate when policy makers consider environmental levies. As Verhoef (1999) points out, there is tension between environmental policy and its distributional impact, and analysts often point toward a trade-off between efficiency and equity. Thus, in practice Pigou taxes are subject to intricate negotiations in the intersection between economic advice and political feasibility. Rose and Kverndokk (1999) argue that because equity concerns are normative, not descriptive, and since economists seem to prefer the descriptive to the normative, a convention in economics has evolved that emphasizes efficiency. As a resulting compromise, then, policy makers are seen to use one tool, such as environmental levies, to combat externalities for efficiency purposes, and another tool, such as direct tax relief, to combat inequity. This article asks the question: Is there a trade-off between efficiency and equity goals in American transportation? The answer appears to be "no, not necessarily".

The answer is reached through empirical scrutiny of consumer expenditures on modes of transportation in the United States for year 2000. The examination shows that there exist clear income patterns in the demand for transportation. Estimates of Engel curves for modes of transportation indicate that air flights, new automobiles, and leisure travel have Engel elasticities above unity. They are luxury modes of transportation, preferred by richer households with higher standards of living, holding demographic composition constant. Mass transit modes, such as bus or train, have Engel elasticities below unity. They are necessary modes of transportation, chosen by poorer households with lower standards of living.

These income patterns hold the potential for an interesting interpretation since they appear to coincide with environmental patterns. More precisely, luxury modes of transportation are likely to pollute more and involve more energy consumption than necessary modes. If, in addition, the gaps between social and private costs are widest for the modes that pollute the most, an externality-correcting, differentiated taxation scheme on different modes of transportation will reach efficiency goals while functioning progressively. Such a scheme will make environmentally costly modes of transportation more expensive, and the taxes will mostly be borne by rich households. Thus, in transportation there may be no conflict between efficiency and equity. On the contrary, policy makers may potentially be in a position to reach two goals with one instrument. This is the background against which economists may find Engel elasticities of transportation worth careful estimation and consideration. Such an estimation of the demand for transportation is the aim of this article.

I detect regularities in the distributional aspects of transportation and travel. Households with higher standards of living travel for leisure more frequently, fly more often, and spend more on high-priced cars. Households with lower standards of living relocate using mass transit and they spend disproportionately more of their budgets on gasoline. The result was first documented for Norway in Aasness and Røed Larsen's (2003) study of transportation Engel curves. They show that modes of transportation that are likely to have more detrimental environmental impact also are seen as luxury modes by consumers. But Norway is a small, homogeneous country, and so the results may not necessarily illuminate the situation in other, larger, heterogeneous countries. In order to test the universality of the results of Aasness and Røed Larsen, I utilize consumer data for a large, heterogeneous country: the United States.

Analysis of consumer patterns in transportation and the study of optimum environmental levies meet at a confluence of several major strains of economics. First, environmental economists are concerned over the effects on amenities and nature attributes from the soaring popularity of transportation and travel. One hundred years ago, purchases linked to getting around amounted to only a few percent of a household's budget. Today, such expenditures amount to one fifth of the budget, according to Segal (2001). Thus, the increased frequency of relocation is a social concern since physical relocation of people requires energy, entails letting discharges into soil, air, and water, involves geographical displacement of alternative activities, implies noise pollution, and entails congestion. As a result, environmental economists seek to estimate properties of consumer behavior in order to identify the determinants of choices and to be able to predict future patterns.

Second, economists have known since Pigou (1920) that environmental externalities may be corrected through price adjustments such as levies on production, purchase, and consumption. If the social costs in the consumption of a good exceed the private costs, the magnitude of the consumption of the good may exceed the social optimum level. Indirect taxes can correct the discrepancy between social and private costs. It is also known from environmental studies that different modes of transportation have different discrepancies between private and social costs. Taxi rides, metro transportation, and bicycle trips may have different wedges between social and private costs. As a result, analysts of public finance seek to derive models of indirect taxation schemes that reflect these differences.

Third, it is likely that levies on transportation will affect different types of households differently. This is known theoretically, but there is a paucity of empirical results; a gap between guesses and facts that this article seeks to remedy. Differentiated Pigou taxes may correct for environmental effects but they may only be politically feasible if they have accepted social profiles, a constraint especially active for European policy makers. Thus, social scientists from many traditions try to assess the simultaneity in and interactions between environmental and distributional concerns. In fact, Sandmo (2000) urges analysts to consider environmental and distributional aspects of levies in tandem. Proost (1999) discusses the importance of the integration of public economics and environmental policy. Contributions in Proost and van Regemorter (1995) and Mayeres and Proost (1997) show the growing interest in the combined aspects of environmental and distributional studies. As de Mooij (1999) points out, "distributional issues, rather than efficiency, often dominate the political discussions about environmental policy instruments". This article shows that it is possible that efficiency and distributional goals coincide; thereby adding to the literature on double dividend with a novel type of such double benefits; see e.g. Bovenberg and de Mooij (1994) and Goulder (1995) for the early debate.

Allow a few introductory words on the estimation framework and results in this article. I use a two-stage-least-squares errors-in-variables model in which the observable purchase expenditure on a given commodity is the sum of two terms, the latent consumption of the transportation commodity and a latent error term. Similarly, total purchase expenditure is the sum of total latent consumption of all commodities and an aggregate error term. In a model where the Engel curve of a transportation commodity is determined by the sum of total consumption and the demographic size and composition of the household, total consumption is an unobservable, latent variable and must be substituted with observable, manifest total purchase expenditure. Since manifest total purchase expenditure contains an aggregate error term, it is correlated with the Engel curve error term. However, using income as an instrument for total expenditure produces consistent coefficient estimates in a 2SLS regression set-up. From the regression estimates I proceed to derive Engel elasticities, and find that air flights, car purchases, and leisure travel have Engel elasticities above unity. These commodities may then be classified as luxury items. Their budget shares increase as standards of living increases, holding relative prices equal. Purchases of gasoline and local public transportation on mass transit means such as buses, trains, and metro have Engel elasticities below unity and are categorized as necessities. Their budget shares fall with standards of living. Most modes of transportation follow the pattern that luxuries are most energy-intense and pollute more, as obtained in Aasness and Røed Larsen (2003).

However, gasoline is an important exception since it involves high levels of energy per person kilometer and pollution, but is seen by consumers as a necessity.

Notice that since the estimation results may be sensitive to choices of functional form, I supplement the analysis with results from a non-parametric technique in order to sketch the contour of the association between total consumption and consumption of different modes of transportation without parametric assumptions, in effect drawing non-parametric Engel curves; see Blundell, Duncan, and Pendakur (1998) and Blundell, Browning, and Crawford (2003) for similar applications and Yatchew (1998) and DiNardo and Tobia (2001) for an overview of use of and advantages in non-parametric techniques.

The article presents new knowledge. First, the estimates of Engel elasticities on American consumer data using the error-correcting 2SLS method, complement and up-date earlier results on household demand for gasoline found in Schmalensee and Stoker (1999). Second, this article adds to the literature on distributional effects in the demand for transportation in general. Third, the non-parametric technique uncovers additional, interpretable patterns that allow us to scrutinize the legitimacy of conventional estimation methods.

Let me state where I am headed and how this article is structured. The next section presents some initial comments on the environmental impact from different modes of transportation and the apparatus used in analyzing distributional aspects. The subsequent section goes through the econometric theory and the following section introduces the non-parametric, supplementary approach. Section five describes, explains, and discusses the empirical results on the demand for transportation and the estimated Engel curves. The final section concludes. Details on the consumer expenditure survey (CES) data are included in an appendix.

2. Transportation, the Environment, and Distribution

Moving people from one place to another demands energy and leads to discharges. Travel and transportation put pressure on the environment, and often involve a degradation of quality. Some modes of transportation require more energy and lead to more discharges than others. Aasness and Røed Larsen (2003) argue that modes of transportation that entail more impact on the environment include short-distance air travel and low-occupancy taxi rides; see Table 1. Modes of transportation that are more environmentally friendly are high-occupancy, long-distance railway, bicycles, and mopeds. This is supported by e.g. Button and Rietveld (1999) who point towards airplanes as environmentally costly. This article cannot review all the evidence of transportation costs since costs include much more than energy and discharges. Costs also include time spent in relocation, congestion, noise, visual intrusion, disturbance of wildlife, and impact on climate. Consider Friedrich and Bickel (2001) for a recent review of the literature.

However, Aasness and Røed Larsen present evidence from several sources on the environmental impact from travel and transportation in order to substantiate the claim that some modes of transportation are more costly than others. In Table 1 below, I include computations that illustrate some of these facets. There is a pattern along certain dimensions. For example, average energy usage and emissions to air decrease as the distance traveled in airplanes increases. The reason why is that it requires much energy to perform physical work against gravity. Hence, lifting airplanes demands much fuel. Once airborne, however, less energy is required to stay airborne. Automobiles show fewer and smaller economies of distance, and average costs do not fall rapidly with distance, given roads and infrastructure. However, the occupancy percentage is important to average energy consumption and emissions per person kilometer since the person load is small comparable to the weight of the car. Buses and trains may carry more people per vehicle weight, so these modes are less energy intense per person kilometer. These patterns may allow us to combine features of environmental impact from transportation and distributional regularities in the demand for transportation. In general, short-distance trips in the air and low-occupancy taxi rides are environmentally costly. Mass transit by bus or train is environmentally less costly.

Table 1. Energy Usage and Emission to Air per Person Kilometers for Several Transport Modes

Mode of transportation	Load (person/car; % of capacity)	Energy (kWh)	CO_2 (g)	SO_2 (mg)	NO_x (mg)	CO (mg)	CH_4 (mg)	NMVOC (mg)	Particles (mg)
Automobile	2.2(normal)	0.25	65	13	130	360	40	30	7
Automobile	3	0.17	43	9	86	238	2.6	20	5
Taxi	1.5(normal)	0.33	87	30	127	206	1.2	20	15
Bus	50 (normal)	0.15	36	17	450	117	0.9	36	31
Rail (Inter-City)	38 (normal)	0.14	0	0	0	0	0	0	0
Rail (Local)	35 (normal)	0.14	0	0	0	0	0	0	0
Rail (Express)	48 (normal)	0.11	0	0	0	0	0	0	0
Air, Boeing 734/735, 400km	65	0.72	191	60	517	412	0.9	18	23
Air, Boeing 734/735, 950km	65	0.60	158	51	465	331	0.5	14	20

Source: Andersen (2001, tables 3, 5, 12, and 13) and Aasness and Røed Larsen (2003, table 4).

However, even if transportation by car and in the air were more energy intensive and involved more pollution than mass transit by bus, rail, and metro it does not follow that the wedge between private and social costs is wider in the former group than in the latter group. The relative prices could potentially already reflect these aspects. In fact, there is no reason a priori why not the gap could be larger for the latter group. After all, energy is costly so it is likely that this cost is internalized in the price. However, there is growing suspicion that energy-intense modes of transportation still involves additional non-internalized environmental costs that are difficult to measure, such as contributions to global warming. Røed Larsen and Aasness (2003) shed some light in this direction in their Table 5, from which it appears that the gap is larger for the former group when it comes to emissions to air. However, the analysis is not complete, so it must be a maintained hypothesis in this article that the gap between private and social costs is widest for the group that includes modes of transportation that pollute more and use more energy per person kilometer.

Given that assumption, let us explore the main idea behind using one simple indicator, the Engel elasticity, for the distributional impact of indirect taxes. The elasticity summarizes multidimensional data into one scalar that tells us how much the demand for a given commodity increases in a typical household when total consumption increases by 1 percent, given relative prices and keeping demographical composition constant. When an Engel elasticity of a commodity is above unity, an environmental levy on the price of this commodity works progressively since a household's budget share of this good increases with total consumption or income. An indirect tax put on the purchase of this commodity has the implication that the richer households pay more taxes as a percentage of total consumption than do poorer households. Notice that this analysis requires the conventional ceteris paribus assumption, as do all partial analyses of this kind. One consequence of the ceteris paribus assumption is that observers need be careful in interpretations of the scenarios of large levies since the analysis builds on the direction of effects following small, incremental changes.

3. The Parametric Econometric Technique

In order to examine the role played by material standards of living in the demand for travel and transportation, we need to establish an apparatus to estimate Engel curves. Engel curves are associations between the demand for a good (or its budget share) and income or total consumption. My econometric model builds upon the set-up in Aasness, Biørn, Skjerpen (1993) and Aasness and Røed Larsen (2003). Røed Larsen (2002) discusses measurement challenges in this framework and presents a discussion of why it is key to model measurement of latent total consumption. This article uses an instrument variable, income, to overcome challenges posed by measurement errors. Let latent consumption of good i for household h be denoted η_{ih} and total consumption for household h be denoted ξ_h. Let the Engel function that governs the relationship between consumption of good i and total consumption be affine and include demographic variables for size and composition of the household as described in equation (1):

$$(1) \qquad \eta_{ih} = \alpha_i + \beta_i \xi_h + \gamma_i z_h,$$

in which z is a vector of number of children and number of adults. Let y_{ih} denote the observable purchase expenditure on good as given in equation (2), which includes a sum of latent consumption of the good and a measurement error that may result from durability, stock-build-up, seasonality, or data acquisition:

$$(2) \qquad y_{ih} = \eta_{ih} + \varepsilon_{ih},$$

in which ε is a conditionally mean-zero, constant-variance error term. Combining equations (1) and (2), noting that latent consumption ξ_h equals the latent sum $\Sigma_i \eta_{ih}$, and letting manifest total purchase expenditure x_h be equal to the manifest sum of expenditures $\Sigma_i y_{ih}$ (so ξ_h is $x_h - \Sigma_i \varepsilon_{ih}$) we obtain in equation (3) the following regression equation (3):

(3) $$y_{ih} = \alpha_i + \beta_i x_h + \gamma_i z_h + u_{ih},$$

in which x_h is manifest total purchase expenditure and u_{ih} is an aggregate error term comprising ε_{ih}-$\beta_i \Sigma_i \varepsilon_{ih}$. In equation (3), total purchase expenditure, x, is endogenous and correlates with the error u that contains the product of the Engel derivative and the aggregate of measurement errors ε from disaggregated commodities. Thus, I use income as instrumental variable and employ the two-stage-least-squares technique to obtain consistent estimates in the presence of such errors-in-variables.

The estimates of the slope derivative, β, of the demand for a given transportation commodity can be put in relation to the average budget share of that commodity, a ratio that is called an Engel elasticity. If the Engel elasticity is above unity, its budget share will increase with total consumption or income, everything else being equal. We say that the commodity is a luxury. If the Engel elasticity is below unity, its budget share will decrease with total consumption or income, and we call such a commodity a necessity. Notice that in the estimation process we keep relative prices constant, an assumption that is a standard feature of cross-section analyses of households at a given point in time.

4. The Non-Parametric Supplementary Approach

Empirical work of this kind faces many challenges. Observers must deal with measurement errors, outliers, heterogeneity, specification of functional form, restrictions from economic theory, omitted variables, the stochastic nature of estimates, household idiosyncrasy, and variable definition. This article seeks to deal with the most pressing of these challenges by supplementing the parametric errors-in-variables technique with a non-parametric approach.

I do this because it is interesting to examine the consumer behavior represented in the tails of the Engel curves and within certain segments of the population. When total consumption or income is especially small or large, the linear approximation used by Aasness and Røed Larsen (2003) may not capture the Engel relations as well as for the typical consumer. While linear models summarize data in highly interpretable ways, have nice summation-of-elasticities features, and are useful for detecting broad consumer patterns, linear models suppress curvature. This article complements the analysis with a segmented, non-parametric Engel curves, specifically designed to investigate for curvature while controlling for demographic composition of the household.

This approach involves several steps. The first step partitions the sample of households into demographic segments such as single-person households, couples without children, and couples with children. This is done to control for demographic composition before drawing the Engel curve between consumption of the transportation commodity and total consumption. The second step projects endogenous total expenditure, x, onto an instrument space consisting of income. Analysts may then obtain a projected consumption variable, X_P, for each household that is exogenous, which help improve the precision in the investigation of Engel curves between the good's share and consumption, as described in equation (4):

$$(4) \qquad \omega_g = f(X_{hP}, D_h) + \lambda_h, \qquad h \in H,$$

where the classically behaved error term λ is independent of the projected consumption X_P, where D denotes other determinants, and where the ω refers to the good's share of projected consumption. The subscript g refers to good, here items within the transportation category. Thus, projecting total expenditure onto the instrument space allows us to explore the relationship in equation (4) non-parametrically by choosing appropriate smoothing parameters. We use the local regression method that fits a linear weighted regression line in a local neighborhood around each X_{hP}. The neighborhood is chosen so that it contains an appropriate number of observations. These neighbor observations are weighted by a decreasing function of their distance to the center X_{hP}. The weights assigned to an observation X_{iP} around X_{hP}, for which the local line is fit, are given by equation (5) and (6):

$$(5) \qquad W(X_{jP}, X_{hP}, b_j) = K_0(t) = K_0\left(\frac{X_{jP} - X_{hP}}{b_j}\right), \qquad j \in J, h \in H, t \in \Re,$$

where X_{jP} is member of the bandwidth set around X_{hP}, where b_j specifies the range of bandwidth, where K_0 is a weighting function, and t its argument. The set J of households is a subset of the sample of household, H. In local regression, the bandwidth specifies the percentage of all (nearest) observations in H that are included in J for each computation mid-point. This article uses the Tri-Cube function for K_0:

$$(6) \qquad K_0(t) = \begin{cases} (1 - |t|^3)^3, \textit{for } |t| \leq 1, \\ 0, \textit{otherwise.} \end{cases}$$

This approach allows us to draw an Engel curve that reveals the association between the consumption of a transportation commodity and total consumption without parametric assumptions on the curvature.

5. Empirical Results

This article finds consumer patterns in the demand for travel and transportation: Consumers appear to view air flights, purchases of new cars, and leisure travel as luxury commodities. They are consumed with increasing frequency and quantity as material standards of living increase. Gasoline, purchases of used cars, and local public transportation on mass transits such as buses, trains, and metro are found to be necessary commodities of transportation, and are thus decreasingly consumed by households with higher standards of living.

Table 2 shows estimation results of the two-stage-least-square (2SLS) regression of selected modes of transportation on total expenditure, number of children, and number of adults, using income as instrument. Table 3 computes the Engel elasticity[1] for selected modes, classifies transportation modes as necessary or luxury ones, and presents budget shares. From Table 2, we first notice that the aggregate good Total Transportation has an Engel derivative of 0.152. Thus, the typical household, given composition and size, uses 15 cents of an extra dollar on transportation, which is somewhat smaller than the budget share at 21 percent. This makes transportation a necessary commodity with an associated Engel elasticity below unity at 0.74, shown in Table 3. Thus, when total consumption increases 1 percent, consumption of transportation increases 0.74 percent. At first an elasticity below unity is somewhat surprising, however, we realize that transportation is an aggregate commodity that includes as diverse means of relocation as local bus rides and air flights. For environmental economists and policymakers it is useful to disaggregate this commodity since both distributional and environmental qualities are so different over the different modes of transportation.

For example, we see that for air flight trips and the larger group (that contains air flight trips) consisting of intercity travel the elasticity is much above unity, nearly 1.7. This means that when total expenditure increases 1 percent, purchases of air flights increase almost 1.7 percent. Since air flights are extremely energy-intensive, this estimate contains environmentally valuable forecasting content. In local transportation, it appears that richer households choose expensive cars and gasoline while poorer households choose inexpensive cars or used cars and gasoline or local public transportation in mass

[1] The Engel elasticity is computed by dividing the estimated Engel derivative with the average budget share.

transit. Mass transit has an elasticity of 0.87, clearly below unity, reflecting the fact that as households become richer, they tend to choose other means of transportation.

Leisure travel is a luxury commodity. A typical household, controlling for composition and size, uses as much as 3.2 cents of an extra dollar on travel, higher than the budget share of 2.0 percent. This entails an Engel elasticity above unity, at 1.57. In other words, when total expenditures increase 1 percent, leisure travel expenditures increase 1.57 percent. Thus, the consumption of travel for leisure rises faster than material standards of living, and an increasing share of total expenses are devoted to such consumption. For environmentalists, this elasticity of 1.57 is especially interesting as it uncovers -- given relative prices -- an increasing tendency to move around for leisure purposes. This brings empirical evidence to the on-going debate on the sustainability of energy-intensive leisure activities. It seems as if the ecological footprints of a society in a travel mode will rise in number.

Demographics matter. When a household adds another member, given total expenditures, two effects occur. First, since the household then becomes larger, its consumption needs to expand. Second, keeping total expenditures constant, the average consumption available to each member decreases since total expenditures divided by size falls. In other words, the material standard available for each household member decreases. How the household balances the two effects can be found by inspecting the two right-most columns of Table 2. We observe that when we control for total expenditure and number of adults, an increase in the number of children is associated with a decrease in transportation expenditure of magnitude 67 dollars. In contrast, when we control for total expenditure and number of children, an increase in the number of adults is associated with an increase in transportation expenditures of magnitude 1440 dollars. These estimates offer a possibility to get a glance into intra-household dynamics since the effects arise from complicated solutions within households to the different needs of households of different sizes and compositions. The picture of demographic effects is slightly different for leisure travel. Both the partial effect of increasing number of children and number of adults result in less monetary outlays devoted to travel. These negative estimates on the partial effects of household membership may easily be interpreted, since an increase in size, given total expenditure, makes a household poorer in the sense that the household may offer less consumption per head. Since leisure travel is a luxury commodity, households reduce the expenditures on it when they experience reduced material standard available per member.

Table 2. Parameter Estimates (t-values) of 2SLS Regression on Total Purchase Expenditure, No. of Children, and No. of Adults, 2000, 5 Quarters (Including 1st quarter 2001)

Mode of Transportation	Total Purchase Expenditure	No. of Childr.	No. of Adults	Adjusted R^2
Total Transportation	0.152 (27.4)	-67.3 (-0.86)	1440.0 (12.9)	0.0894
Cars and Trucks, new	0.0506 (11.1)	-222.7 (-3.4)	247.5 (2.7)	0.0112
Cars and Trucks, used	0.0114 (3.0)	230.5 (4.2)	653.3 (8.4)	0.0104
Gasoline and motor oil	0.0169 (34.7)	73.7 (10.7)	295.7 (30.0)	0.2160
Vehicle Finance	0.00610 (18.1)	26.8 (5.6)	77.8 (11.4)	0.0564
Maintenance and Repairs	0.0118 (20.6)	2.23 (0.3)	73.4 (6.3)	0.0449
Vehicle Insurance	0.0126 (26.0)	-32.6 (-4.8)	203.6 (20.9)	0.1088
Vehicle Rental, Leases	0.0223 (27.4)	-42.9 (-3.7)	-45.9 (-2.8)	0.0494
Public Transportation	0.0180 (23.1)	-101.6 (-9.2)	-56.3 (-3.6)	0.0339
of which a) Public Transportation on Trips	0.0164 (21.5)	-101.9 (-9.4)	-57.8 (-3.8)	0.0295
b) Local Public Transportation	0.00156 (10.6)	0.341 (0.2)	1.59 (0.5)	0.0093
Travel	0.0321 (34.0)	-139.3 (-10.5)	-70.8 (-3.7)	0.0722
Trip, gas and oil	0.00220 (22.2)	-9.83 (-7.0)	-3.3 (-1.6)	0.0328
Trip, vehicle rental, fees, tolls	0.00231 (22.1)	-10.0 (-6.8)	-12.0 (-5.7)	0.0292
Trip, car/truck, rental	0.00197 (19.7)	-8.58 (-6.0)	-9.45 (-4.7)	0.0233
Trip, other expenses A(tolls etc)	0.00033 (20.4)	-1.28 (-5.6)	-2.34 (-7.2)	0.0240
Trip, air	0.0122 (20.6)	-67.1 (-8.0)	-42.7 (-3.6)	0.0268
Trip, bus, train, ship	0.00334 (14.7)	-28.6 (-8.9)	-10.7 (-2.3)	0.0150
Trip, local: taxi, bus etc.	0.000871 (15.9)	-6.25 (-8.0)	-4.37 (-3.9)	0.0161
Trip, RV, campers, boats	0.000118 (3.6)	-0.664 (-1.4)	-0.956 (-1.4)	0.0006

Note: Regression: 2sls. Mode of transportation on a constant term (unreported), total expenditure, number of children, and number of adults in household. Endogenous: total expenditure. Instruments: income before taxes, number of children, number of adults. Most recent figure for household income used. No weights used in regression. 17018 observations used.

Table 3. Marginal Use of One Extra Dollar and Mean Expenditure, Share of Budget, and Engel Elasticity, Selected Modes of Transportation, 2000, 5 Quarters (1st q. of 2001 included)

Mode of Transportation	Use of One Extra Dollar, in Cents	Mean Expenditure, in Dollars	Budget Share	Engel Elasticity
Total Transportation	15.2	7132	20.7%	0.74
Luxury Goods of Transportation				
Purchase of Cars and Trucks, new	5.06	1565	4.54%	1.12
Vehicle Rental, Leases	2.23	523	1.52%	1.47
Out-of-Town Public Transportation on Trips, including Air Flights, Intercity Bus/Train	1.64	341	0.99%	1.66
Necessary Goods of Transportation				
Cars and Trucks, used	1.14	1699	4.93%	0.23
Gasoline and motor oil	1.69	1237	3.59%	0.47
Vehicle Finance	0.61	323	0.94%	0.65
Maintenance and Repairs	1.18	578	1.68%	0.70
Vehicle Insurance	1.26	764	2.21%	0.57
Local Public Transportation, including Mass Transit	0.16	62	0.18%	0.87
Leisure Travel				
Leisure Travel	3.21	703	2.04%	1.57
Trip, gas and oil	0.22	83.5	0.24%	0.91
Trip, vehicle rental, fees, tolls	0.23	38.7	0.11%	2.06
Trip, car/truck, rental	0.20	31.7	0.09%	2.14
Trip, other expenses (tolls etc)	0.03	6.8	0.02%	1.67
Trip, air	1.22	258	0.75%	1.63
Trip, bus, train, ship	0.33	65	0.19%	1.77
Trip, local: taxi, bus etc.	0.09	17.8	0.05%	1.69
Trip, RV, campers, boats	0.01	1.97	0.01%	2.07

Interesting patterns arise when we investigate the different modes of transportation in detail. Notably, the purchase of new cars is a luxury item with an elasticity of 1.12, but the purchase of used cars is a necessity with an estimated elasticity much below unity. The richer you are, the more money you spend on new cars. Not only do richer households spend more, but the percentage increase on new cars is larger than the percentage increase in total consumption or income. In comparison, local public transportation on mass transits is clearly a necessary good. This yields insights into how local transportation needs are solved among richer and poorer. The poorer you are, the more mass transits you tend to use, everything else being equal. The richer you are, the more likely you are to put much money into new cars. However, while car purchase is a luxury, gasoline is not. It has a very low Engel elasticity at 0.47. This discrepancy between new cars and gasoline, which are complementary goods, requires careful comment.

The high Engel elasticity of new automobiles is no surprise. In modern society, a car is not only a mode of transportation, but it is also a status signal, an ingredient in a life-style, and reflects group-identity. Aasness and Røed Larsen find that for cars the Norwegian Engel elasticity is 1.60, making it a highly luxurious commodity. Not only is the American car purchase elasticities lower than the Norwegian one, the American elasticity of gasoline, at 0.47, is much lower than the Norwegian one of 0.7. These accentuated results may reflect American distributional features in general, but also the availability of transport substitutes. In America, you need a car to get around, and this fact secures it the status as a necessary good of transportation. In the United States, the package of gasoline and a cheap, used car constitutes an entrance ticket for relocation, whereas in Norway consumers may have access to a well-developed infrastructure of public transportation in trains, metro, and local buses. Thus, poorer households or households that do not need a car for coordination and logistical purposes, may in Norway easily find other means.

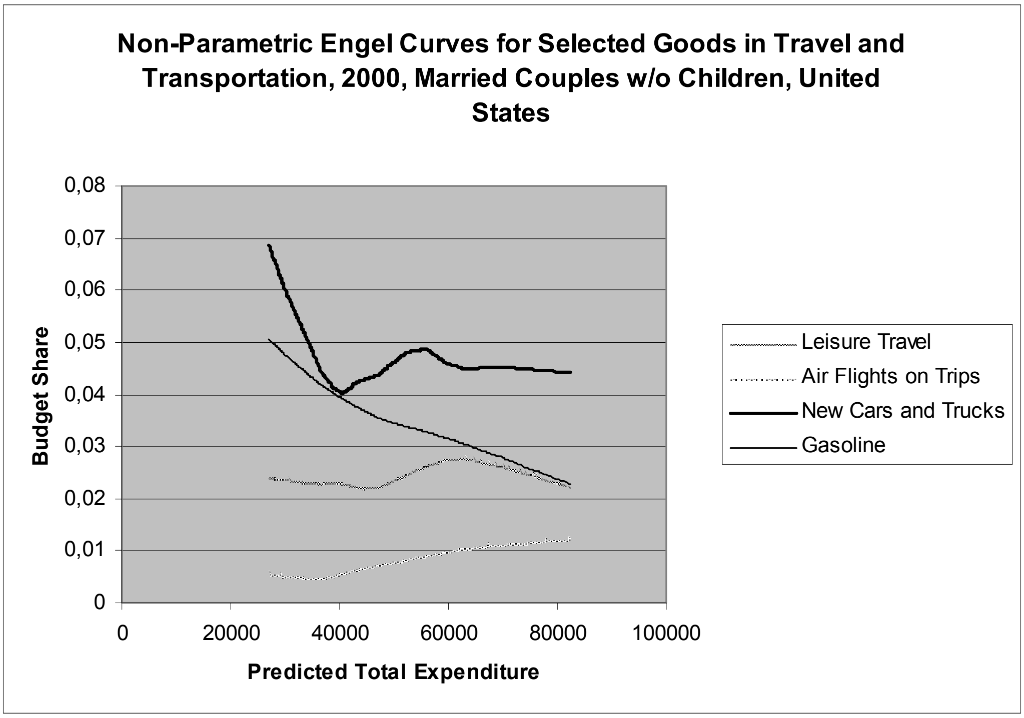
The challenges demographic composition pose to a household is interestingly reflected in the estimates of the demographic effects on the purchase of gasoline. Comparing two typical households with the same total expenditures, the household with one more child spends 73 dollars more on gas. The household with one more adult spends 296 dollars more. This can for example come from the fact that multiple-person households use cars to coordinate tasks such as driving children to school and each other to work. So the balance among the two effects of increased membership, higher demand and lower standards per member, tips towards the former when it comes to gasoline. More members lower standards per member given total expenditure, but the needs for getting around more than compensates for this effect, and the result is increased consumption of gasoline.

Overall, the impression from Norway documented by Aasness and Røed Larsen seems to hold for the United States: new cars, air flights, and leisure travel are transport commodities associated with higher standards of living whereas mass transits and gasoline are necessities.

Figures 1-3 depict the computed non-parametric Engel curves for three types of households: married middle-age couples without children, married middle-age couples with two children, and singles 30 to 50 years of age. We notice that the budget share for gasoline falls with predicted total expenditure for all three types. This supports the clear finding from the parametric, linear model above that yields a very low Engel elasticity. Households with high material standard of living dedicate a small share of budgets on gasoline, clearly making it a necessary good. Air flights are opposite. For all types the budget share devoted to flights increases with predicted total expenditure. As material standard of living increases, so does the budget share for flights. Thus, households' purchasing patterns make this a luxury.

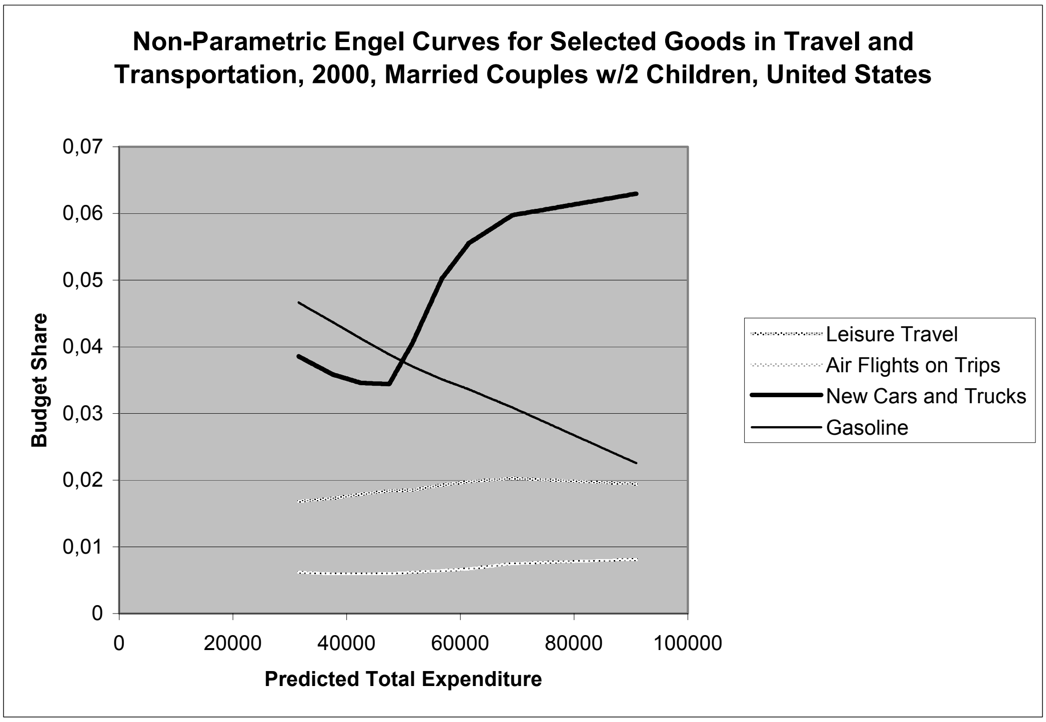
Leisure travel seems to follow the luxury pattern, although the Engel curve for married couples without children is somewhat opaque. It appears to be fairly horizontal. The good with most divergent results over types is purchase of new cars and trucks. Married couples with children behave as if this was a luxury item, while singles treat it as a necessity. Married couples without children of low material standards behave as if it was a necessity, while those households that enjoy higher material standards treat it neutrally. This finding probably reflects several facts. First, it is an infrequently purchased good so the non-parametric approach may contain some imprecision. Second, as is discussed above, automobiles represent more than a means of transportation in modern society. It is a symbol of status and a mirror of wallets. Thus, for certain sub-segments this effect dominates the transportation features. Singles appear to solve this by fulfilling status-signaling desires and by satisfying transportation needs differently from other types.

Figure 1. Non-Parametric Engel Curves in Travel and Transportation, Year 2000, Married Couples without Children, United States



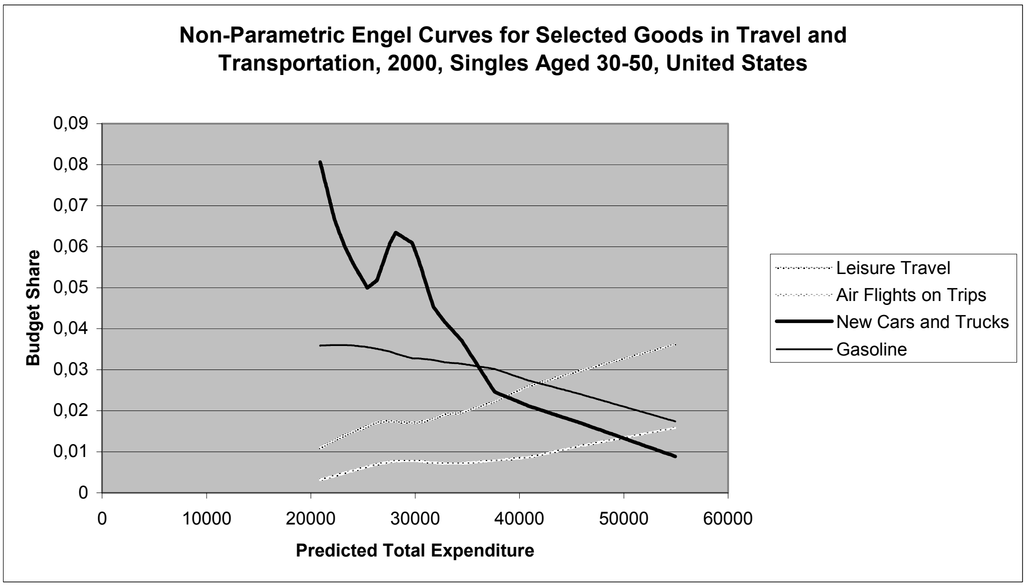
Note: Married couples without children, all races, reference person aged 30-60, income in interval [20000.01,149999.99], Adjusted R^2 for Linear Projection of Total Expenditure on Income before Taxes: 0.263. T-value for income coefficient in that regression: 19.4. Number of observations: 1012. Smoothing parameter in non-parametric regressions: 0.60.

Figure 2. Non-Parametric Engel Curves in Travel and Transportation, Year 2000, Married Couples with 2 Children, United States



Note: Married couples with 2 children, all races, reference person aged 25-55, income in interval [20000.01,149999.99], Adjusted R^2 for Linear Projection of Total Expenditure on Income before Taxes: 0.245. T-value for income coefficient in that regression: 19.0. Number of observations: 1105. Smoothing parameter in non-parametric regressions: 0.80.

Figure 3. Non-Parametric Engel Curves in Travel and Transportation, Year 2000, Single-person Households, Age 30-50, United States



Note: Singles, all races, aged 30-50, income in interval [20000.01,99999.99], Adjusted R^2 for Linear Projection of Total Expenditure on Income before Taxes: 0.190. T-value for income coefficient in that regression: 13.2. Number of observations: 740. Smoothing parameter in non-parametric regressions: 0.60.

6. Concluding Remarks and Policy Implications

Estimated consumer patterns in choices of transportation in the United States for the year 2000 show that there is a strong association between material standards of living and preferred mode of transportation. Households with higher material standard of living prefer to fly, to purchase expensive cars, and to enjoy leisure travel. Households with lower material standards of living tend to choose local public transportation in the form of mass transit. They spend a disproportionate large share of budgets on gasoline. These findings have several policy implications. First, households with lower material standard of living may imitate households with high material standard of living. Thus, the consumer patterns found in richer households may contain forecasting potential for how poorer households may consume in the future. As society grows richer and societies around the world develop, it is likely that households want to spend a higher proportion of their budgets on flights, cars, and leisure travel. Since land is scarce this may involve congestion and conflicts over use of land. Additionally, it raises sustainability concerns since such transportation and travel involves pollution and requires much energy.

Second, the luxury items chosen by richer households also seem to pollute more and involve more energy-consumption per person-kilometer. The necessary goods chosen by poorer households seem to pollute less and involve less energy-consumption per person-kilometer. These two empirical findings may be combined to analyse distributional effects of Pigou taxes, given the additional assumption that the wedge between private and social costs is wider the more pollution is involved. Environmental levies introduced in the form of a system of differentiated indirect taxes that aims to correct for externalities by closing the gap between private and social costs, will then function as an indirect progressive taxation system. An indirect tax put on the purchase of this commodity has the implication that the richer households pay more taxes as a percentage of total consumption than do poorer households. Thus, this article shows that there is not necessarily a trade-off between efficiency and equity when it comes to environmental taxes on modes of transportation. This result may seem surprising to some. For example, Bye, Kverndokk, and Rosendahl (2002) survey top-down analyses of carbon abatement mitigation costs and find that distributional effects are mostly regressive.

Evidence from a non-parametric approach supports most of the findings in the condensed, parsimonious linear errors-in-variables model. However, it uncovers differences among household types in choices made for purchasing cars. Singles behave as if cars were a necessity, and the budget share falls with material standards of income. Married couples with two children, on the other hand, appear to treat cars as if cars were luxury items. This divergence hints at interesting, uncovered ground of dynamics in the interaction of multipurpose goods. Cars are both important symbols of status and group identity at the same time as they serve as vehicles of transportation needs.

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Consumer Expenditure Data

This article uses consumer expenditure survey (CES) data obtained for the United States by the Bureau of Labor Statistics (BLS) as described in U. S. Dept. of Labor, Bureau of Labor Statistics (2002) (documentation available online at http://www.bls.gov) for the four quarters of 2000 and the first quarter of 2001, and makes use of the interview component of the CES system. The data were downloaded from the ICPSR-site at the University of Michigan, Ann Arbor (available online at http://www.icpsr.umich.edu).

The interview component of the CES-system collects data on major items of expense, household characteristics, and income in a continuous flow of surveys. Each consumer unit is interviewed every three months over a 15-month period, and it is estimated that the interview cover 90 to 95 percent of expenditures. Each quarter sample is designed to be representative of the United States population. The results in this article are based on the reports from the 5-quarter period starting with January 2000 and ending with March 2001. Because of the rotating sampling scheme, some households report more often than others. BLS derives corrective weights that restore population properties, and this article uses such weights in the computations of the variable means.

Reported expenditures for all reporting households are transformed to an annual basis by dividing by number of reporting months and multiplying by 12. The fewest number of reporting months used by an observed household is 3. In the two-stage-least-square estimation process this article uses income as instrument variable. When several observations occur on this variable, FINCBTAX (income before taxes) for a given household, I use the newest available data in the reports. For the computation of means in the denominator of the Engel elasticity, I use corrective weights supplied in the data set from the Bureau of Labor Statistics, constructed to calibrate demographic composition for different sampling probabilities. Notice that children are defined as household members below 18 years of age.

In total, 17018 households were used, after omitting 799 households due to missing values.

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