Estimating individual driving distance by car and public transport use in Sweden

OLOF JOHANSSON-STENMAN
Department of Economics, Göteborg University, Box 640, SE-40530 Göteborg, Sweden.
Fax: 46 31 7731326, Phone: 46 31 7732538, E-mail: Olof.Johansson@economics.gu.se

Abstract: How much to drive, and how much to use public transport, are modelled as three- and two level decisions, respectively, based on micro-data for Sweden. The choices whether to have a car, whether to drive given access to a car, and how much to drive given that the individual drives at all are then estimated using a three equation model. Also after correcting for other variables, such as income, men are driving much more, and using less public transport, compared to women. People living in big cities are less likely to drive, but those who do are on average driving about as much as others. Age and access to company-cars are also important determinants for travel behaviour, but being a member of an environmental organisation is not. Driving increases with income, but to a lower degree compared to most aggregated studies on national level. The difference is explained in a simple model with income-dependent structural changes, implying that it becomes more difficult to live without a car when average income increases. This indirect effect is found to be of a similar size as the ordinary income elasticity typically found in cross-section analysis within a country or region.

***Proposed running title*:** Driving and public-transport use in Sweden

***Keywords*:** Transport demand, car ownership, car use, driving, public transport demand, multi-level decisions, social context, gender and transport.
***JEL-classification*:** R41

I. Introduction

The aim of this paper is to estimate both individual (as opposed to household) annual driving-distance by car and the annual number of public-transport trips, as functions of explanatory variables such as income, age, sex etc. In the driving-distance case, the travel choice is modelled as a three-level decision.[1] The first decision is whether to have a car or not, the second whether to drive or not given that the household has a car, and the third is how much to drive given that the individual drives at all. For public transport, the first decision is whether to use public transport at all, and the second decision is how much to travel given a positive public-transport use.

It is of interest to know the determinants of individual travel behaviour for several reasons. First, from a policy perspective it is important to know the consequences of various measures. For example, proposed increases of fuel taxes, or other transport-related taxes or charges, are almost always followed by distributional discussions, both regarding income groups and regions. Second, they may be of interest from a gender and age perspective; and third, it is interesting to see whether or not attitudes towards the environment matter for actual travel behaviour.

This study is based on data from the Household Market and Nonmarket Activities (HUS) survey, which includes a representative Swedish sample of 3240 individuals (adults) in 1922 households, conducted in 1996. The survey consists of two parts: A panel survey, addressed to respondents who have been interviewed before, and a supplementary survey addressed to young people in the households who were born between 1975 and 1977, as well as certain new household members who had not previously been interviewed. For the panel survey (about 95% of the respondents), a combined contact and main interview was conducted by telephone, after which a self-enumerated questionnaire was sent out to each respondent by mail. For the supplementary survey, the respondents were not interviewed by telephone until they had been interviewed personally.

Section II provides a descriptive picture of the travel pattern and Section III aims at explaining this pattern by means of econometric analysis. Section IV discusses and tries to explain the large differences found between income elasticites of car use in cross-section analysis *within* a country, on the one hand, and cross-section *between* countries or time-series analysis on the other. Section V summarises and provides some concluding remarks for policy.

II. DESCRIBING THE TRAVEL PATTERN

Annual Private Driving Distance

3065 individuals, or about 95% of the total sample, answered the driving-distance question. Table 1 reports the annual driving-distance for the whole sample, as well as for various sub-samples divided on men and women; big cities, intermediate cities and other areas;[2] whether the household has access to a car or not; whether the individual is driving or not; and whether the household has access to a so called company-car or not.

We see that men have a very much larger mean driving-distance than women, and that this difference depends both on the mean driving-distance for those who drive and on a larger fraction of non-drivers among women, which is consistent with earlier research such as Polk (1998). We also see that the driving-distance is consistently larger in all sub-groups for those who have access to a so called company-car, i.e., a car which is paid by the firm and for which the driver has virtually zero marginal cost on private trips.[3] The fraction of non-drivers is larger in big cities, but the mean driving-distance for drivers is about the same as for those living in the countryside and in smaller cities.

[Table 1 about here]

Public-transport Use

3134 individuals, or about 97% of the total sample, answered the public-transport question. Table 2 reports the annual number of trips (weekly number of trips on average, multiplied by 50) for the whole sample, as well as for various sub-samples.

[Table 2 about here]

We see that as much as 72% report no public-transport trips per week. Women tend to use public transport to a larger degree, but men tend to make slightly more trips on average if they use public transport at all. Furthermore, availability of a private car consistently decreases the mean number of public-transport trips, which is expected. As is also expected, a larger fraction of people uses public transport in big cities, where such transport is more readily available. However, for those who actually use public transport, the number of trips per time unit is about the same on average in all sub-groups.

III. ECONOMETRIC ANALYSIS

Many of the questionnaires were incomplete, primarily due to incomplete responses on income. Therefore, the econometric estimations include only 2504 responses out of 3240 in the whole sample. However, using a standard t-test we cannot reject the hypothesis of equal means in the smaller sample and the whole sample, for either the annual driving-distance or the annual number of public-transport trips.

Econometric Models

The dependent variables, driving-distance and public-transport use, are censored since they are zero for a large fraction of the observations; hence, a basic ordinary least square (OLS) regression would be biased. The most commonly used model to deal with this problem is perhaps still the standard one-equation Tobit (type 1) model. However, this model is very restrictive, for example since it is based on the assumption that the choice whether to drive or not is explained by the same variables, and in relative terms to the same extent, as how much to drive. But whether to have a car or not is a quite different decision, compared to the decision how much to drive given that you have a car. Therefore, two- and three equation models, where the decision processes are modelled separately, are more appropriate.

The first specification used is that of Cragg (1971), where the probability of a zero observation is assumed to be independent of the regression model for the positive observations. Therefore, in the driving-distance case, the three decisions – whether to have a car or not, whether to drive or not given a car, and how much to drive given a driving-distance larger than zero – are estimated separately. In the public-transport case, the two decisions – whether to use public transport or not, and how many trips to make given a positive use of public transport – are estimated separately. The selection equation, concerning whether to travel or not, is estimated by a Probit model and given by:

$$d^{*} = x'?+u \qquad (1)$$

where x' is the vector of independent variables, $?$ is the associated parameter vector to be estimated, and u is the error term. Only the sign of d^* is observed, and in our case d^* is either zero or positive. The structural equation, how much to travel, is a truncated regression model estimated by maximum likelihood:

$$Q^* = x'ß + e \tag{2}$$

where $Q = 0$ if $d^* = 0$; $Q = Q^*$ if $d^* = 1$. The expected number of trips, given a positive number, is given by

$$E[Q \mid Q > 0] = [x'ß + s\,?(x'ß / s)] \tag{3}$$

where $?(z) = \dfrac{f(z)}{F(z)}$ is Mill's ratio, where $F(z)$ and $f(z)$ are the standard normal distribution function and the standard normal density function, respectively. In the driving-distance case, we have instead two independent Probit equations followed by the truncated regression based on the observations with a positive driving-distance.

The assumption of independence can be questioned, however. Assume for example that both the probability of an annual driving-distance larger than zero (given a car), and the actual distance driven (given a positive driving-distance), depend positively on income (which is reasonable). The second (structural) effect can then be assumed to depend negatively on the first effect, since one may assume that individuals who change from zero to a positive driving-distance would drive less (on average) than those who had been driving all the time. This would be the result if the error terms e and μ were positively correlated. It is not equally clear why the first two Probit stages would be correlated, however.

In the public-transport case, the expected sign from income in the second stage is not obvious, since higher income will both allow more trips but it will also allow a switch to more expensive modes (e.g. by private car). Still, at least for the purpose of comparison, we will assume (or test for) a correlation between the error terms also in the public-transport case.

The other sequenced model estimated is therefore a Tobit type 2 model (Amemiya 1981), where a covariance parameter $?$ between the error terms u and e is estimated. Then we have a selection equation

$$d^* = x'? + u \tag{4}$$

and a structural equation

$$Q^{*} = x'ß + e \tag{5}$$

where again $Q = 0$ if $d^{*} = 0$ and $Q = Q^{*}$ if $d^{*} > 0$. A covariance parameter between the error terms is estimated

$$Cov[e,u] = ? \tag{6}$$

implying that the expected number of trips, given a positive number, is given by:

$$E[Q \mid Q > 0] = [x'ß + ?s\,?(x'?)] = [x'ß + ß_{?}\,?(x'?)] \tag{7}$$

This model is estimated using Heckman’s (1979) two-step estimation procedure, where the selection equation (the Probit) is estimated by maximum likelihood and the structural equation is estimated by ordinary least squares. In the driving-distance case, we first estimate a Probit for having a car in the household or not, and then independently, given a car, estimate a Tobit 2 for the driving-distance decisions. The Tobit 2 model would collapse to the Cragg model for $? = 0$, if we disregard the fact that the second step in the Cragg is estimated by a truncated regression.[4]

Estimating Annual Driving Distance

Table 3 reports the estimated marginal effects for the models discussed.

[Table 3 about here]

The Lambda-coefficient for Tobit 2 has the expected sign but is insignificant and we can consequently not reject the Cragg model. However, this does not necessarily imply that the “true” model is close to a Cragg specification, or that the correlation between the error terms in the two steps is unimportant, since the Probit stage explained the selection somewhat poorly, which is unfortunately quite common with this type of models. (The goodness of fit for the Probit equation is relatively low, with a likelihood ratio index of 0.13.)

Starting with the choice whether to have a car or not in the household we find that the marginal effect (of variables in log-form) associated with household income is positive and significant as expected. A one percent increase in household income (per equivalent adult) would increase the probability of having a car by about 0.034%.[5] We see that having a partner with income *per se* seems generally more important for this choice. The probability increases further with the number of children, which seems reasonable even though the disposable income per person normally decreases with the number of children. The probability increases with age but decreases with age squared, implying a maximum probability at about 45 years (0.0033/(2*.000037)=45).

For single adult households, men have a larger probability than women of having a car. The probability is significantly lower in big and intermediate cities but independent of education. The choice to drive or not, given a car in the household, follows a similar pattern. This choice, however, is at least partly an individual choice, for which it is intuitively possible that also *individual* income (and not only household income) could be important. Indeed, in this study it is found that *only* the individual income matter for the choice whether to drive or not. The probability with respect to age reaches again its maximum at about 45 years. Living in big cities decreases this probability, but having access to a company-car increases it.

The reported marginal effects, and their corresponding t-values, for the Cragg and Tobit 2 models have the same interpretation, and the differences between them are generally quite small. The reported marginal effect with respect to income can be interpreted as elasticities for dependent variables in log form, evaluated at sample mean, i.e. at the mean of the log of driving-distance. For example, a one percent increase in after-tax income, holding the income of a possible partner constant, would imply an expected increase in driving-distance by about 0.3% in the Tobit 2 case. A corresponding increase of the partner's income would be expected to increase the driving-distance by only slightly more than 0.02%. If income increases by one percent for both of them we would have the sum of these effects on driving. Hence, we see that for an individual's own driving-distance it is again the individual income, rather than the household income, that matters. For a dummy variable, such as sex, we have that men have about 70% longer driving-distance, given that the person drives at all. The pattern with regards to age is the same here as well, and the effects of living in cities are insignificant. Having a company-car increases the expected driving-distance by about 50%.

Being a member of an environmental organization implies no significant effects on either the choice of having a car, or whether to drive or how long to drive. If anything, there may be a small positive effect on the choice to drive given a car. This may seem surprising since these organizations often argue forcefully in favor of various measures to reduce private car use.

The income-elasticity of driving

In order to obtain the overall income-elasticity of the expected driving-distance we simply differentiate the log of the expected Q with respect to the log of income; cf. McDonald and Moffitt (1980). It follows that:

$$E[Q] = \Pr[Car > 0]\Pr[Q > 0 \mid Car > 0]E[Q \mid Q > 0] \tag{8}$$

and hence that the income-elasticity is given by:

$$\begin{aligned}
&\frac{\partial \ln E[Q]}{\partial \ln y} = \frac{\partial \ln[\Pr[Car > 0]\Pr[Q > 0 \mid Car > 0]E[Q \mid Q > 0]]}{\partial \ln y} \\
&= \frac{\partial \ln(\Pr[Car > 0])}{\partial \ln y} + \frac{\partial \ln(\Pr[Q > 0 \mid Car > 0])}{\partial \ln y} + \frac{\partial \ln(E[Q \mid Q > 0])}{\partial \ln y} \\
&= \frac{\partial \Pr[Car > 0]}{\partial \ln y} \Big/ \Pr[Car > 0] + \frac{\partial \Pr[Q > 0 \mid Car > 0]]}{\partial \ln y} \Big/ \Pr[Q > 0 \mid Car > 0] \\
&+ \frac{\partial \ln(E[Q \mid Q > 0])}{\partial \ln y}
\end{aligned} \tag{9}$$

Note that the last term in (9) is not strictly identical to the reported marginal effects in table 3, which are instead given by $\frac{\partial E[\ln Q \mid Q > 0]}{\partial \ln y}$.[6] Still, assuming that $E[\ln Q \mid Q > 0] \approx \ln E[Q \mid Q > 0]$ we get in the Tobit 2 case the overall income-elasticity for a change in income of both the individual and the partner as 0.038/0.85+(0.090-0.0061)/0.89+0.295+0.023 = 0.46 < 1.[7] Hence, although car driving increases with income, the ratio between driving-distance and income decreases strongly with income.

Estimating Annual Number of Public-transport Trips

Table 4 reports the estimated marginal effects for the econometric models discussed.

[Table 4 about here]

We see generally that the Probit stage seems to be explained better than the subsequent conditional stages, and in the Tobit 2 case all marginal effects are insignificant. This is not very surprising given the data presented in table 2, where the mean value of the annul number of public-transport trips, given a positive use, were almost constant for different sub-groups. The probability of using public transport decreases with own income but increases slightly with the partner's income. The latter effect, however, is smaller and insignificant. This follows a similar pattern as with driving-distance, where both the probability of driving (given a car) and the annual driving-distance, depend stronger on own income than on the partner's income. Hence, it seems that in relations where income differ, the one with a larger income has a larger probability of using the car, and the one with lower income has a larger probability of using public transport. (Note that we have corrected for the fact that men drive more than women per se). Children seem to affect the likelihood negatively, which is reasonable. Age follows an inverted pattern compared to the driving-distance case, with a minimum probability of using public transport at about the age of 55. Being highly educated, woman, and living in a big city increases the probability of using public transport. The latter is of course largely a result of a larger public-transport supply in big cities compared to smaller cities and the countryside. Having access to a car decreases the probability, which is also expected (Golob, 1989).

Focusing on how many trips to make, given a positive use, we see from the Cragg estimation that the conditional income-elasticity is negative, both with regard to own income and the partner's income, which is not obvious. The number of trips to make reaches a maximum at about the age of 28-30, and living in a big city also affects the amount of trips positively. The Lambda-coefficient is insignificant in the public transport case too, which is not surprising for theoretical reasons.

The income-elasticity of public-transport use

In a similar way as for driving-distance, we can calculate the income-elasticity of the expected number of public-transport trips from table 4. In the Tobit 2 case we have that the income-elasticity is given by (-0.037+0.014)/0.28-0.058-0.068 = -0.21. In this calculation the number of cars is treated as given. If we instead take the indirect effect from the fact that the number of households with access to a car will increase we should add a term given by –0.203/0.28*0.038/0.85 = -0.03. The overall income-elasticity, taking the indirect effect of cars into account for the Cragg and Tobit 2 estimations, are then equal to about –0.25. This result should be used with care, however, since the statistical significance of some factors is rather poor.

IV. MICRO VERSUS MACRO STUDIES OF CAR USE

The income elasticities in this study are of the same order of magnitude as in other comparable disaggregated studies based on micro-data. De Jong (1990) found an overall income elasticity of private mileage equal to 0.63 for Holland, where about 50% were due to effects of car ownership. De Jong (1997) found again a similar result for Holland but also a car-use income elasticity of 0.38 for Norway, and Bjorner (1997) obtained a car-use income elasticity of 0.42 for Denmark. Pearman and Button (1976) reported a car ownership income elasticity of about 0.3 for the UK.

It is interesting to compare these income elasticites with studies based on aggregated data on national level, which often find an income elasticity of car use of about unity (or higher). For example, Johansson and Schipper (1997) found income elasticities of about 1.2, where almost all were due to changes in the number of cars, based on both cross-sectional variation and time-series variation for a data-set consisting of 12 OECD countries. Further, gasoline-demand studies often find an income-elasticity of demand larger than unity (see e.g. Dahl and Sterner 1991 or Sterner *et al*. 1992). Since the gasoline-demand income-elasticity is equal to the travel-demand elasticity plus the elasticity of fuel intensity per kilometre driven, and the latter is often rather small (Johansson and Schipper 1997, Dahl 1995), the implicit travel-demand income elasticities are large also in these studies.

Explaining the elasticity differences

A possible explanation for larger income elasticities in aggregated studies may be that structural changes follow from increased income over time. For example, when a large fraction of the population has access to a car, the infrastructure of roads, shops and various institutions adapt, making it more difficult to live without a car. Consider the following simple model to illustrate this: Assume that travel demand Q is a function of private income and infrastructure, we have

$$Q = q(y, S) \tag{10}$$

where S is an index of the (non)accessability of the infrastructure so that $\frac{\partial q}{\partial y} > 0, \frac{\partial q}{\partial S} > 0$. The infrastructure, in turn, is a result of both market forces and political decisions. Consider for example the development of shops. People (naturally) prefer low prices and high accessibility (e.g. shops close to where they live), but there is typically a trade-off between the two since fewer bigger shops in general can manage to have lower prices. In this trade-off, people with cars would generally prefer a situation with lower prices and lower accessibility compared to the preferences of people without cars. Hence, when more people have access to cars and are driving, the more is *S* likely to increase by the basic laws of supply and demand. *S* may also depend directly on income since, for example, higher income tends to imply a higher living area per individual, and hence a more scattered living. Political decisions often go in the same direction, i.e., public planning is (at least to some extent) reflecting individual preferences and tend over time to be more and more adapted to a society with cars, when a larger and larger fraction of the population is driving. Thus, we can write $S = s(Q, y)$ where $\frac{\partial s}{\partial Q} > 0, \frac{\partial s}{\partial y} > 0$. Substituting this into (10) gives

$$Q = q(y, s(Q, y)) \tag{11}$$

Hence, travel demand depends on income directly, and indirectly through changes in the infrastructure. Total implicit differentiation of (11) with respect to income implies

$$\frac{dQ}{dy} = \frac{\partial q}{\partial y} + \frac{\partial q}{\partial S}\frac{\partial s}{\partial Q}\frac{dQ}{dy} + \frac{\partial q}{\partial S}\frac{\partial s}{\partial y} \tag{12}$$

implying the following total marginal effect of travel with respect to income:[8]

$$\frac{dQ}{dy} = \frac{\partial q/\partial y + \partial q/\partial S\ \partial s/\partial y}{1 - \partial q/\partial S\ \partial s/\partial Q} \tag{13}$$

or in elasticity form

$$\begin{aligned} s_y^{tot.} &= \frac{dQ}{dy}\frac{y}{Q} = \frac{\frac{\partial q}{\partial y}\frac{y}{Q} + \frac{\partial q}{\partial S}\frac{\partial s}{\partial y}\frac{y}{Q}}{1 - \frac{\partial q}{\partial S}\frac{\partial s}{\partial Q}} = \frac{s_y^{part.} + s_y^{sy}}{1 - \frac{\partial q}{\partial S}\frac{\partial s}{\partial Q}} \\ &= s_y^{part.} + s_y^{sy} + \frac{\frac{\partial q}{\partial S}\frac{\partial s}{\partial Q}}{1 - \frac{\partial q}{\partial S}\frac{\partial s}{\partial Q}}(s_y^{part.} + s_y^{sy}) = \left(s_y^{part.} + s_y^{sy}\right)(1 + \Omega) = s_y^{part.} + s_y^{s} \end{aligned} \tag{14}$$

In the cross-section case within a country, where everybody has a similar infrastructure (i.e., with a low level of segregation), we are simply measuring $s_y^{part.} \equiv \frac{\partial q}{\partial y}\frac{y}{Q}$, i.e. the partial income elasticity for a fixed infrastructure. But in the case of time-series, or cross-section between countries with different (mean) incomes, we are measuring $s_y^{tot.}$, i.e. the income elasticity including indirect effects trough endogenous infrastructure changes. There are two different effects working in the same direction of increasing the estimated income-elasticity compared to disaggregated analysis within a country. First we have what we may denote the indirect travel demand income elasticity $s_y^{sy} \equiv \frac{\partial q}{\partial S}\frac{\partial s}{\partial y}\frac{y}{Q}$, measuring the percentage change in travel due to a one percent change in income *through the changes in the infrastructure due to this income increase*. Hence, this term is due to infrastructure changes directly through an income increase, and hence not through increased transportation *per se*. The factor $\Omega \equiv \frac{\partial q}{\partial S}\frac{\partial s}{\partial Q}\bigg/\left(1-\frac{\partial q}{\partial S}\frac{\partial s}{\partial Q}\right)$, on the other hand, is due to the fact that the infrastructure changes due to increased transportation, e.g. through an increased number of out-of-town shopping centres and fewer local stores when travelling by car increases. Since the empirical results typically indicate a total income elasticity $s_y^{tot.}$ of about 1, and a partial income elasticity $s_y^{part.}$ of about 0.5, we have that the overall effect due to a changed infrastructure $s_y^s = s_y^{tot.} - s_y^{part.} = s_y^{sy} + \Omega\left(s_y^{part.} + s_y^{sy}\right)$ would correspond to an income elasticity of about $1-0.5=0.5$. The relative importance of income induced (s_y^{sy}) versus travel induced (Ω) changes in infrastructure is still an open question, however.

In addition to direct physical changes there may exist what may be considered to be sociological explanations related to possible evolutions of social norms and conventions. Although often overlooked, these ideas are far from novel in economics (see Mason, 1998). For example, already Adam Smith noted that women in England required better clothing to appear in public without shame than did women in Scotland. In the case of transportation today it may in many countries be considered necessary to have access to a car in order to function normally, and people may be excluded from normal social interaction if they do not; cf. Brekke and Howarth (2000), Galbraith (1991), Sen (1985) and Veblen (1899). Such mechanisms would thus also work in the direction of increasing the income elasticity gap between aggregated and disaggregated studies. More research is clearly needed in this area.

V. CONCLUSIONS

In this paper, annual individual driving-distance by car and number of trips by public transport are analysed. We have seen that even after correcting for other variables, such as income, men are driving considerably more, and using less public transport, compared to women, also in a country like Sweden, which is often considered to have a relatively high degree of gender equality. As one would be inclined to believe, people living in big cities are less likely to drive than people living in the countryside. Hence, the frequent statement that people in the countryside would on average suffer harder from fuel-price increases (and similar measures) seems correct. However, we have also seen that this effect is not as large as is often claimed, and that in fact drivers' mean driving-distance is about the same in city areas as in the countryside.

Driving increases with income similar to other cross-section studies within a country or region, but the elasticity is much lower compared to most aggregated studies on national level. This difference, it is argued, is probably largely due to structural effects and a simple theoretical model is developed to illustrate this. For policy considerations it is of course important which income elasticity to choose. For example, if the purpose is to estimate the distributional effects within a country of a certain policy measure, the lower elasticity (such as the one in this study) should be used. Hence, using an income-elasticity based on aggregate data on a national level would tend to under-estimate possible negative distributional welfare effects. If, on the other hand, the purpose is mainly to forecast the future long-run traffic changes based on various assumptions on income growth, the estimated elasticities in this paper (and similar) offer little help.[9]

Contrary to what is implicitly assumed in many applied studies, we have seen that individual income, and not only household income, is important for explaining transport demand of different modes. It seems that in partner relations where income differ, the one with a larger income has a much larger probability of using the car, and the one with a lower income has a larger probability of using public transport. This indicates that it may sometimes be questionable to see the household as the only relevant economic subject in this type of analysis.

Age is also found to be an important explanatory variable and both the probability of driving and the expected annual driving-distance reach a peak at about the age of 50, whereas the probability of using public transport reaches a minimum at about the same age. Having access to a so called company-car increases the private driving-distance dramatically, which is expected since the marginal cost is then close to zero. Being member of an environmental organisation had no significant effect either on driving or on public-transport use. This indicates that even if the government (or other authorities) would be successful in changing people's attitudes in favour of environmental values, and against private car use, the actual effects in terms of a changed travel pattern may be smaller than anticipated.

ACKNOWLEDGEMENTS

The author has received useful comments from an anonymous referee, and benefited largely from cooperation with Fredrik Carlsson in related research activities. Financial support from the Swedish Transport and Communications Research Board (KFB) is gratefully acknowledged.

REFERENCES

Amemiya, T. (1981) Qualitative response models: A survey, *Journal of Economic Literature* **19**(4), 1483-1536.

Bjorner, T.B. (1997) En okonomisk model for bilejerskab og bilkorsel, *Nationalokonomisk Tidsskrift* **135**(3), 233-50.

Brekke, K.A. and R.B. Howarth (2000) The social contingency of wants – implications for growth and the environment, *Land Economics* (in press).

Cragg, J.G. (1971) Some statistical models for limited dependent variables with application to the demand for durable goods', *Econometrica* **39**(5), 829-44.

Dahl, Carol A. (1995) Demand for transportation fuels: A Survey of demand elasticities and their components, *The Journal of Energy Literature* **1**, 3-27.

Dahl, C.A. and T. Sterner (1991) Analyzing gasoline demand elasticities, A survey, *Energy Economics* **13**, 203-10.

De Jong, G.C. (1990) An indirect utility model of car ownership and private car use, *European Economic Review* **34**(5), 971-85.

De Jong, G.C. (1997) A microeconomic model of the joint decision on car ownership and car use, in P. Stopher and M. Lee-Gosselin *Understanding Travel Behaviour in an Era of Change*, Oxford: Pergamon.

Galbraith, J. K. (1991), *The Affluent Society*, fourth edition, London: Penguin books.

Golob, T. F. (1989) The causal influences of income and car ownership on trip generation mode, *Journal of Transport Economics and Policy* **23**(2), 141-62.

Heckman, J. J. (1979), Sample selection bias as a specification error, *Econometrica* **47**(1), 153-61.

Jansson, J.-O. (1989), Car demand modelling and forecasting: A new approach', *Journal of Transport Economics and Policy* **23**(2), 125-40.

Johansson, O and L. Schipper (1997), Measuring long-run automobile fuel demand; Separate estimations of vehicle stock, mean fuel intensity, and mean annual driving distance, *Journal of Transport Economics and Policy*, **31**(3), 277-92.

Mason, R. (1998) *The Economics of Conspicuous Consumption - Theory and Thought Since 1700*, Cheltenham: Edward Elgar.

McDonald, J.F. and R.A. Moffitt (1980) The uses of Tobit analysis, *Review of Economics and Statistics* **62**(2), 318-21.

Pearman, A.D. and K.J. Button (1976) Regional variations in car ownership, *Applied Economics* **8**(3), 231-33.

Polk, M. (1998) *Gendered Mobility. A Study of Women's and Men's Relations to Automobility in Sweden*, PhD-dissertation, Humanekologiska skrifter no. 17, Department for Interdisciplinary Studies of the Human Conditions, Göteborg University.

Sen, A. K. (1985) *Commodities and Capabilities*, Oxford: North-Holland.

Sterner, T., C. Dahl and M. Franzén (1992) Gasoline tax policy, carbon emissions and the global environment, *Journal of Transport Economics and Policy*, **26**, 109-19.

Veblen, T. (1899), *The Theory of the Leisure Class*, New York: Macmillan.

[1] The author is not aware of any earlier research which has modelled driving, or private transport use, as a three-level decision.

[2] "Big cities" are the three biggest cities in Sweden: Stockholm, Göteborg and Malmö, with surroundings. About 27% of the respondents (and the population) live in big cities, 53% live in "intermediate cities", and the remaining 20% live in "other areas".

[3] The employee must tax for this benefit, however, but their marginal cost is zero for private trips. The system is now (after the survey was made) changed in Sweden and the intention is that individuals should pay their own variable costs for *private* trips. However, it appears that most users have chosen the (still-existent) alternative where their variable costs for private trips are zero.

[4] The difference in result from the case with a standard OLS in the second stage was always negligible, however.

[5] It is likely that very low reported incomes are positively correlated with positive transfers from the central or local government, which we have not been able to measure. Therefore, we included both a dummy variable for individuals with an annual income lower than 20,000 SEK, and a variable equal to the product of the dummy variable and income. Thus, all reported income parameters, and elasticities, are associated with individuals with an annual income higher than 20,000 SEK. (1£ = 13.5 SEK, November 1, 2000.)

[6] In other words, the income elasticity of the expected value of driving is not in general identical to the expected value of the income elasticity.

[7] The alternative would be to calculate them by simulation (using another functional form).

[8] For the expression in (13) to be finite we clearly need that $\partial q / \partial S \, \partial s / \partial Q < 1$. Otherwise the equilibrium would not be stable since a small perturbation in travel quantity would induce infrastructure changes which in turn would increase travel with an amount which is larger or equal to the initial perturbation, and so forth.

[9] In this case it may also be important to take the influence of different age cohorts into account; see for example Jansson (1989).

Table 1. *Annual private driving distance in km*10*

		Mean	Std.	Median	No. zeros	Max	N
Whole sample		1092	1587	1000	25%	20,000	3065
Given household has a car		1222	1637	1000	16%	20,000	2597
Given positive driving distance		1453	1681	1000		20,000	2305
Given a positive driving distance and a company car		2303	1817	2000		20,000	365
Men:	all responses	1571	1860	1200	11%	20,000	1532
	Given a car	1693	1893	1500	4%	20,000	1342
	Given Q>0	1769	1900	1500		20,000	1284
	Given Q>0 and Company car	2585	1897	2000		20,000	280
Women:	all responses	615	1060	200	38%	15,000	1533
	Given a car	719	1106	500	28%	15,000	1255
	Given Q>0	1000	1192	1000		15,000	903
	Given Q>0 and Company car	1374	1098	1000		5,000	85
Big city:	all responses	1029	1541	750	31%	20,000	666
	Given a car	1218	1636	1000	20%	20,000	514
	Given Q>0	1516	1696	1200		20,000	413
	Given Q>0 and Company car	2626	2562	2000		20,000	74
Intermediate city:	all responses	1101	1531	1000	21%	17,000	1321
	Given a car	1186	1541	1000	14%	17,000	1179
	Given Q>0	1382	1580	1000		17,000	1012
	Given Q>0 and Company car	2222	1523	2000		10,000	177
Other areas:	all responses	1121	1680	1000	25%	15,000	1078
	Given a car	1271	1754	1000	16%	15,000	904
	Given Q>0	1508	1815	1000		15,000	762
	Given Q>0 and a Company car	2219	1641	2000		10,000	114

Table 2. *Annual number* of public transport trips

	Mean	Std.	Median	No. zeros	Max	N
Whole sample	91	208	0	72%	2500	3134
Given positive amount of travel	329	279	250		2500	871
Given a car in the household	69	175	0	77%	1500	2645
Men: all responses	80	206	0	77%	2500	1557
Given Q>0	349	301	300		2500	358
Given a car	56	158	0	81%	1500	1357
Women: all responses	103	210	0	67%	1650	1577
Given Q>0	315	261	250		1600	513
Given a car	82	190	0	73%	1500	1288
Big city: all responses	171	255	0	51%	1650	681
Given Q>0	351	255	300		1650	331
Given a car	123	204	0	59%	1000	522
Intermediate city: all responses	64	171	0	79%	1500	1345
Given Q>0	299	259	500		1500	287
Given a car	58	166	0	81%	1500	1199
Other areas: all responses	76	205	0	77%	2500	1108
Given Q>0	334	314	250		2500	253
Given a car	53	161	0	82%	1500	924

Table 3. *Marginal effects (evaluated at sample means) for driving distance by car. Cragg and Tobit type 2 specifications. t-values (absolute values) in parenthesis*

	Choice to have car or not. Probit	Choice to drive or not, given a car. Probit	How much to drive, given positive distance Cragg	How much to drive, given positive distance Tobit 2
Log (mean household income +1)	0.038 (2.4)			
Log (Income + 1)		0.090 (6.0)	0.294 (5.2)	0.295 (3.9)
Log (Partner's income +1)		-0.0061 (0.4)	0.025 (0.4)	0.023 (0.3)
Partner with income	0.14 (10.3)	0.29 (1.0)	-0.0003 (0.0)	-0.001 (0.0)
No. children	0.019 (2.5)	0.0074 (1.2)	0.030 (1.3)	0.030 (1.1)
Age	0.0033 (1.3)	0.0074 (3.3)	0.041 (4.5)	0.041 (3.9)
Age*Age	-0.000037 (1.5)	-0.000082 (3.6)	-0.00040 (4.2)	-0.00040 (3.7)
Sex (1=male)	0.046 (3.6)	0.16 (9.9)	0.719 (14.6)	0.722 (7.8)
Education (years)	-0.0033 (1.5)	0.0009 (0.4)		
Env. Org (1=member)	-0.0002 (0.009)	0.034 (1.6)	0.057 (0.8)	0.057 (0.7)
Big city (1=living in big city)	-0.12 (6.9)	-0.036 (2.2)	-0.065 (1.0)	-0.066 (0.9)
Intermediate city	-0.027 (1.6)	-0.0014 (0.1)	-0.082 (1.6)	-0.082 (1.4)
Company car		0.20 (5.1)	0.521 (8.8)	0.494 (4.8)
Lambda				0.128 (0.5)
No. of observations	2504	2155	1823	1823
Log-likelihood	-880	-711	-1845	-2650
Restr. Log-likelihood	-1011	-926		

Table 4. *Marginal effects (evaluated at sample means) for travel by public transport. Cragg and Tobit type 2 specifications. t-values (absolute values) in parenthesis*

	Choice to use public transport or not. Probit	How many trips to make per year, given positive travel. Cragg	How many trips to make per year, given positive travel. Tobit 2
Log (Income + 1)	-0.037 (1.6)	-0.066 (0.8)	-0.058 (0.6)
Log (Partner's income +1)	0.014 (0.5)	-0.076 (0.7)	-0.068 (0.5)
No. children	-0.019 (1.9)		
Age	-0.024 (6.7)	0.018 (1.3)	0.020 (0.6)
Age*Age	0.00022 (6.0)	-0.00032 (2.3)	-0.00033 (1.0)
Sex (1=male)	-0.10 (5.0)	-0.049 (0.7)	-0.039 (0.3)
Education (years)	0.015 (5.0)	0.016 (1.4)	0.014 (0.6)
Env. Org (1=member)	-0.026 (0.8)	0.158 (1.3)	0.160 (1.0)
Big city (1= living in big city)	0.300 (11.4)	0.317 (3.1)	0.29 (0.8)
Intermediate city	0.074 (3.1)	0.098 (1.0)	0.092 (0.6)
Household owns a car (1=yes)	-0.203 (8.0)	-0.115 (1.5)	-0.085 (0.4)
Lambda			0.35 (0.7)
No. of observations	2504	672	672
Log-likelihood	-1202	-858	-852
Restr. Log-likelihood	-1456		