The benefits of car use in Switzerland - First evidence from a hedonic approach

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Abstract

The benefits of car use must be derived from a demand function. Trying to translate this simple idea into an empirical approach poses serious problems. As a matter of fact the price per kilometre driven is not independent from the amount of individual car mobility per year. As a consequence the attempt to estimate a demand function regressing kilometres driven on the price per kilometre results in positive price elasticities - more mobile individuals buy more expensive cars. In this paper we propose an alternative approach using the [Rosen (1974)] hedonic model. In this framework the kilometres driven are considered as an attribute of an individual's yearly car mobility. The total expenditure for this mobility can hence be regressed on the number of kilometres driven per year and other variables characterising an individual's mobility. The resulting implicit prices of mobility can be used in a second step to estimate an individual willingness to pay function. From this we calculate estimates of consumer surplus. The described empirical program has been implemented using a limited data set on individual car use in Switzerland in 1999. First results indicate a consumer surplus of 4'000 CHF per year for the Median individual in the sample. Apart from the need to confirm this result on the base of a representative sample the research undertaken asks for critical reflection on a theoretical and empirical level: Can the kilometres driven indeed be interpreted as a characteristic of an individual’s car mobility? What would ideally be other relevant variables describing this mobility? Which would be the theoretically correct functional form for the estimation? Is the individual mobility equilibrium assumption implied in the model justified for an estimation on a yearly base? The paper presents first hints to the answer of some of theses questions.

Keywords

Car use – hedonic regression – benefits of transport – Swiss Transport Research Conference – STRC 2001 – Monte Verità

1. Introduction

This paper considers an empirical approach to measure the short run benefits of private car traffic. The focus is on consumer surplus of individual automobile usage. Different approaches have been applied to estimate behavioural parameters. Due to the small amount of observations in the data set, this clearly was not optimal. Originally, the model was estimated by a *discrete/continuous* model where car use was conditional on the discrete decision of owning a automobile[1]. Unfortunately the slope of the demand function turned out to be significantly positive. As a consequence it was impossible to calculate a useful surplus from the surface below the demand curve. We suppose that the small data set, based on a non representative pre-test, is one reason for this[2]. Another problem might have occurred by assuming that the marginal willingness to pay of individuals using their car to an above average extent is high, due to their significant demand for comfort, safety etc. Thus, the more time spent due to a more intensive car use, the higher the cost per kilometre they are willing to bear.

This consideration motivated the following step. Assuming car usage (individual kilometres driven) to be a heterogeneous good, we applied a *hedonic regression* model to the data. In fact, a driven kilometre has to be assessed differently in terms of comfort, safety, engine performance etc. in a luxury car as compared to a midget car. According to *household production theory*[3] an individual is supposed to produce his/her mobility by some input factors –e.g. car use - in order to receive the benefits of the output in form of mobility, characterised by comfort, driving distance etc.. Therefore, an implicit hedonic price function of those different characteristics (first step) was used to estimate an individual's marginal willingness to pay for the above mentioned attributes., e.g. the yearly driven amount of kilometres in a second step.

Due to the limited number of observations and the limited data quality with respect to the possibilities to distinguish different car characteristics, the estimation results serve rather as an illustration of the method than as representative measure of the benefit of private automobile use in Switzerland.

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[1] See e.g. [Jong (1990)].

[2] This hypotheses might to be tested with the complete data set being available by the end of 2001.

[3] See e.g. [Becker (1965)].

2. The data set and the hedonic technique

The data set we used to estimate the model consisted in a pre-test of the Mikrozensus Verkehr 2000 surveyed by the Bundesamt für Statistik. 1'000 households were questioned concerning their travel behaviour. Finally, 571 interviewed persons answered the questionnaire, whereof 285 observations were complete and could be used for the estimation of our model. The final survey with 20'000 to 30'000 observations is expected to be terminated in autumn 2001.

The hedonic regression model was applied according to the pioneering paper by [Rosen (1974)]. According to him, the household chooses a technology (in our case a given car) to produce a certain mobility dependent on his/her preference structure. Therefore the good available on the market is described by an n-dimensional vector of attributes.

(1)

$$\vec{z} = (z_1, z_2, ..., z_n)$$

Due to the fact that different cars indicate different characteristics the hedonic function displays the evaluation of those attributes by the market. This fact obviously implies that the observed prices are based on an equilibrium analysis. Thus, the observed price results from the maximisation of consumers and producers benefit and thereby clears the market[4]. The price function is defined by:

(2)

$$p(\vec{z}) = p(z_1, z_2, ..., z_n)$$

[4] This is one of the central assumptions in the [Rosen (1974)] model. For this reason, full information of households concerning the prices and the automobile characteristics, the absence of transaction costs and perfect price reactions on changes of demand and supply, respectively, is needed. See [Freeman (1979a)] p. 159.

The hedonic price function reflects consumer preferences on the one hand and marginal costs of producers on the other[5]. In our model the price variable was not observed on a market. The total (user) cost[6] of owning and using an automobile has been calculated as a mix of user costs[7] and the correctly depreciated fixed cost of the car[8].

In a hedonic regression framework the price of the market good mobility - in our case the yearly expenditure for car mobility - is regressed in a first step on the different car attributes. Thereby the implicit (shadow) prices of these characteristics are determined. The implicit price of a characteristics is given by differentiating (2) with respect to the particular characteristic.

(3)

$$\frac{\partial \vec{p}}{\partial z_i} = p_{z_i}(z_1, z_2, ..., z_n)$$

This partial derivative indicates the marginal increase of the price for the good $\bar{z}$ due to a marginal increase of the attribute z_i. The implicit price function displays the value of a single characteristic. In the market equilibrium the marginal implicit price of an attribute is equal to the marginal willingness to pay for this given characteristic and therefor the implicit price function is tangent to an individual's marginal willingness to pay function.

In a second step, this marginal implicit price serves, therefore, as the dependent variable to be regressed on the variables determining willingness to pay. Thus, this estimated function is an inverse demand function. An inverse demand function implicitly assumes the endogenity of prices and as a consequence exogenity of quantity[9]. Accordingly the exogenous and hence

5 Which of course is only correct in the case of perfect competition.

6 For the following analysis user costs is used in terms of [Deaton und Muellbauer (1980)] pp 107 ff. The reason is that actually we are in a stock-flow model of durable consumption goods.

7 The costs were calculated according to the [TCS (2000)].

8 Using [Eurotax (3/2000)] tables.

9 See [Kim (1997)].

fixed supplied quantity is price inelastic. It is assumed that producers would not react on price changes in the observed period.

Especially on an aggregated market this assumption seems to be valid[10]. Hence the price variations are based exclusively on changes of the demand to clear the fixed market supply. This hypothesis is also supported by the our empirical analysis. The R^2 of the inverse demand estimation is significantly higher than the one of the ordinary demand function.

Another inherent problem of hedonic models is the difficulty of identification. As already noted, the observed values are indicate market transactions where demand equals supply. Estimating a demand function it is therefore necessary to separate the demand from the supply side in order to identify the demand function. Since the appearance of [Rosen (1974)] many authors discussed this fundamental problem[11].

One possible solution of the problem is the segmentation of the market. The supply function then has the following shape:

(4)

$$P_i = P_i(Z_1, Z_2, ..., Z_n, Z_m)$$

Z_m is a vector of attributes which is independent from the demand and thereby from the utility function. The Z_m are specified in the model by dummy variables characterising different car types as for example vans or off road cars etc.. Beside this, the assumption of an exogenous given completely price inelastic supply side determines a uniquely identifiable demand function.

Concerning the utility function on which the marginal implicit price function is based, there is neither a general theoretically founded guideline nor are there fixed restrictions imposed.

[10] This could also be true when the individual supply is perfectly price elastic. See [Hicks (1956)].

[11] See eg. [Rosen (1974)], [Freeman (1979a)], [Freeman (1979b)], [Diamond und Smith (1985)] or [Hsiao (1990)].

Moreover the functional form of the marginal implicit price function should not decide on the sign of the ascent. Because of the observation of market equilibria the slope can be either positive or negative depending on demand or supply changes, respectively.

To improve the estimation of the marginal implicit price function a homogenous individual preference structure is achieved by market segmentation. The demand structure within the market segments therefore should be as similar as possible. Separability of the utility function turns out to be a useful restriction in order to estimate the distance independently from the level of prices and other arguments. Moreover the quasilinear utility function[12] guarantees the path independence of the considered good from other prices and income. Therefore the expenditures for the measured good is assumed to be only a small part of total income[13]. Thus the area under the *Marshallian* demand curve is becoming a reasonable approximation of consumer welfare. Let us assume, that in this case two stage budgeting is permitted. Then this assumption implies that car mobility is a separable good and as a consequence budgeted independently from all other goods[14]. Hence, cross price elasticity is becoming zero and the price effects of all other goods cannot influence the demand for the considered good[15].

[12] This implies by theory, that the demand of a good is only dependent on its own price change and not on the price changes of any other goods. Of course this assumption is quite crucial but sometimes a reasonable approximation. If the demand for a good does not change much when income changes, the income effect doesn't matter too much and the change in consumer's surplus will be an acceptable approximation to the change in consumer's utility. See e.g. [Varian (1992)].

[13] The median value of the yearly car-expenditure income share is 0.13.

[14] See e.g. [Deaton und Muellbauer (1980)] pp. 120 ff.

[15] The reason of ruling out all the other mobility goods is simply non availability of data.

3. Specification of the marginal implicit price function

To estimate the marginal implicit price function we preferred a log-linear form. In contrast to the linear form complete arbitrage of the characteristics bundle not implied. Because there is no theoretical foundation for the functional form of the equation to be estimated, a Box-Cox transformation was carried out[16]. The estimated value of the parameter λ was 0.126 and just weakly significant (t-value 2.6) on the 95% level[17]. The low value of λ which is close to zero suggests al log-linear form. Moreover, the values of all other estimated coefficients were only slightly different from the log linear specification[18].

Therefore, the marginal implicit price function has the following form and specification:

(5)

$$\ln TC = \alpha + \beta \ln AKM + \gamma_1 ccm + \gamma_2 L4 + \gamma_3 L5 + \gamma_4 K5 + \gamma_5 G3 + \gamma_6 G5 + \gamma_7 S2 + \gamma_8 C2 + \gamma_9 V5 + \varepsilon$$

$\ln TC$:	natural logarithm of the total costs of automobile.
$\ln AKM$:	natural logarithm of driven kilometres.
ccm:	cubic capacity of the engine.
L4:	Dummy Limousine with 4 doors.
L5:	Dummy Limousine with 5 doors.
K5:	Dummy station wagon with 5 doors.
G3:	Dummy off road car with 3 doors.
G5:	Dummy off road car with 5 doors.
S2:	Dummy Coupé with 2 doors.
C2:	Dummy Cabriolet with 2 doors.
V5:	Dummy Minivan with 5 doors.

[16] See [Box und Cox (1964)]. For a critique to the Box-Cox transformation see [Cassel und Mendelsohn (1985)].

[17] A comparison of the estimation results caused by different specifications of the implicit marginal price function can be found in the appendix.

[18] For unrealistically restrictive assumptions being imposed by a linear model [Deaton und Muellbauer (1980)] pp. 254 ff. To fit some non-linear functions to segmented markets is justified when households do not have identical, homothetic preferences. By segmenting markets, household preference curves will become more similar.

Due to the data set[19] a more exact characterisation of the different cars in terms of length, space and so on was unfortunately not possible for all of the different brands. Moreover, the less variables are used to specify the model the smaller possible multicollinearty problems become[20]. Segmenting the market through the use of dummy variables improves the similarity of consumers marginal rate of substitution.

[19] The information on cars unfortunately was limited with respect to the car brand, the cubic capacity of the engine, the driven kilometres, and the construction year.

[20] Of course, the size and the space of a car are correlated, as well as also cubic capacity and engine performance etc.

4. Specification of the indirect demand function

We are now able to derive the demand function in the following way. The variables determining the demand have to be regressed on the marginal implicit price estimated in the first step. In our case we are focusing on the driven distance.

The total cost equation according to (5) is[21]:

(6)

$$TC = e^{a} * AKM^{\beta} * e^{\gamma_1 ccm + \gamma_2 L4 + \gamma_3 L5 + \gamma_4 K5 + \gamma_5 G3 + \gamma_6 G5 + \gamma_7 S2 + \gamma_8 C2 + \gamma_9 V5 + \varepsilon}$$

By taking the derivative of (6) with respect to the distance, the marginal price per kilometre is calculated as can be seen in (7).

(7)

$$\frac{\partial TC}{\partial AKM} = \underbrace{e^{a+\gamma_1 ccm + \gamma_2 L4 + \gamma_3 L5 + \gamma_4 K5 + \gamma_5 G3 + \gamma_6 G5 + \gamma_7 S2 + \gamma_8 C2 + \gamma_9 V5 + \varepsilon} * AKM^{\beta}}_{TC} * \beta AKM^{-1} = p_{AKM}$$

$$p_{AKM} = \beta \frac{TC}{AKM} = MZB_{AKM}$$

The calculations done in (7) result in the dependent variable for the demand equation. The specification of the demand equation has the following form.

(8)

$$\ln MZB_{AKM} = \alpha + \beta \ln AKM + \gamma \ln Y + \delta_1 Freiz + \delta_2 Geschf + \delta_3 Arb + \phi WoAb + \varepsilon$$

$\ln MZB_{AKM}$: natural logarithm of the marginal willingness to pay for an additional. kilometre of car mobility.

[21] The variable age was not significant and therefore neglected.

$\ln AKM$:	natural logarithm of driven car kilometres
$\ln Y$:	natural logarithm of the income..
Freiz:	Dummy when mainly car usage is for spare time.
Arb:	Dummy when mainly car usage is for working.
Geschf:	Dummy when mainly car usage is for business matters.
Woab:	Number of working hours per week.

As displayed in (8) the (inverse) demand function has been estimated in a log-linear form. As a consequence the coefficients are directly representing elasticities.

5. Evidence from the estimation of the marginal implicit price function and the inverse demand function.

This section provides the results from the estimation of equation (5) and (8) and the interpretation of the results. Due to the many problems with the small data set and the lack of exact specification of some car brands within the set, the results have only illustrative character. The analysis of measuring the consumer benefits of transport with a hedonic model should be improved as soon as the complete data set is available by the end of 2001. Then, the more precise specification of some of the car brands could provide a statistical good basis for a much better specified marginal implicit price function.

Moreover the specification of the (inverse) demand function might benefit as well from a larger data set. The following table gives some descriptive statistics.

Table 1 Descriptive statistics of the estimated variables

	Mean	Std. dev.	Median	Minimum	Maximum
Total costs	10296.000	4493.310	9277.200	4070.060	31396.100
Numb. of kilometres	14131.800	12796.100	11500.000	100.000	100000.000
Cubic capacity	1841.540	491.250	1800.000	1200.000	3200.000
Limousine 4 doors	0.253	0.436	0.000	0.000	1.000
Limousine 5 doors	0.249	0.433	0.000	0.000	1.000
Station wagon 5 doors	0.149	0.357	0.000	0.000	1.000
Off road car 3 doors	0.009	0.095	0.000	0.000	1.000
Off road car 5 doors	0.023	0.149	0.000	0.000	1.000
Coupé 2 doors	0.036	0.187	0.000	0.000	1.000
Cabriolet 2 doors	0.009	0.095	0.000	0.000	1.000
(Mini-) Van 5 doors	0.054	0.227	0.000	0.000	1.000

According to Table 1 the values of the dummy variables represent the market shares of the different car types. T reference car (Limousine 3 doors) is not displayed. The Limousines with four and five doors respectively constitute about 50% of the whole market. The values of the remaining variables are to be discussed in Table 3 after the elimination of the extremely high-and low distance drivers. Those were eliminated not to avoid a bias of the estimation results[22]. The estimation results of equation (5) are reported in the following table:

Table 2 Estimation results of the implicit hedonic price function

	Coefficients	Std. dev.	t-value	P{|Z|>z}
Constant	6.785	0.145	46.797	0.000
Natural logarithm of Numb. of kilometres	0.243	0.015	15.728	0.000
Cubic capacity	0.031	0.008	3.877	0.000
Limousine 4 doors	0.060	0.048	1.264	0.208
Limousine 5 doors	-0.109	0.046	-2.350	0.020
Station wagon 5 doors	0.137	0.054	2.540	0.012
Off road car 3 doors	0.225	0.163	1.385	0.168
Off road car 5 doors	0.470	0.107	4.377	0.000
Coupé 2 doors	0.033	0.088	0.378	0.705
Cabriolet 2 doors	0.254	0.163	1.562	0.120
(Mini-) Van 5 doors	0.230	0.077	2.989	0.003
Adjusted R2		0.629	Numb. of observations	221

As indicated in Table 2 the total cost increases with increasing kilometres driven, however at a degressive rate, which can be seen by an elasticity of 0.24. The same can be said for the cubic capacity of the engine. Another interesting point is the interpretation of the not significant dummy variables for market segmentation. They simply indicate the additional costs of the different car types to the reference model (Limousine 3 doors). Due to the households not owning a car the number of observations fell to 221 and the adjusted R^2 of 0.62 is satisfactory. In Table 3 the descriptive statistics for the estimation of the demand function is indicated:

[22] Remember the small data basis in order to estimate the equations.

Table 3 Descriptive statistics for the estimated demand equation data.

	Mean	Std. dev.	Median	Minimum	Maximum
Total cost	9764.490	3130.190	9249.250	4070.060	24286.600
Numb. of kilometres	12441.400	7272.160	11250.000	1000.000	33500.000
Income	77242.700	35274.000	65000.000	13000.000	169000.000
Main purpose of car use for leisure time	0.374	0.485	0.000	0.000	1.000
Main purpose of car use for work	0.476	0.501	0.000	0.000	1.000
Main purpose of car use for business	0.029	0.169	0.000	0.000	1.000
Number of working hours per week	25.587	22.259	37.500	0.000	90.000

The value of the driven kilometres per year corresponds quite exactly to the Swiss average[23] which is also true for the average income[24]. The average total costs at an average driven distance of 12'000 kilometres per year result in an average price of a new car of CHF 30'000[25]. Table 4 indicates the estimation results for the (inverse) demand function:

[23] See: [Bundesamt und Dienst (1996)].

[24] See: [Gesellschaft (1999)].

[25] This calculation was made on the basis of the [TCS (2000)] calculations.

Table 4 Estimation results of the (inverse) demand function

	Coefficients	Std. dev.	t-value	P{|Z|>z}
Constant	4.456	0.411	10.830	0.000
Natural logarithm of Numb. of kilometres	-0.733	0.024	-31.063	0.000
Natural logarithm of income	0.072	0.034	2.111	0.036
Main purpose of car use for leisure time	0.040	0.054	0.743	0.458
Main purpose of car use for work	0.006	0.055	0.102	0.919
Main purpose of car use for business	0.163	0.108	1.506	0.134
Number of working hours per week	-0.001	0.001	-1.028	0.305
Adjusted R^2		0.842	Numb. of observations	206

As already mentioned the dependent variable is calculated according to (7). It is the marginal implicit price of a specific car kilometre.

The results correspond to the theoretical expectations. The coefficients indicate the right sign and the adjusted R^2 is reasonably good. The number of driven kilometres will have a negative impact on the marginal willingness to pay as can be seen from the (inverse) elasticity of –0.73. The income variable has as well a small but scarcely significant impact on the marginal willingness to pay of 0.07.

6. Calculation of the consumer benefits

Under the already mentioned condition[26] of a small enough income effect the plane under the estimated *Marshallian* demand function provides a more or less good approximation of the consumer benefit, which would be measured correctly by the area under the *Hicksian* demand. Under the circumstances of a lack of quality and number of data and observations respectively, this fact should not influence the illustrative character of the results in a too serious manner.

The area under the *Marshallian* demand function is calculated as followed:

(9)

$$ZB_{AKM} = \int_{AKM_0}^{AKM_1} e^{\alpha} AKM^{\beta} Y^{\gamma} dAKM = \left. \frac{e^{\alpha} Y^{\gamma} AKM^{\beta+1}}{\beta+1} \right|_{AKM_0}^{AKM_1}$$

Obviously by calculating the integral in (9) only variables with significant coefficients were considered. Additionally at the upper and lower borders of the integral the extremely high and low values of driven kilometres were ruled out. The lower border was set at 1'000 km per year to overcome the problem of an upward biased calculation of (9) in the sense, that the demand curve is touching the y-axis at an improbable high value of cost[27]. The observations with extremely high values of driven kilometres per year were excluded because of the conjecture that most of the driven kilometres were for business purposes and therefore the consumers would not bear the pecuniary costs of driving. This resulted in the exclusion of 15 further observations.

[26] For example by assuming a Price- Income independence which is implied by a quasilinear preference structure.

[27] Consumers with a totally yearly driven distance of about 100 to 1'000 km were not considered as car users on a regular basis. This problem might be due to an inappropriate data set and probably could be overcome by the final set.

The results presented in the following table are provisional and have to be interpreted most carefully. Not only is the number of observations small but in addition the demographic context was unknown and we ignored whether the survey was done in an urban area or not.. This fact might influence and bias the results in a significant way. For the remaining 206 observations the integral we calculated in (9) yields the values presented in Table 6[28].

Table 5 Results from calculating the consumer benefits of car use.

Values in CHF per year	Income		
	Min: 13'000	Med: 65'000	Max: 169'000
low distance drivers (1. Quartil) 6'900 Km	2’763	3’104	3’326
Median drivers 11'000km	3’638	4’087	4’379
high distance drivers (3. Quartil) 15'000 km	4’303	4’834	5’179

[28] The calculations considered only the first car in each household in order to overcome the even more incomplete data concerning the second or third cars in each household. Moreover the lack of information prohibited the inclusion of car occupation.

7. Conclusions

As illustrated in this paper we tried to estimate the benefits of car use with a hedonic approach. Either due to the small data set or because of the wrong assumption that individuals driving a high number of kilometres per year would experience lower variable costs it was not possible to gain valid results by estimating the data with a *discrete/continuous* model.

The presented results indicated the possibility to overcome the mentioned possible misassumption by a *hedonic regression* model.

The given data set unfortunately allowed only for an illustrative estimation of the model which has still to be tested for its validity. Therefore, the questions put in the abstract can not be fully answered by now. If our results were proved to be accurate, the consumer benefits of an average car driver in Switzerland would be about CHF 4'000. The total pecuniary cost of car mobility calculated by the model amounted to CHF 9'700 in average. The hypothesis of the log-linear specification of both the marginal implicit price function and of the inverse demand function were not rejected by the data.

The not significant dummy variables in the estimated (inverse) demand equation displayed in Table 4 might be caused by the fact, that a great advantage of car mobility is the very universal form of transport and therefore the purpose of car use is suitable for all kinds of mobility.

The calculated consumer benefits are not meant to indicate the external (technical) benefits of transport. They are clearly internal according to microeconomic theory. In addition there is no economic justification for taxing off these benefits by the state as many automobile organisations might fear. The measured benefit is an ordinary benefit as can be calculated for any other good[29]. There might be a possibility to skim off some benefits by two-part tariffs in order to cover possible deficit in the 'Strassenverkehrsrechnung' or some external (technical) costs of car traffic. But note that in this latter case there would be no reduction in car traffic in contrast to a strategy of internalisation of (technical) external effects.

[29] Of course if it is not supplied under the condition of perfect price differentiation.

Finally it would be very useful for further research to prove the correctness of the introduced model by a larger and more detailed data set in order to gain more insight in modelling consumer benefits of transport and to develop a possible powerful tool for this topic.

8. References

Becker G.S. (1965). “A Theory of the Allocation of Time.” *The Economic Journal* LXXV: 493 - 517.

Box G.E.P. und Cox D.R. (1964). “An Analysis of Transformation.” *Journal of the Royal Statistical Society* 26: 211 - 243.

Bundesamt f.S. und Dienst f.G. (1996). Verkehrsverhalten in der Schweiz 1994, Mikrozensus Verkehr 1994. Bern, Statistik Schweiz: 119.

Cassel E. und Mendelsohn R. (1985). “The Choice of Functional Forms for Hedonic Price Equations: Comment.” *Journal of Urban Economics* 18: 135 - 142.

Deaton A. und Muellbauer J. (1980). "Economics and consumer behaviour", Cambridge University Press.

Diamond D.B. und Smith B.A. (1985). “Simultaneity in the Market for Housing Charakteristics.” *Journal of Urban Economics* 17: 280 - 292.

Eurotax (3/2000). Personenwagen: Marktbericht für Neu- und Occasionsfahrzeuge Verkauf, Eurotax (Schweiz) AG, CH-8808 Pfäffikon.

FreemanIII A.M. (1979a). “Hedonic Prices, Property Values and Measuring Environmental Benefits: A Survey of the Issues.” *Scandinavian Journal of Economics* 81: 158 - 173.

FreemanIII A.M. (1979b). "The Benefits of Environmental Improvement: Theory and Practice", The John Hopkins University Press, Baltimore, Maryland.

Gesellschaft z.F.d.S.W. (1999). Zahlenspiegel der Schweiz 1999/2000. Zürich: 210.

Hicks J.R. (1956). "Revision of Demand Theory", Oxford; Clarendon Press.

Hsiao C. (1990). "Identification". in: J. Eatwill, M. Milgate und P. Newman. "The new Palgrave: Econometrics", W.W. Norton & Company, New York, London.

Jong G.C.d. (1990). “An Indirect Utility Model of Car Ownership and Private Car Use.” *European Economic Review* 34: 971 - 985.

Kim H.Y. (1997). “Inverse Demand Systems and Welfare Measurement in Quantity Space.” *Southern Economic Journal* 63(3): 663 - 679.

Rosen S. (1974). “Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition.” *Journal of Political Economy*: 33 - 55.

TCS T.u.U.d. (2000). Kilometerkosten 2000, Touring Club der Schweiz.

Varian H. (1992). "Microeconomic Analysis", W.W. Norton & Company, New York.

Appendix A:

Table 6 Comparisons of the results of different specifications of marginal implicit price function.

	linear form		Log-linear form		Box-Cox transformation (λ)	
	coeff.	t-value	coeff.	t-value	coeff.	t-value
Constant	4.740	13.181	6.785	46.797	13.066	3.876
Natural logarithm of Numb. of kilometres	0.028	24.661	0.243	15.728	0.215	22.975
Cubic capacity	0.271	3.710	0.031	3.877	0.072	2.182
Limousine 4 doors	0.929	2.129	0.060	1.264	0.279	1.416
Limousine 5 doors	-0.459	-1.081	-0.109	-2.350	-0.356	-1.716
Station wagon 5 doors	1.281	2.579	0.137	2.540	0.404	1.706
Off road car 3 doors	3.090	2.069	0.225	1.385	0.786	0.540
Off road car 5 doors	5.217	5.245	0.470	4.377	1.496	1.922
Coupé 2 doors	0.932	1.157	0.033	0.378	0.103	0.333
Cabriolet 2 doors	3.317	2.219	0.254	1.562	0.802	0.773
(Mini-) Van 5 doors	2.867	4.066	0.230	2.989	0.834	1.459
λ					0.126	2.604
adjusted R^2		0.790		0.629		0.999