INFERRING PRICE ELASTICITIES OF CAR USE AND MORAL COSTS OF DRIVING WITHOUT A LICENCE

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Abstract

The article develops a model which makes it possible to infer drivers' perceived extra costs per km of driving without a license and the moral costs of doing so. Furthermore, it gives estimates of the ratios between responses to car license suspension in different time perspectives. The calculations are carried out using data over car holders' willingness to pay for not losing their driving license for 12 months and 24 months, their yearly driving distance and variable car usage costs. The elasticity ratios estimated here are compared with previous studies of short-term and long-term elasticities of car usage with respect to car usage costs.

Keywords: Licence suspension, car usage, elasticity ratios, moral costs

1. INTRODUCTION

The starting point for this study is that there is no physical hindrance of driving without a license but driving illegally implies higher perceived driving costs to the drivers. Given this, the aim of this work is twofold. The first is to infer car drivers' perceived extra costs per km and their moral costs of driving without a license. The second is to estimate the ratios between drivers' short-term and long-term responses to license suspension. The analyses are carried out using data over: (1) car drivers' willingness to pay for not losing their driving license for 12 months and 24 months; (2) car usage costs per km; (3) yearly driving distance per year; and (4) short-term elasticities of car usage for car drivers with respect to car usage costs.

The above elasticity ratios are compared with the results from estimates of short-run and long-run responses or car use to price changes; see Goodwin (1992), Graham and Glaister (2004) and Goodwin et al. (2004) and references therein for review. These works show that the elasticities of car travel are significantly higher in the long run than in the short run. Short-run elasticities are estimated from time series data and are generally defined as responses made within one year, although the actual time-dimension depends on the time interval of the data used. Long-run responses are estimated either from the stationary levels of dynamic models based on time series or on cross section data of car usage and prices in different geographical areas. Only with dynamic models, however, is it possible to determine how the magnitudes of these elasticities change over different time horizons. The common conclusion of the literature reviews is that elasticity of car use with respect to the fuel price is -0.1 in the short run (1-year) and -0.3 in the long run and that the complete response takes up to 6 years.

The further organization of the paper is as follows. In section 2 we present the model and the estimation procedure. Section 3 briefly describes the data used and Section 4 presents and discusses the results. Finally in section 5 we briefly summarize our work.

2. THEORETICAL FRAMEWORK

2.1 The model

Supposing a car driver's demand for car usage, measured in car- km driven, for 12 months (X_{12}) and 24 months (X_{24}) can be described by the following Cobb-Douglas Marshallian demand curves:

(1) $$X_{12} = aP^{-d} \qquad a, d > 0$$

(2) $$X_{24} = bP^{-\lambda d} \qquad b, \lambda > 0$$

where P are variable or km dependent car usage costs per km. The –d and $(-\lambda d)$ parameters are the elasticities of car driving with respect to car usage costs for intervals of 12 months and 24 months, respectively. The long-run elasticity is higher, in absolute value, than $(-\lambda d)$ because we ignore any adjustments made after two years. Based on previous research regarding the magnitudes of elasticities for car usage, we assume that that $\lambda > 1$.

Assume that $P = P_0$ is the car usage cost per km for the driver when he holds his driving license. If car usage is in equilibrium with respect to these prices in all time horizons, it follows that $X_{24} = 2X_{12}$. Using equations (1) and (2) , we thus have:

(3) $$b = 2aP_0^{d(\lambda-1)} \quad .$$

From (3) follows that $b \geq 2a$ when $\lambda > 1$ and $P_0 \geq 1$. In the special case where the demand response is independent of the time period ($\lambda = 1$), then b = 2a.

Using the demand functions above, the driver's willingness to pay for not losing his driving license for 12 months (WP_{12}) and 24 months (WP_{24}) can, thus be described by the following formulas: [1]

[1] In the following we assume, in line with most empirical analyses that the area under the Marshallian demand function is a good approximation for the true value of WP, see for example Hausman et al. (1993).

$$(4) \qquad WP_{12} = \int_{P_0}^{P_0+Q} aP^{-d}\,dp = \frac{a}{1-d}\left[(P_0+Q)^{1-d} - P_0^{\ 1-d}\right] \quad , \ d \neq 1$$

$$(5) \qquad WP_{24} = \int_{P_0}^{P_0+Q} bP^{-\lambda d}\,dp = \frac{b}{1-\lambda d}\left[(P_0+Q)^{1-\lambda d} - P_0^{\ 1-\lambda d}\right] \ , \ \lambda d \neq 1$$

in which (P_0+Q) are usage costs when driving without a license. The value of Q is the sum of the perceived inconvenience of driving illegally (moral costs pr km), perceived expected penalty costs per km and perceived increase in expected accident costs per km for the car driver. All these factors are likely to vary significantly among drivers and consequently, so does the value of Q. From the above formulas it can be deduced that $WP_{24} < 2WP_{12}$ when $\lambda > 1$ whilst $WP_{24} = 2WP_{12}$ when $\lambda = 1$.

The situations described above are visualized in Figure 1. When the driver loses his driving license, the number of km he drives, is reduced from X_{12}^0 to X_{12}^1 during 12 months and from X_{24}^0 to X_{24}^1 during 24 months. Furthermore, the area A denotes WP_{12} and the (A + B) area denotes WP_{24}.

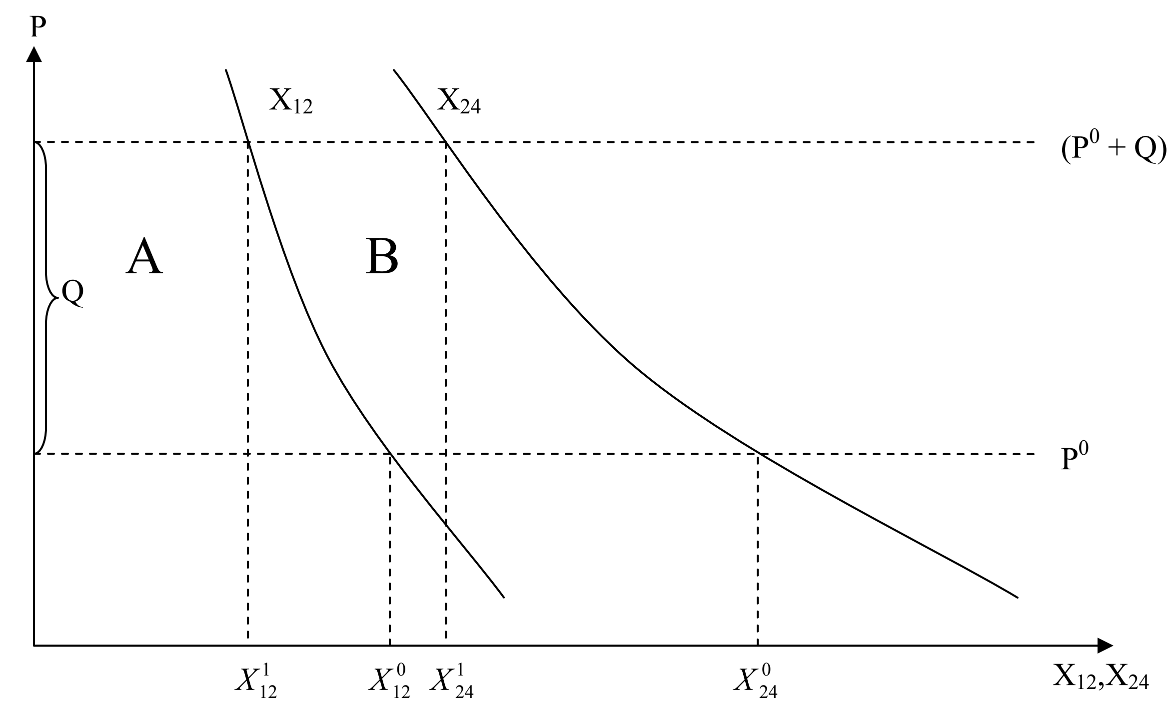

Figure 1. A car driver's demand for car usage for 12 months and 24 months.

2.2 Estimation procedure

In the following, the drivers' willingness to pay for not losing their driving license (WP_{12} and WP_{24}), driving distance per 12th months (X_{12}), car usage costs per km (P_0) and the 12-month car usage elasticity (-d) are known or exogenous. The value of λ and thereby the value of the 2-year elasticity ($-\lambda d$) can then be estimated using the following procedure:

Stage 1: Estimating a.

Taking equation (1) as a starting point, the value of *a* can be deduced from the following formula:

(6) $$a = X_{12} \cdot P_0^{\,d}$$

Stage 2: Estimating Q.

From (4) follows that the value of Q is determined by the following equation:

(7) $$Q = \mu - P_0 \quad \text{where} \quad \mu = \left[\frac{WP_{12}^{*}(1-d)}{a} + P_0^{1-d} \right]^{\frac{1}{1-d}}$$

In the following we make the reasonable assumption that Q is independent of the length of the period the driver loses his license; that is the total perceived extra costs per km of driving without a license is independent of the length of the suspension period.

Stage 3: Estimating λ.

Using equation (3) in combination with equation (5), the value λ that satisfies the latter equation can be found by simulation.

3. DATA USED

3.1 Drivers' willingness to pay

Jørgensen and Wentzel-Larsen (2002) estimated Norwegian drivers' willingness to pay for not losing their driving license for 6 months, 12 months and 24 months. The data set used was collected by the Institute of Marketing Research in Norway in 1997 and 1287 driving license holders answered, among other things, the following question: *"Supposing you have been caught for a serious traffic offence implying suspension of your driving license. What is the maximum amount you are willing to pay for not losing your driving license for 6 months, 12 months and 24 months?"* For a thorough description and discussion of the survey and data collection procedure, we refer to the above work.

Table 1. Norwegian drivers' willingness to pay for not losing their driving license for 12 months and 24 months in 1997 (Nkr)*.

Reported values (WP)	Undiscounted values (WP*)	Ratio undiscounted values
12 months, WP_{12} = 8.985	12 months, WP^*_{12} = 9065	-
24 months, WP_{24} = 14.244	24, months, WP^*_{24} = 14624	$\frac{WP^*_{24}}{WP^*_{12}} = 1.62$

*1€ ≈ 8 Nkr

The average reported values and average undiscounted values for WP_{12} and WP_{24} are shown in Table 1. One striking feature with these results is that the value of WP_{24} is not twice as high as WP_{12}. This may partly be explained by the discounting of future disadvantages of not having a driving license and partly by their greater opportunity to change life style and travel patterns the longer the time horizon. Taking the first factor into account by adjusting the WP_{24} value using an interest rate of 3.5 % per year (Hervik, 2004), or 1.76 % per 6th month, the undiscounted WP's (WP*) still show that the ratio between $WP_{24}^{*} / WP_{12}^{*}$ is less than two.[2] The WP*-values, therefore, indicate that drivers gradually adjust to a life without a driving license. In the following estimations, we use the undiscounted values, WP*.

3.2 Other exogenous values

According to information from the Norwegian Directorate of Roads and the Central Bureau of Statistics of Norway, a Norwegian car license holder drives on average about 10000 km a year implying that X_{12} = 10000 kms and X_{24} = 20000 kms. Larsen and Rekdal (1997) estimate the variable car usage costs per km driven, including tyre ware, insurance and depreciation to be 1.60 Nkr. The petrol costs alone amount to about 0.80 Nkr. Whether the drivers take all variable usage costs into account when making the decision to drive or not, is open to debate, see for example Button (1993). In the following we will therefore do our calculations under two assumptions: 1) that drivers perceive only a small part of expenses other than petrol costs as km-dependent (P_0 = 1.00 Nkr, lower limit); and 2) that they take all relevant km-dependent costs into account (P_0= 1.60, upper limit).

Based on data from 1998/99, Voldmo et al. (1999) estimated the short-term elasticity of car usage with respect to car usage costs in Norway to be -0.12. Their estimations were based on cross-section data, holding car ownership constant. Goodwin et al. (2004), based on a literature review of a large number of studies for many countries, suggest a short-term car usage elasticity with respect to fuel price per liter to be -0.10. Bearing in mind that petrol costs amount to about half of total car usage costs in many countries, this implies a short-run elasticity with respect to total car-use costs of -0.2, so that car usage in Norway appears to be less price elastic than in many other countries.[3] This is not surprising because, compared to many other European countries, a larger proportion of

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[2] $\mathrm{WP}_{24}^{*} = \frac{WP_{12}}{2}\left(1+1.0176\right)$, $\mathrm{WP}_{24} = \frac{WP_{24}}{4}(1+1.0176+1.0176^{2}+1.0176^{3})$

[3] From the formula of the elasticity of composite functions, see for example Sydseater and Hammond (1995), follow that $EL_V X = EL_P X \cdot EL_V P$ in which $EL_V X$ and $EL_P X$ are car usage elasticities with respect to petrol price and car usage costs, respectively. $EL_V P$ is the elasticity of car usage costs with respect to petrol price. When $EL_V P < 1$ it follows that $\left|EL_V X\right| < \left|EL_P X\right|$.

the population in Norway live in rural areas, and people in rural areas are more dependent on the car and are thus less-price sensitive.

In the following we assume that the Voldmo et al. (1999) estimate of the short-term car usage elasticity refers to a time horizon of 12 months. As mentioned above, the demand curves in (1) and (2) describe the demand for car *driving*, that is, it does not include *riding* in a car as a *passenger*. Since the demand for driving a car and riding as a passenger are near substitutes, these demand curves are likely more elastic than the demand for car usage in general. This is because it is less serious to lose one's driving license than to lose the possibility of travelling by private car. Hence, d = 0.12 must be regarded as a minimum value. We will, therefore, do our calculations of the value of the perceived extra costs per km of driving without a license (Q) and of the ratio between car driving elasticities (the value of λ) for the two periods under consideration assuming different values of the short- term elasticity – d.

4. ESTIMATION RESULTS

The main results, which are summarized in Table 2, are based on the estimation procedure described in section 2.2 and the exogenous values stated in section 3. The findings in Table 2 give rise to several comments.

Perceived cost per km

Table 2 shows that the estimations of drivers' perceived extra costs per km of driving without a license (Q) increase with d. This means that the more elastic one assumes that drivers short-term demand for car usage is, the higher the estimated value of Q. Table 2 reveals too that Q is higher the higher the value of P_0 is. The average value of all the Q-estimations in Table 2 is 1.00 Nkr. Assuming drivers' perceived variable usage costs per km when holding the license are between 1.00 Nkr and 1.60 Nkr (1.30 Nkr), this implies that the total variable cost per km is 2.30 Nkr when driving without a license. Consequently, losing the driving licence increases perceived variable driving costs from 1.30 Nkr to 2.30 Nkr or by 77%.

Some rough calculations indicate that expected penalty of driving without a license is small in Norway. The penalty of being caught for such an offence is a fine amounting to 3000 Nkr. The probability of being caught is hard to estimate, but it is likely far less than the probability of being caught speeding because driving without a license can not be

Table 2. Estimated values of extra costs per km with loss of driving license and estimated ratios between car driving elasticities with respect to car usage costs within 12 months and 24 months.

Assumed values of P_0	Assumed values of d	Resulting a-values	Resulting Q-values (Nkr)	Resulting λ - values	Resulting (λd) - values
P_0= 1.00 Nkr (lower limit)	d = 0.10	a = 10000	Q = 0.94	λ = 7.0	(λd) = 0.70
	d = 0.20	a = 10000	Q = 0.98	λ = 4.0	(λd) = 0.80
	d = 0.30	a = 10000	Q = 1.02	λ = 2.9	(λd) = 0.87
	d = 0.40	a = 10000	Q = 1.07	λ = 2.4	(λd) = 0.96
	d = 0.50	a = 10000	Q = 1.11	λ = 2.1	(λd) = 1.05
P_0= 1.60 Nkr (upper limit)	d = 0.10	a = 10481	Q = 0.93	λ = 10.0	(λd) = 1.00*
	d = 0.20	a = 10986	Q = 0.96	λ = 5.8	(λd) = 1.16
	d = 0.30	a = 11514	Q = 0.98	λ = 3.9	(λd) = 1.17
	d = 0.40	a = 12068	Q = 1.01	λ = 3.1	(λd) = 1.24
	d = 0.50	a = 12649	Q = 1.02	λ = 2.6	(λd) = 1.30
Average values of Q, λ and (λd)			Q^A = 1.00	λ^A = 4.4	$(\lambda d)^A$ = 1.03

* It can be deduced from (2) that when (λd) → 1 follows: $\lim WP_{24} = b \cdot \ln(1 + \frac{Q}{P_0})$

noticed from driving behaviour. The latter probability is estimated to about $8.0 \cdot 10^{-5}$ per km on Norwegian roads outside automatic control zones (Jørgensen and Pedersen, 2005) in 1997. Consequently, a maximum value of expected penalty cost per km of driving without a license was 0.24 Nkr ($8.0 \cdot 10^{-5} \cdot 3000$) or 24 % of average estimated value of Q. in Table 2.

Combining information from the Norwegian insurance companies and Central Bureau of Statistics in Norway the probability of being involved in an accident on Norwegian roads was about $9.5 \cdot 10^{-6}$ per km in 1997. When this happens it will always be revealed if the drivers drive illegally; consequently a minimum value of expected penalty cost per km of driving illegally can be estimated to 0.03 Nkr ($9.5 \cdot 10^{-6} \cdot 3000$) or 3 % of average Q. One may argue that the costs of being involved in an accident are higher when driving illegally. The Norwegian insurance companies say, however, that there are no clear rules whether driving without a licence reduces the insurance cover when an accident takes place, and, in any case, the reduction would not be very high. In summary, the above suggest that most of the perceived costs of driving without a license are moral costs.[4]

Estimated elasticity ratio

Table 2 shows, firstly, that the value of λ decreases with d. This means that the more elastic one assumes that car drivers' demand is with respect to car usage costs in the short run, the lower is the ratio between elasticities describing different time horizons. Despite the decrease in this ratio, the absolute value of drivers' 2 year car usage elasticity increases with the magnitude of sensitivity one assumes for car usage with respect to car usage costs in the short run. The estimated ratios as well as the 2-years elasticities are higher the higher the value of drivers' perceived car usage costs per km are. The average value of λ in Table 2 is 4.4. This means that the adjustments to driving licence suspension as far as driving is concerned, is four times higher over a 2 years period than during the first 12 months.

The 2 years elasticities estimated in Table 2 are much higher (average value of 1.03) than long-run elasticities from other studies, in spite of the fact that they do not reflect the long run. It is not surprising since they relate to changes in *driving* with respect to car usage costs and that these elasticities are likely to be higher than those for car usage in general because driving and being a passenger in a private car are near substitutes, especially for those living in households where several members hold a driving licence. Studies of car usage elasticities with respect to car usage costs therefore give limited information about

[4] There are many stories in Norway about drivers finally being caught after having driven up to 50 year without a driving license.

the value of d except that d must be higher than indicated by such studies. Never the less, the elasticities estimated here are rather higher than one would expect.

In their literature review of empirical estimates of elasticities of road traffic, Goodwin et.al (2004) define short-term elasticities as responses made within one year and find that long-term adjustment takes between 3 and 5 years. They also conclude that the ratio between long-term and short-term (1-year) elasticities of vehicle km with respect to petrol prices is about 3.0. A reasonable assumption is that this ratio is broadly the same whether one changes the petrol price or total car usage costs. In comparison, our results suggest that the response to increases in car usage costs for drivers occurs more quickly and is substantially greater than for car use in general.

5. CONCLUDING REMARKS

In this paper we have inferred drivers' perceived extra costs per km of driving without a license. Furthermore, we have estimated the ratios between the elasticities of car driving with respect to car usage costs when the time horizons in question are 12 months and 24 months.

The estimations are done using data for car usage costs per km, yearly driving distance for car drivers and their willingness to pay for not losing their driving license for 12 months and 24 months. The calculations are carried out for: 1) different assumptions regarding the short-term elasticity of car driving with respect to car usage costs and; 2) two different assumptions concerning variable car usage costs per km.

The results show that Norwegian drivers' perceived cost per km of driving increase from about 1.30 Nkr to about 2.30 Nkr (by 77 %) when they lose their driving licence. The perceived extra costs per km of driving illegally are, thus, about 1.00 Nkr. Since the estimated expected penalty per km and other pecuniary costs of driving without a license are very low, most of these perceived extra costs are moral costs. The ratio between the short-term (1-year) elasticity of car driving with respect to car usage costs and the 2- year elasticity is about 4 implying that less than one forth of the responses to driving licence suspension are completed after one year. Considering our results in the light of other empirical studies analysing car usage elasticities suggests that adaptations of driving are more significant and seem to happen more quickly than the responses of car usage in general.

REFERENCES

Button, K (1993): *Transport Economics, 2nd Edition*. Edward Elgar. Cambridge.

Goodwin , P.B (1992): A review of new demand elasticities with special reference to short and long run effects of price changes*. Journal of Transport Economics and Policy,* 26, pp 155-163.

Goodwin, P.B, Dargay, D and Hanly, M (2004): Elasticites of road traffic and fuel consumption with respect to price and income: A review. *Transport Reviews*, Vol 24, No 3, pp 275-292.

Graham, D.J and Glaister, S (2004): Road traffic demand elasticities: A review. *Transport Reviews,* Vol 24, No 3, pp 261-274.

Hausman, J, Leonard, G and McFadden, D (1993): Assessing use value losses caused by natural resource injury*. Contingent valuation. A critical assessment* ed J. Hausman, pp 341-368. Amsterdam: North-Holland Publishing Company.

Hervik, A (2004): Justering av diskonteringsrenten.(Adjustment of the discount rate). *Økonomisk Forum*, Nr 6, pp 20 – 25 (in Norwegian).

Jørgensen, F and Wentzel-Larsen, T (2002): Car drivers' willingness to pay for not losing their driving license. *Transportation* 29, pp 271-286.

Jørgensen, F and Pedersen, P (2005): Enforcement of speed limits: Actual policy and drivers' knowledge. *Accident Analysis and Prevention* 37, pp 53-62.

Larsen, O and Rekdal, J (1997): Transportmodeller og nytte/kostandsmetodikk (Transport models and cost- benefit analyses). TØI paper nr 1058/1997. Institute of Transport Economics, Oslo, Norway (in Norwegian).

Sydsaeter, K and Hammond, P.J (1995): *Mathematics for economic analysis*. Prentice Hall, Englewood Cliffs, New Jersey.

Voldmo, F, Hamre, T, Larsen, O and Rideng, A (1999): Nasjonal transportplan 2002 – 2011. Datagrunnlag for persontransporter. (National transport plan 2002 - 2011. Data bases for personal transport). TØI paper 1128/1999. Institute of Transport Economics, Oslo, Norway (in Norwegian).