The Effect of Personal Characteristics on Drivers’ Speed Selection

An Economic Approach

By Finn Jørgensen* and John Polak†

1. Introduction

The topic of drivers’ speed selection is one that has attracted considerable research effort over the past decades (see, for example, the recent review by Aljanahi, 1993). Most of this work has concentrated on the relationship between drivers’ speed selection, speed limits and the characteristics of the road (alignment, number of lanes, surface condition, and so on) and the vehicle (type, age, engine capacity, and so on). It has found ready application in the context of the development of standards and criteria for the setting of speed limits on different classes of road (for example, O’Flaherty and Coombe, 1971; McLean, 1981).

Recently researchers have sought to develop a better understanding of the factors influencing drivers’ speed selection by extending the scope of analysis to include drivers’ personal characteristics and attitudes (Glad et al., 1990; Mannering et al., 1990; Nilsson, 1989; Wasielewski, 1984). Such work has established the importance of a number of factors: drivers’ perception of safety hazard (Hauer, 1970); their sensitivity to the perceived cost implications of alternative speeds (Tepley, 1978); and the availability and comprehension of information regarding speed limits (Hogg, 1977). However, the models developed by these authors have not been based on an economic theory of driver behaviour, and thus do not enable the linking of speed selection to other aspects of economic behaviour. This is an important limitation since it inhibits the consideration of speed selection within the wider economic context of travel choice. It is important to be able to locate speed selection decisions within such a wider context, particularly in the context of the economic evaluation of policy interventions such as speed limits, fines and enforcement effort, where desired impacts on safety, energy use, and so on must be considered in relation to capital cost and changes in drivers’ welfare.

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The objective of this paper is to present a simple economic model of drivers’ speed selection behaviour which takes into account the influence of certain personal and attitudinal factors. The model is estimated using data from a survey carried out by the Institute of Transport Economics (TØI) in Norway (Glad et al., 1990). The data consist of measurements of drivers’ actual speed recorded over a stretch of rural road, together with the results of an interview carried out with the drivers after the speed measurements were made.

The structure of the paper is as follows. In the second section we present an economic model of a driver’s speed selection behaviour. This model is based on a concept of drivers as risk-neutral utility-maximising agents, and takes into account considerations of travel time, safety hazard, and the effect of speed limits (Blomquist, 1986; Janssen and Tenkink, 1988; Feltzman, 1975). The third section briefly describes the data used in the study and outlines the econometric specification of the models estimated. The fourth section discusses the estimation results and the final section summarises the main results of the study.

2. An Economic Model of Speed Selection

We assume that drivers are subjectively rational, risk-neutral utility maximisers and that the perceived pecuniary cost per unit distance driven is constant. Under these assumptions, we suppose that drivers select a speed \( s \) that minimises their total cost of travel \( TC \), where \( TC \) is defined as:

\[
TC = T(s) + p(s)L(s) + qF(s)
\]  

(1)

where \( T(s) \) is the cost (or disutility) associated with travel time per unit of distance travelled, \( p(s) \) is the perceived probability that an accident will occur per unit distance driven, \( L(s) \) is the perceived private accident loss for the driver if an accident does occur, \( q \) is the perceived probability of being caught per distance travelled exceeding the speed limit \( s_{\text{max}} \) and \( F(s) \) is the perceived magnitude of the fine when caught speeding. We also make the following regularity assumptions:

\[
T_s < 0, \ T_{ss} > 0, \ p_s > 0, \ p_{ss} > 0, \ L_s, \ L_{ss} > 0 \\
F, \ F_s, \ F_{ss} > 0 \text{ if } s > s_{\text{max}}, \ F = 0 \text{ if } s \leq s_{\text{max}}
\]

where \( Y_X = \frac{\partial Y}{\partial X} \).

The \( T(s) \) relationship is influenced by the driver’s per unit valuation of travel time \( (k) \). The value of \( k \) is usually assumed to be influenced by, among other things, the driver’s income, the purpose of the journey and qualitative aspects of the vehicle (Bruzelius, 1979; MVA et al., 1987). The \( p(s) \) relationship is influenced by the technological characteristics of the car, the quality of the roads and the level of the driver’s skill. The \( L(s) \) function is influenced by the quality of the car, the driver’s conditions of insurance and by the number of passengers. The last factor has impact on \( L(s) \) because it is reasonable to assume that the car driver is concerned about the safety of others, especially family and friends (see, for example, Jones-Lee, 1989).
Although the actual probability of being caught and the actual penalty for minor speeding offences are the same for all car drivers and for all types of car in Norway,\footnote{For serious speeding offences \(s > s_{\text{max}}\) where suspension of the driver's driving licence and/or imprisonment are the means of punishment, the actual penalty is not the same for all persons; for instance, the penalty for the driver of losing his licence will be greater the more dependent he is on the car. For a more thorough discussion of these problems see Jørgensen (1991).} it has been found that the value of \(q\) and the \(F(s)\) function vary significantly across the Norwegian driving population (Endresen, 1978; Østvik, 1988; Glad et al., 1990). However, neither \(q\) nor \(F(s)\) vary significantly with car type (Jørgensen, 1991). It is worth noting that the actual penalty function \(F(s)\) in Norway is in fact a function increasing stepwise with speed for \(s > s_{\text{max}}\). The number of steps is, however, rather large — at least ten — and therefore our assumption of a smooth relationship between perceived penalty and speed is reasonable.

Another important assumption underlying the model is that the car driver is amoral; that is, he has no conscience or scruples about committing speeding offences. This means that if the perceived value of \(q\) is zero, then the existence of speed limits per se has no impact on driving behaviour. Although this amorality assumption is a common approach amongst economists when dealing with issues of crime and punishment (see Becker, 1968), there is some evidence from the transport sector that moral considerations do affect drivers' behaviour, for example in relation to particular categories of illegal parking (Cullinane and Polak, 1992; Jones, 1990). The evidence for the existence of moral effects in speed selection behaviour is, however, much less clear cut.

If we wished to accommodate this type of moral effect, then the basic speed selection model could be extended with a new function \(C(s)\) (where \(C, C_\tau, C_{ss} > 0\) when \(s > s_{\text{max}}\)) indicating the "moral costs" to the car driver of exceeding the speed limit. The speed selection model would then have the form:

\[
TC = T(s) + p(s)L(s) + q(s)F(s) + C(s)
\]  \hfill (1*)

and the effect of the \(C(s)\) term would be to increase the cost associated with speeds above the speed limit and lead to a lower optimal speed being selected. Although we acknowledge the potential importance of this moral dimension of behaviour, unfortunately our data do not allow us to treat this issue explicitly in the remainder of the paper.

### 2.1 Specifying functional forms

Assuming that the value per unit of travel time \((k)\) is not influenced by speed (that is, that there are no qualitative effects due to, say, variations in ride quality with speed), then the \(T(s)\) function can be specified as:

\[
T(s) = \frac{k}{3}, \quad T_s = -\frac{k}{s^2}, \quad T_{ss} = \frac{k}{s^3}
\]  \hfill (2)

Further, we will impose the following form on the \(p(s)\) and \(L(s)\) functions over the relevant range of speed:

\[
p(s) = a_0s^{a_1}, \quad a_0 > 0, a_1 > 1
\]  \hfill (3)

\[
L(s) = b_0s^{b_1}, \quad b_0 > 0, b_1 > 1
\]  \hfill (4)
These specifications for \( p(s) \) and \( L(s) \) are both intuitively reasonable and lead to mathematically tractable model formulations. Moreover, under this specification the parameters \( a \) and \( b \) have useful empirical properties (Salusjärvi, 1982; Jørgensen, 1991). In particular, Jørgensen (1991) found that the value of the sum \( (a_1+b_1) \) displays considerable stability across the Norwegian driving population. Thus, in the following, we will assume that the drivers’ characteristics influence the values of \( a_0 \) and \( b_0 \) only.

Finally, we give \( F(s) \) the following specification:

\[
F(s) = c_0(s - s_{\text{max}})^{c_1}, \quad c_0 > 0, c_1 > 1, \text{ if } s < s_{\text{max}}; \quad F(s) = 0 \text{ otherwise}
\]  

(5)

For Norwegian drivers, the value of \( c_1 \) lies in the range 2.7 and 3.0 (Jørgensen, 1991). For convenience we will assume that \( c_1 \) does not vary amongst car drivers. Hence, different perceptions of the penalty function influence \( c_0 \) in equation (5) only.

2.2 Optimal speed selection without speed limits

In this case \( F(s) = 0 \), for all \( s > 0 \) and in our model speed selection is determined solely by the trade-off between travel time costs and perceived expected accident loss. Using equations (2) to (4), equation (1) may be written:

\[
TC = \frac{k}{S} + as^b, \quad a = a_0 + b_0 \quad b = a_1 + b_1
\]  

(6)

where the parameter \( k \) captures the effect of travel time considerations on speed selection and the parameter \( a \) captures the effect of expected accident loss. The value of \( s \) which minimises \( TC \) is given by:

\[
s^* = \left(\frac{k}{ad}\right)^{d}, \quad \text{where } d = \frac{1}{1+b}
\]  

(7)

From equations (3) and (4) it follows that \( b > 2 \) and thus it is straightforward to show from equation (6) that \( TC_{s^*} > 0 \), so that \( s^* \) is a global optimal value. From equation (7) it is clear that the value of the optimal selected speed \( s^* \) is an increasing function of the value of travel parameter \( k \) and a decreasing function of the accident expected loss parameter \( a \). Figure 1 shows this variation over realistic ranges of \( k \) and \( a \).

2.3 Optimal speed selection with speed limits

When speed limits do exist the situation becomes more complicated, since in addition to travel time and safety considerations we must also take into account drivers’ perceptions of the cost associated with being caught speeding. Under these conditions equations (1) to (5) imply:

\[
TC = \frac{k}{S} + as^b + qc_0(s - s_{\text{max}})^{c_1}, \quad a = a_0 + b_0, \quad b = a_1 + b_1
\]  

(8)

where

\[
\begin{align*}
& c_0 = 0 \text{ when } s \leq s_{\text{max}} \\
& c_0 > 0 \text{ when } s > s_{\text{max}} \text{ and} \\
& c_1 > 1.
\end{align*}
\]

Figure 2 shows the relationship between travel costs (\( TC \)) and speed (\( s \)), in the cases with and without speed limits.

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Figure 1
Variation of Optimal Speed $s^*$ with the Parameters $k$ and $a$

Figure 2
The Relation between Travel Costs and Speed with and without Speed Limits

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Unfortunately, in the case where speed limits are exceeded the optimal speed \( \$ \) cannot be deduced in closed form from equation (8). However, we can derive a tractable approximation by taking a first-order Taylor approximation to the sum \([as_1^b + qC_0(s - s_{\text{max}})^c] \) in (8) around the point \( s = s_1, (s_1 > s_{\text{max}}) \).\(^2\) It then follows that:

\[
TC = \frac{k}{s} + Ds_{\text{max}}, \quad s > s_{\text{max}}^\star
\]

where

\[
D = [as_1^b + qC_0(s_1 - s_{\text{max}})]s_1^{-D_1},
\]

\[
D_1 = lb + (1 - l)s_1^{-c_1}
\]

and

\[
l = \frac{as_1^b}{as_1^b + qC_0(s_1 - s_{\text{max}})}.
\]

Since both \( as^b \) and \( qC_0(s - s_{\text{max}})^c \) are increasing convex functions of \( s \) \((s > s_{\text{max}})\), the remainder term in the Taylor expansion is well behaved and the \( Ds_{\text{max}}^b \) function is a good approximation. (Jørgensen (1991) provides a more thorough discussion of this approach.)

Thus, to a good first-order approximation, the optimal speed of drivers who exceed the speed limit can be expressed as:

\[
\$ = \left(\frac{k}{DD_1}\right)^h,
\]

where

\[
h = \frac{1}{1 + D_1}.
\]

Jørgensen (1991) has shown that over the relevant range of speed considered in this study, Norwegian penalty rules for speeding offences imply that

\[
\frac{s_1c_1}{s_1 - s_{\text{max}}} > b.
\]

Thus, from the definition equations following (9) it follows that \( D_1 > b \). Thus, \( TC_{\text{opt}} > 0 \) and \( \$ \) is a global optimal value.

### 3. Data Sources and Empirical Model Specification

#### 3.1 Description of survey and data

The dataset used in this study was collected in a survey carried out by TØI (see Glad et al., 1990). The survey collected two types of data. The first consisted of information on the speed of all private vehicles measured over a 3.7km section of rural road 200 kms north of Oslo, on two consecutive days in September 1986. Various speed limits were in force over the survey section; 90km/h for the first 2.8km, 70km/h for the next 0.2km and 60km/h for the final 0.7km.

\(^2\) It is reasonable to set the value of \( s_1 \) to a figure such as the average speed of drivers who exceed the speed limit. For instance, when \( s_{\text{max}} = 80 \text{ km/h}, \ s_1 \) may be set to 87 km/h.
### Table 1

**Personal and Attitudinal Information Collected in Driver Interviews**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\hat{s}$</td>
<td>Driver’s measured average speed</td>
<td>Measured on the basis of recorded travel time over the surveyed section of road</td>
</tr>
<tr>
<td>$s^*$</td>
<td>Driver’s preferred free speed</td>
<td>Stated preferred speed over the surveyed 90 km/h zone under the same driving conditions as at the time of survey but in the absence of speed limits</td>
</tr>
<tr>
<td>EXP</td>
<td>Driving experience</td>
<td>Calculated as the product of the number of years the driver has possessed a driving licence and the average annual distance driven over the past 3 years</td>
</tr>
<tr>
<td>AGE</td>
<td>Driver’s age</td>
<td>Measured in years</td>
</tr>
<tr>
<td>SEX</td>
<td>Driver’s sex</td>
<td>Dummy variable (male = 1, female = 0)</td>
</tr>
<tr>
<td>TTS</td>
<td>Importance of travel time savings on current journey</td>
<td>Measured on a five point semantic scale (from “very important” to “very unimportant”), then grouped into two categories to give indicator variable (high importance = 1, low importance = 0)</td>
</tr>
<tr>
<td>PPC</td>
<td>Perceived likelihood of being caught speeding on the surveyed section of road</td>
<td>Measured on a six point semantic scale then grouped into two categories to give indicator variable (likely = 1, unlikely = 0)</td>
</tr>
<tr>
<td>PLC1</td>
<td>Perceived loss if caught exceeding the speed limit by 15 km/h</td>
<td>Measured on a five point semantic scale then grouped into three categories to give two indicator variables corresponding to high ($PL C_1 = PLC_2 = 1$), moderate ($PL C_1 = 0, PLC_2 = 1$) and low ($PL C_1 = PLC_2 = 0$) levels of loss</td>
</tr>
</tbody>
</table>

After the drivers passed through the survey section they were stopped and asked to complete a brief questionnaire which collected a range of personal and attitudinal information. Table 1 summarises the relevant information collected in this survey. Of the 1933 drivers whose speed was recorded, 502 answered this follow-up questionnaire in a satisfactory way. Glad *et al.* (1990) report that there was no significant difference in the speed distribution between the drivers who did and did not complete the questionnaire, and conclude that the sample is representative for all the drivers who passed through the section. Our subsequent analysis is based on this sample.
Most of the definitions in Table 1 are quite straightforward; however, it is important to point out that in the case of the variable PLC drivers were asked about their assessment of loss when caught exceeding the speed limit by exactly 15km/h. Thus if, for instance, drivers A and B give answers indicating high loss and medium loss respectively, we can only infer that the perceived expected penalty costs are higher for A than for B when they drive 15km/h above the speed limit, that is:

\[ F_A(s) > F_B(s), \text{ when } s - s_{\text{max}} = 15 \]

Consequently, if we wish to infer that \( c_0 \) in equation (5) is larger for driver A than for driver B, then we have to impose the following additional conditions:

- When driver A reports higher perceived expected penalty costs than driver B when exceeding the speed limits by 15 km/h, the same will be the case when they exceed the speed limit by any amount. This means that the perceived expected penalty costs functions for A and B will never intersect (that is, \( F_A(s) > F_B(s) \) when \( s > s_{\text{max}} \)).
- Car driver A has a steeper penalty function than car driver B (that is, \( F_A(s) > F_B(s) \) when \( s > s_{\text{max}} \)).

### 3.2 Empirical specification of speed selection models

Equations (7) and (10) present formal specifications of the speed selection models. In this section we relate these formal specifications to the survey data and derive estimable forms of the models.

Considering first the case of speed selection without speed limits, it follows from equation (7) that the optimal speed \( s^* \) can be written as:

\[ \ln s^* = d [\ln k - \ln a - \ln b] \tag{11} \]

where, by assumption (see Section 2.1), \( k \) and \( a \) are the parameters of interest, and \( b \) and \( d \) are known constants.

Our survey data provide us with certain indicators of the behavioural parameters \( k \) and \( a \), but not direct measurements of the parameters themselves. Therefore in order to operationalise equation (11) we must relate these indicators to the underlying parameters. The approach we have adopted is very simple. In the case of the accident loss parameter \( a \), we assume that

\[ \ln a = f_0 + f_{\text{exp}} \ln EXP + f_{\text{age}} \ln \text{AGE} + f_{\text{sex}} \text{SEX} + f_{\text{tts}} \text{TTS} \tag{12} \]

and for the value of time parameter \( k \) we assume that

\[ \ln k = f_0' + f_{\text{tts}}' \text{TTS} \tag{13} \]

The relations (12) and (13) are not, strictly speaking, deterministic in nature, but embody errors associated with the imperfections of the chosen indicators. However, if we are prepared to assume that these errors are normally distributed, the additive structure of equation (11) implies that we can combine (11), (12) and (13) to give the following equation in which the errors are also normally distributed

\[ \ln s^* = v_0 + v_{\text{exp}} \ln EXP + v_{\text{age}} \ln \text{AGE} + v_{\text{sex}} \text{SEX} + v_{\text{tts}} \text{TTS} \tag{14} \]
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where

\[
\begin{align*}
  v_0 &= d(f'_0 - f_0 - \ln b) \\
  v_i &= -df_i^i i = (EXP, AGE, SEX) \\
  v_{TTS} &= d(f'_{TTS} - f_{TTS})
\end{align*}
\]

In this specification, the values of the parameters \( f \) and \( v \) have a straightforward interpretation; the \( f_i \), \( v_i \) \((i = EXP, AGE)\) denote the elasticities of \( a \) and \( s^* \) respectively with regard to \( EXP \) and \( AGE \), while \( 100f_i \) and \( 100v_i \) \((i = SEX, TTS)\) denote the percentage change in \( a \) and \( s^* \) respectively with regard to a change in \( SEX \) or \( TTS \) from 0 to 1. With estimates of the \( v \) parameters from (14) and given an exogenous estimate of \( d \), the values of \( f \) and of \( (f'_{TTS} - f_{TTS}) \) can be deduced.

Turning to the case where speed limits are in force, Jørgensen (1991) has shown that there is little inter-personal variation in the values of the terms \( D \) and \( h \) in equations (9) and (10). Thus, we may regard \( D_1 \) and \( h \) as constants, analogous to the terms \( b \) and \( d \) in the no-speed-limit case. With this simplification we may express equation (9) as:

\[
\ln \bar{S} = h[\ln k - \ln D - \ln D_1]
\]

(15)

Since \( D_1 > b \) it follows from equations (7), (9) and (10) that \( 0 < h < d \). The term \( D \) includes effects associated with both accident loss and speeding penalty loss. Thus the following extended specification is used:

\[
\ln D = g_0 + g_{EXP} \ln EXP + g_{AGE} \ln AGE + g_{SEX} \ln SEX + g_{TTS}TTS
\]

\[+ g_{PPC}PPC + g_{PLC1}PLC1 + g_{PLC2}PLC2 \]

(16)

and, as before,

\[
\ln k = g'_0 + g'_{TTS}TTS
\]

(17)

So, by combining equations (16) and (17), equation (15) can be written as:

\[
\ln \bar{S} = w_0 + w_{EXP} \ln EXP + w_{AGE} \ln AGE + w_{SEX} \ln SEX + w_{TTS}TTS
\]

\[+ w_{PPC}PPC + w_{PLC1}PLC1 + w_{PLC2}PLC2 \]

(18)

where

\[
\begin{align*}
  w_0 &= h(g'_0 - g_0 - \ln D) \\
  w_i &= -h_i^i i = (EXP, AGE, SEX, PPC, PLC) \\
  w_{TTS} &= h(g'_{TTS} - g_{TTS})
\end{align*}
\]

In this case, the parameters \( g \) and \( w \) have analogous interpretations (as elasticities and percentage changes) to the \( f \) and \( v \) parameter discussed above.

3.3 Some expectations concerning parameter values

Effect of driving experience

There is evidence from a number of studies that increased driving experience increases drivers' vehicle handling and perceptual skills (Elvik, 1988; Institute of Transport Economics (ToI), 1989; Wilde, 1984). Moreover, recent research by Jørgensen (1991) indicates that experienced drivers are more likely than less experienced drivers to overestimate their driving skills. Therefore, other things being equal, we would expect the
value of $a$ to decrease with $EXP$. These observations indicate that the relationship between a driver’s perceived expected accident loss per unit distance and speed shifts downwards with increasing driving experience (that is, $f_{\text{EXP}, \text{EXP}} S_{\text{EXP}} < 0 \Rightarrow v_{\text{EXP}, \text{W}_{\text{EXP}}} > 0$). For a more extensive discussion of this issue, see Jørgensen (1993).

**Effect of age**
Previous research suggests that younger car drivers are more likely to overestimate their driving skills than older drivers (Finn and Bragg, 1986). Further, many younger drivers receive a subsidy from their parents towards the cost of vehicle acquisition and/or replacement and are therefore likely to carry less of the financial burden in the event of an accident than older drivers. Both these factors suggest that $a$ increases with $AGE$ (that is, $f_{\text{AGE}, \text{AGE}} \geq 0 \Rightarrow v_{\text{AGE}, \text{W}_{\text{AGE}}} < 0$).

However, this effect is offset by the fact that as people grow older there will, in general, be a reduction in the net present value of the loss of future cash flow consequent upon physical or psychological injury. Hence, it is likely that the opportunity costs of injury will decrease with age. This points in the opposite direction.

**Effect of gender**
There is little evidence indicating that gender has a direct influence on car drivers’ skills. However, since women tend to earn less than men, one could argue that the opportunity monetary costs of being involved in accidents which cause injuries are less for women than for men (that is, $f_{\text{SEX}, \text{SEX}} \geq 0 \Rightarrow v_{\text{SEX}, \text{W}_{\text{SEX}}} < 0$). On the other hand, since women generally have greater responsibilities for the care and welfare of other family members than men have, in the event of an accident which inhibits such a role being carried out, their overall perceived accident loss may well be higher than for men. It is therefore difficult to form a clear presumption regarding the signs of $v_{\text{SEX}}$ and $w_{\text{SEX}}$.

**Effect of attitude towards travel time savings**
We would expect drivers who regard travel time savings as “very important” in general to have higher values of time than those who do not (that is, $g_{\text{TTS}} f_{\text{TTS}} > 0$). In addition, such drivers are also likely to have higher incomes and therefore to suffer higher opportunity monetary loss if involved in accidents (that is, $g_{\text{TTS}} f_{\text{TTS}} > 0$). Therefore, the signs of the terms $w_{\text{TTS}} (= d(g_{\text{TTS}} f_{\text{TTS}}))$ and $v_{\text{TTS}} (= h(f_{\text{TTS}} - g_{\text{TTS}}))$ are difficult to establish by a priori reasoning alone.

**Effect of perceptions of the probability of detection and the severity of penalty for speeding**
Drivers who perceive that there is a high probability of being caught speeding will tend to have higher values of $q$ than those who regard this probability as ‘low’. It follows from equation (9) that $D$ is larger for the former group and therefore we would expect to find that $g_{\text{PPC}} > 0$ and $w_{\text{PPC}} < 0$.

Similarly, drivers who perceive the penalty of being caught speeding as ‘low’ will have lower values of $c_0$ than those who perceive the penalty as ‘moderate’, who in turn have
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a lower value of $c_0$ than those who perceive the penalty as 'high'. It follows that we would expect $g_{PLC1}$, $g_{PLC2} > 0$ and therefore $w_{PLC1}$, $w_{PLC2} < 0$.

**Magnitudes of model parameters**

Finally, since $f_i$ and $g_i$ ($i = EXP, AGE, SEX, TTS$) denote percentage changes in the parameters $a$ and $D$ respectively, it follows that:

$$|f_i| > |g_i|, \quad (i = EXP, AGE, SEX, TTS);$$

(19)

and further, since $D > b$, it follows from the definitional equations following (14) and (18) that:

$$|v_i| > |w_i|, \quad (i = EXP, AGE, SEX, TTS).$$

(20)

**4. Estimation Results**

**4.1 Models of speed selection**

Table 2 presents the results of the estimation of the two models of speed selection, using Ordinary Least Squares (OLS) regression. In the first model the dependent variable is the drivers’ stated preferred free speed ($s^*$) while in the second it is the drivers’ measured speed ($\hat{s}$). Both models are significant at the 1 per cent level (although only marginally so in the case of the ‘with speed limits’ model). The model coefficients are generally significant and have signs and relative magnitudes that are broadly in line with prior expectations. In the case of both models, plots of residuals show no systematic traits and no systematic deviation from normality.

Salusjärvi (1982) and Jørgensen (1991) show that the parameter $b$ is roughly equal to 4 which combined with equation (7) implies that $d = 0.2$. With this in mind, our empirical results may be given the following interpretation.

**Speed selection without speed limits**

- The coefficient of $EXP$ implies that the elasticity of drivers’ free speed ($s^*$) with respect to driving experience is 0.01. Moreover, it follows from the definition of $v$ and $f$, that the elasticity of drivers’ perceived expected accident loss ($as^*$) with respect to driving experience is 0.05.

- The coefficient of $AGE$ implies that the elasticity of drivers’ free speed ($s^*$) with respect to age is -0.115 per cent; and it similarly follows that the elasticity of drivers’ perceived expected accident loss ($as^*$) with respect to age is 0.586.

- The coefficient of $SEX$ implies that, other things being equal, men will select a free speed some 3.6 per cent higher than women. It also follows that men’s perceived expected accident loss is 17 per cent lower than women’s.
Table 2
Speed Selection Model Estimation Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Without Speed Limit (Dependent variable = $^{*}$)</th>
<th>With Speed Limit (Dependent variable = $^\dagger$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXP</td>
<td>0.010 (1.7)</td>
<td>0.009 (2.0)</td>
</tr>
<tr>
<td>AGE</td>
<td>-0.115 (-7.3)</td>
<td>-0.025 (-1.8)</td>
</tr>
<tr>
<td>SEX</td>
<td>0.036 (2.6)</td>
<td>-0.009 (-0.7)</td>
</tr>
<tr>
<td>TTS</td>
<td>0.052 (4.6)</td>
<td>0.035 (3.3)</td>
</tr>
<tr>
<td>PPC</td>
<td>—</td>
<td>0.0003 (0.3)</td>
</tr>
<tr>
<td>PLC1</td>
<td>—</td>
<td>-0.024 (-2.6)</td>
</tr>
<tr>
<td>PLC2</td>
<td>—</td>
<td>-0.024 (-1.2)</td>
</tr>
</tbody>
</table>

Diagnostics

<table>
<thead>
<tr>
<th></th>
<th>Without Speed Limit</th>
<th>With Speed Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>508</td>
<td>508</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.21</td>
<td>0.07</td>
</tr>
<tr>
<td>$F$</td>
<td>33.8</td>
<td>4.8</td>
</tr>
</tbody>
</table>

- The coefficient of $TTS$ implies that, other things being equal, car drivers who report that time savings are important to them have a desired free speed some 5.2 per cent higher than those who report travel time savings as less important. The coefficient of $TTS$ also implies that $(f'_TTS - f_{TTS}) = 0.26$. This difference is in itself hard to interpret directly. However, if $f_{TTS} > 0$ then this implies that $f'_TTS > 0.26$ so that according to equation (13), drivers who assess travel time savings as important have at least 26 per cent higher values of time than those who assess such savings as less important.

**Speed selection with speed limits**

- The coefficient of EXP implies that the elasticity of drivers’ actual selected speed ($^\dagger$) with respect to driving experience is 0.009.

- The coefficient of AGE implies that the elasticity of drivers’ actual selected speed ($^\dagger$) with respect to age is -0.025 per cent.
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- Although SEX does have a significant effect on the selection of free speed it does not have a significant effect on drivers' actual speed in the presence of speed limits. A number of explanations for this effect are possible including the suggestion that male drivers have greater scruples than females in committing speeding offences.

- The coefficient of TTS implies that, other things being equal, car drivers who report that time savings are important to them actually drive 3.5 per cent faster than those who report travel time savings as being less important.

- The coefficient of PPC implies that drivers' actual selected speed is essentially unaffected by their perception of the perceived probability of being apprehended speeding. This result, combined with the significance of the PLC coefficients, suggests that drivers may in fact be responding in a risk-averse manner to enforcement measures, although the evidence here is by no means conclusive.

- The coefficients of PLC1 and PLC2 indicate that the higher a driver's perceived cost of being caught speeding, the lower is his actual speed over the surveyed section of road. In each case the transition from "low" to "moderate" and from "moderate" to "high" levels of perceived cost brings about a 2.4 per cent reduction in actual speed.

It is worth noting that over the actual ranges of the independent variables $x_i$ ($i = EXP.AGE.SEX.TTS$) the estimated value of $s^*$ is greater than the estimated value of $\bar{s}$ even if $PPC = PLC1 = PLC2 = 0$ (that is, minimal perceived expected penalty costs for speeding offences). This is to be expected since drivers' preferred free speed refers to the 90km/h zone on the surveyed section. It is likely that the driving conditions are poorer over the survey stretch where the speed limits are lower than in the 90km/h zone. It follows that the average speed without speed limits over the entire survey section would be lower than the value reported for the 90km/h zone.

Given the particular features of our data, it is therefore difficult to say whether the difference between $s^*$ and $\bar{s}$ where $PPC = PLC1 = PLC2 = 0$ reflects the influence of moral costs or not. If this is the case, however, then it is possible to claim that speed limits have some 'intrinsic' calming effect on drivers' speed selection (that is, $C(s) > 0$ when $s > s_{\text{max}}$ in equation (1*)).

5. Concluding Remarks

In this paper we have developed and estimated economic models of drivers' speed selection behaviour, both with and without the presence of speed limits. The empirical results indicate the importance of a number of different driver characteristics and attitudes on both free speed and 'limited' speed selection behaviour. The nature and magnitude of

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3 It is well known that risk-averse offenders are less deterred by a certain percentage increase in detection rate than by the same percentage increase in fines; see Becker (1968).
the empirical effects are reasonable and broadly in line with prior expectations. In particular, the key economic variables in our model (attitudes towards travel time savings and perceptions of the penalty costs for speeding) have been shown to have effects that conform closely to the strong prior expectations derived from the underlying economic model. The empirical results also suggest that certain moral hazard and risk aversion effects may also be present.

There are, however, a number of areas in which the current study might usefully be strengthened and extended in future work.

At a theoretical level, it would clearly be desirable to extend the framework of analysis to take explicit account of moral costs and also to accommodate a wider range of attitudes towards the risk of apprehension (in particular, risk aversion).

At a methodological level, there remain important issues to be addressed concerning appropriate means of assessing and measuring such concepts as desired free speed. In the current study drivers were simply asked to nominate this quantity, which is neither a natural nor entirely straightforward manner of approach. In the absence of suitable opportunities to make appropriate observations of paired ‘free speed’ and ‘limited speed’ selection behaviour, it might be appropriate to consider using a more sophisticated form of hypothetical questioning, perhaps employing techniques developed in stated preference work. This style of research would also potentially enable the empirical exploration of attitudinal and perceptual issues which might otherwise be difficult to approach. Another interesting and related possibility is the use of driving simulators to perform repeated measurements on the same individual, under a variety of travel and roadway conditions.

There were also significant limitations placed on the study by the nature of the specific empirical data to hand. Several of the key behavioural variables (such as drivers’ value of travel time) were available only through rather crude indicators. Here again, it is possible to imagine a situation in which stated preference methods might usefully be deployed to provide more satisfactory individual-level estimates of these quantities.

The rather low $R$-squared values for both the estimated models also point to the omission of a number of key explanatory variables. The most conspicuous ones are perhaps: (i) factors related to the vehicle (for example, size, type, vintage, and so on); (ii) factors related to safety considerations (for example, wearing of seat belts); (iii) factors related to the characteristics of the journey (for example, number of passengers, arrival time deadlines); and (iv) factors related to drivers’ knowledge and perceptions of speed limits and their attitudes towards risk.

Despite these limitations, the work has nevertheless established the feasibility of adopting a simple economic approach to modelling drivers’ speed selection behaviour, and therefore provides an important basis for the design and assessment of a range of traffic management and road safety policy interventions.

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Note, however, that Wasielewski (1984) did not find any significant relationship between speed and the weight of the car (the age of the car seemed to have a weak negative impact upon speed selection). Nor did Nilsson (1989) find any significant relationship between vehicle type and speed selection behaviour.
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