Disaggregate Analysis of Speeding Behavior of Drivers

MOSHE HIRSH

ABSTRACT

Speeding behavior of drivers is addressed by developing empirical models of speed choice that consider explicitly the drivers' speeding records together with their free speed choices. A data collection strategy for cases in which drivers' characteristics cannot be obtained from secondary sources is also presented. Two types of empirical models are developed: a binary choice model with alternatives of driving above the legal speed limit or driving under the speed limit, and a linear regression model. The estimation results support the hypothesis that speeding is the outcome of a choice that is made on a continuous scale rather than a discrete one. The application of continuous choice models is suggested to model speed choice in order to explain speed distributions. The factors that were found to affect drivers' speed choice significantly are (a) vehicle characteristics, including vehicle age and engine volume; (b) trip characteristics, including trip purpose and number of passengers; and (c) vehicle ownership. Drivers' speeding records were not found to significantly affect their speed choice.

Speeding behavior of drivers is addressed by developing empirical models of speed choice that consider explicitly drivers' speeding records together with their free speed choices. A data collection strategy for cases in which drivers' characteristics cannot be obtained from secondary sources is also presented.

Speeding is defined as driving a vehicle at a speed in excess of the maximum legal limit. According to Treat et al. (1), in-depth accident reports indicated that speeding is a conscious, intentionally undertaken behavior. Cleveland (2) suggests that drivers are relying on factors other than the speed limit in selecting their travel speed, but he does not provide any empirical evidence. Another study (3) reported some contradictory findings regarding the effect of speed limit on the drivers' choice of speed. The study claims that there is a general consensus that speed limits are disobeyed on a large scale, particularly where they are seen as unreasonably low.

Marks et al. (4) conducted a survey to determine the possible reasons for committing the "relative-speed-too-fast unsafe driving actions." In that study the various reasons are classified under the following three categories:

- Responses associated with the drivers: These include fear of enforcement, state of mind such as being late or in a hurry, being in a specific mood, use of alcohol or other drugs, and presence of passengers.
- Responses associated with the vehicle: These include vehicle type, vehicle condition, and vehicle ownership.
- Responses associated with the roadway: These include roadway locality, roadway characteristics, and roadway conditions.

Norstrom (5) developed a casual model for explaining speeding behavior. The model is based on empirical data obtained by mailed questionnaires on which speeding behavior is reported by the respondents. The researcher found that speeding is affected by age, motoring (defined as frequency of travel), and the assessment of the risk of speeding.

Few studies have been concerned with the effect of police enforcement on the behavior of drivers. There is evidence (6,7) that drivers react to the presence of enforcement by lowering their speed, but the reduction is temporary. There are few studies available on the effect of procedures that aim to increase the apprehension and punishment of traffic law violators. In particular, there are very few studies that examine subsequent behavior of drivers who were subjected to such policies. Fitts (8) studied the effect of written police warnings. To this end he compared the subsequent behavior of drivers who received a written warning and the subsequent behavior of drivers who received a citation for traffic law violation. The reported results are that the citation group committed fewer violations than were statistically expected, whereas the warning group committed more violations than were statistically expected. There is no comparison, however, of the subsequent behavior of drivers who received a citation or warning and the behavior of those who had never been caught for violating traffic laws.

Several studies (9,10) adopt microeconomic principles to explain drivers' speed behavior. The idea is that drivers are wealth maximizers, and as such they have some optimal driving speed that balances the value of time, the running cost, and the accident cost. These studies, however, do not present empirical models based on this theory.

Empirical models of drivers' speed choices were developed by studies (11,12) in which observed vehicle speeds were modeled as a function of drivers' characteristics, trip attributes, and vehicle characteristics. The concern in these studies is explaining the speed distribution with no explicit consideration of speeding behavior. Wasielewski (12) also included the number of accidents involved and a driver's violation points as explanatory variables in the model. Data were collected by photographing automobiles and their plate numbers and then obtaining additional demographic information about the owners of the vehicles through use of the plate number with the help of the appropriate authorities. Note, however, that this method is applicable only

The Transportation Center, Northwestern University, Evanston, Ill. 60201.

in states in which updated information is kept by the appropriate authorities and the authorities are cooperative. Also, this method provides data about vehicle owners only. However, the findings of this study suggest that vehicle ownership is a significant factor in a driver's choice of speed.

The following conclusions are drawn from the studies reviewed:

- A driver's free speed and his speeding behavior are the outcome of choice.
- Many factors affect the selection of travel speed, including the driver, the trip, the vehicle, and the road characteristics.
- There is evidence of the immediate effects of police enforcement on travel speed. However, the effect on subsequent behavior is unknown.

This paper deals explicitly with drivers' speeding behavior by developing a binary choice model that represents speeding choice and includes explicitly the driver's speeding record. The binary choice model is then compared with a continuous regression model calibrated on the same data set in order to gain insight into the appropriate ways to model and explain speed distributions.

SPEEDING CHOICE MODEL

The speeding choice model developed in this work is a binary choice model that estimates a driver's choice of two alternatives: (a) exceeding the speed limit or (b) traveling at or under the speed limit.

The behavioral basis of the discrete choice model lies within its structure. The discrete choice model assumes that the driver can assign a utility to each alternative in his choice set. The driver is then assumed to select the alternative with the highest utility. For a variety of reasons, the utility of each alternative can be treated, from the analyst's point of view, as a random variable. The two alternatives are denoted i and j, and the utility of each alternative as U_i and U_j, respectively. Because the utilities are random variables, each utility is divided into two additive parts:

$$U_i = V_i + e_i$$

$$U_j = V_j + e_j \quad (1)$$

where V_i and V_j are the systematic components of the utility and e_i and e_j are the random components. Assuming that the random components are independent and identically distributed (IID) and that the distribution of each is Gumbel, it can be shown (13) that the probability that a driver will prefer alternative i over j is given by the following logit model:

$$\begin{aligned} Pr(i) &= Pr(U_i > U_j) \\ &= \exp(V_i)/[\exp(V_i) + \exp(V_j)] \end{aligned} \quad (2)$$

The systematic component of the utility can be expressed as

$$V = bx \quad (3)$$

where x is a vector representing the driver and the alternative attributes and b is a vector of coefficients.

The model in Cleveland (2) is calibrated using observed behavior; that is, the actual choice of each driver. Estimation of the choice model with linear specification of systematic utility (3) can be easily accomplished with available software packages. The attribute vector (x) can include explanatory variables like the driver, the trip, the vehicle, and the road characteristics and the attributes of the alternatives (e.g., the expected trip time and trip cost for each alternative).

The choice model assumes that the underlying process of choosing is discrete. That is, drivers consider explicitly the choice of driving above or under the legal speed limit. However, an alternative process can be specified in which the speed limit may be only one of many relevant factors affecting choice of speed, and that choice may be made over a continuous scale rather than a discrete one. To test this hypothesis, there is a need to compare the discrete model with an alternative continuous model using the same data set. Hence, a regression model is also developed in this paper.

The regression model is an empirical model that correlates observed speed with various attributes. The behavioral basis of the regression model lies mainly within the scope of its independent variables. The specification of the regression model is the following:

$$y = x \cdot b + e \quad (4)$$

where y is the driver's travel speed, x is a vector of attributes, b is a vector of coefficients, and e is the random error component. The effect of the speed limit can be introduced into the regression model as an explanatory variable. For this, however, observations from several locations with various speed limit conditions are needed.

DATA SET

In this section is described the data collection effort conducted in 1982 in Israel for this study. At that time there were only three freeway sections in Israel. The major freeway section was part of the highway connecting the cities of Haifa and Tel Aviv. The speed limit on this freeway was 90 km/hr (around 55 mph). Drivers were intercepted at three gas stations located at entrances to the freeway. The drivers were interviewed while waiting to be serviced (there was no self-service option at those stations). They were told that the purpose of the survey was a study on fuel consumption patterns.

Before the interview, the following information was observed and recorded for each vehicle: vehicle make and color, full license plate number, drivers' gender, estimated age group of the driver (under 20, 20 to 30, 30 to 40, 40 to 50, and above 50), and number of children and adult passengers in the vehicle. The drivers were then asked to provide the following information: trip destination; engine volume; vehicle age; trip purpose; educational level of the driver; marital status of the driver; ownership of the vehicle; whether the driver had ever been caught by the police for speeding and, if so, when was the last time.

The last two items called for self-report of illegal behavior and thus are subject to some distortion. As Marks et al. (4) point out, it is reasonable to assume that drivers' answers will be affected by the social desirability phenomenon. The driver may wish to give a certain picture of himself or to impress the interviewer favorably or to preserve this own self-image, and thus provide a distorted answer. Cook and Selltiz (14) suggest that a data collection method should include the following elements in order to increase data reliability: assurance of anonymity, emphasizing the importance of honest answers in order to contribute to the desired outcomes, inclusion of items that are irrelevant to the behavior in which

the interviewer is interested, building up rapport between the interviewer and the respondent, and building an atmosphere in which an unfavorable reply is likely to be considered acceptable.

Given these considerations, careful attention was paid to the data collection procedure. At the time of the survey there was a proposal to deregulate the fuel market in Israel. Thus the drivers were told that the survey was about fuel consumption habits, and questions were included to support this impression. Toward the end of the interview (which lasted 2 to 3 min only), the driver was asked if travel speed affects fuel consumption. The next question was: "At what speed do you usually travel the freeway section between Haifa and Tel Aviv?" Only after this question was the driver asked whether he had been caught in the past by the police for speeding, and when was the last time. The interviewers reported that none of the drivers refused to answer that question.

The data collection was conducted for several days during early morning. Because the number of drivers who entered the gas stations was small, it was possible to approach all the drivers so there was no need to sample.

At the same time, another group of two observers was set at a point on the freeway located about 20 km (13.5 mi) from the gas stations. This point was in the middle of a level and straight highway section, so there were no geometric constraints on speed. The time from the interview at the gas station until the vehicles reached the second point was 25 to 30 min.

Using an audiocassette recorder, the two observers recorded the free speed of vehicles at that point. The speed was measured only for vehicles traveling alone and not in a platoon. A vehicle was considered part of a platoon if at any point along the straight section the observers could have suspected that the car was following another vehicle. Free speed was measured by a speed gun; one observer called out the vehicle make, color, and plate number, and the other read the measured speed. It is evident that this method could not record the free speed of all the drivers who were intercepted at the gas stations. The matching rate was 55 percent, meaning that the free speed of 45 percent of the intercepted drivers could not be measured for various reasons. Ten hours of measurements conducted in 5 days resulted in a sample of 186 drivers for whom both free speed and desired attributes were available. The average speed was 86.9 km/hr with standard deviation of 8.6 km/hr. Twenty-one percent of the drivers were traveling above the speed limit of 90 km/hr and 7 percent were traveling at a speed of more than 100 km/hr. Thirty-one percent of the drivers reported that they had a speeding record with the police.

ESTIMATION RESULTS

The estimation results for the binary choice model and the regression model are given in Tables 1 and 2, respectively. Comparing the two models, the first conclusion that can be drawn is that the binary choice model is inferior to the regression model in explaining drivers' speed choice. Whereas the regression model exhibits several significant variables and an R^2 value of 0.42, the binary choice model has only one significant variable with a relatively poor value of ρ^2.

This result implies that the process of choosing speed takes place on a continuous scale and that by representing it with a binary choice set only, most of the variability in drivers' behavior is lost. One implication is that speeding behavior is the outcome of a choice that is affected by many factors, and the speed limit is not the most important one. This hypothesis, however, can be tested more rigorously by introducing explicitly the speed limit into the regression model. In this case, however, data reflecting various speed limit conditions were not available.

TABLE 1 Binary Choice Model

Variable	Estimate	t
Dummy for speeding	-0.2	0.5
Use of own vehicle	-1.7	2.0
Trip for social visit	0.4	0.1
Vehicle less than 5 years	0.8	2.4
Vehicle 5-10 years	0.2	0.4
Engine volume > 1600 cm^3	0.4	1.3
College education	-0.3	0.9
Driver under 30	0.1	0.7
No. of passengers	-0.2	1.2
Driver has speeding record	-1.2	1.1

Note: $\mathcal{L}(0) = -46.4$, $\mathcal{L}(\hat{\beta}) = -40.7$, and $\rho^2 = 0.12$.

TABLE 2 Regression Model

Variable	Estimate	t
Use of own vehicle	-4.2	2.8
Trip for social visit	8.9	3.2
Vehicle less than 5 years	7.9	3.7
Vehicle 5-10 years	2.6	1.9
Engine volume > 1600 cm^3	4.5	2.1
No. of passengers	-1.2	2.3
College education	-1.5	0.9
Driver under 30	-2.5	1.3
Driver has speeding record	-1.8	1.1
Constant	80.4	

Note: $R^2 = 0.42$.

Thus, if speed choice models are to be developed, continuous choice models should be tested rather than discrete ones. Recently, there has been progress in the development and application of continuous choice models [e.g., Ben-Akiva et al. (15)], and the continuous logit model, for example, may prove to be useful in modeling drivers' choice of speeds.

Because the regression model proved to be better, the following discussion is based on the estimation results for this model that are given in Table 2.

The vehicle characteristics are represented by a set of dummy variables that describe the vehicle age and its engine volume. These variables are found to be significant: the main effect belongs to the vintage of the vehicle. Drivers of newer automobiles drive significantly faster than drivers of older ones. The same applies to drivers of larger automobiles who drive faster than those who have smaller automobiles. These results show that the vehicle capabilities play a major role in drivers' choice of speed.

Drivers' characteristics were not found to affect significantly their speed choice. Note that the coefficient for drivers younger than 30 years old is negative, which implies that younger drivers drive slower than older drivers. This result contradicts the findings of other studies. A possible explanation is that young drivers in Israel own small or old automobiles because of the extremely high prices of cars. The educational level of the driver was not found to be significant. As for gender, 96 percent of the sample population were males; thus analysis of the effect of this variable is impossible.

Vehicle ownership proved to be a significant variable with the expected direction of influence. Drivers whose household owned the automobile were driving significantly slower than those who traveled

using somebody else's vehicle. The probable explanation is that drivers who own the vehicle have to pay by themselves the out-of-pocket costs of the trip and thus try to minimize their trip cost by lowering their travel speed. Another possible explanation is that drivers who do not own the vehicle also do not have to pay for a speeding ticket if they are caught for speeding.

Trip characteristics are represented by the trip purpose and by the number of passengers. The results show that when the trip is for a social visit, the drivers tend to drive significantly faster than they do for other purposes. The presence of other passengers in the car contributes to a slight decrease in travel speed.

The driver's speeding record is represented by a dummy variable that indicates whether the driver has ever been caught for speeding. The estimation results show an insignificant decrease in the travel speed of drivers with speeding records. This implies that enforcement does not have a continuing effect, and subsequent speed choice is not affected by a driver's speeding record. On the other hand, the results do not support the hypothesis that speeding is habitual behavior; that is, that drivers who were speeding in the past are likely to be speeding again.

These results demonstrate the advantages of using disaggregate methods in analyzing driver behavior. The type of explanatory variables that can be used in the disaggregate analysis offer better possibilities for explaining driver behavior than does the commonly used aggregate analysis.

SUMMARY

A disaggregate analysis of drivers' speeding behavior has been presented. The disaggregate framework enabled the study of the effect of some variables that otherwise would have been difficult to identify such as trip purpose, number of passengers, vehicle ownership, and driver's speeding record. Data were collected by interviewing drivers and observing their free speeds later. This data collection strategy is proposed in cases in which information is not available from sources other than the driver. Two types of empirical model were developed: a linear regression model and a discrete binary choice model with the alternatives of traveling above or under the speed limit. The estimation results show that the continuous model represents the behavior of drivers better than the discrete choice model. It is concluded that speeding is an outcome of a choosing process that is affected by many factors, among them the speed limit.

The factors that were found to significantly affect drivers' speed choices are (a) vehicle characteristics, including vehicle age and engine volume; (b) trip characteristics, including trip purpose and number of passengers; and (c) vehicle ownership. Drivers' speeding records were not found to significantly affect their speed choices.

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