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Speed enforcement in Norway: Testing a game-theoretic model of the interaction between drivers and the police

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ABSTRACT

This paper probes the relationship between changes in the risk of apprehension for speeding in Norway and changes in the amount of speeding. The paper is based on a game-theoretic model of how the rate of violations and the amount of enforcement is determined by the interaction between drivers and the police. This model makes predictions both about how drivers will adapt to changes in the amount of enforcement (the more enforcement, the less violations) as well as how the police will adapt to changes in the rate of violations (the less violations, the less enforcement). The paper attempts to test the game-theoretic model empirically. Testing the model rigorously is difficult, mainly because some of the relevant variables are not reliably measured and are endogenous. Two models were developed: one to identify sources of changes in the rate of violations, one to identify sources of changes in the amount of enforcement. The predictions of the game-theoretic model were supported, although the results were not statistically significant in the model of how the police adapt enforcement to changes in the rate of violations.

1. Introduction

Traffic offences remain a large road safety problem. An estimate for Norway (Elvik, 2011) suggests that the number of traffic fatalities can be reduced by more than 50 percent and the number of traffic injuries reduced by more than 30 percent by eliminating 15 different traffic violations. Eliminating traffic offences is not a realistic objective in the short run. There are limits to how much police enforcement there can be. The police cannot be everywhere at all times. Technology such as speed cameras is used to enforce traffic law. However, this technology is expensive and cannot be deployed everywhere at all times. Vehicle technology, like speed monitoring and recording systems, can in principle replace current means of enforcement, but is still not widely used.

One potential limit to conventional police enforcement that has not been studied extensively, is how the police adapt enforcement to changes in the rate of violations. If the rate of a certain violation is very low, as is the case in Norway for drinking-and-driving (which makes up less than 0.5 percent of all driving), the police may find it unproductive to do enforcement specifically targeted at the violation, because they would need to check hundreds or maybe thousands of sober drivers before encountering a drunk driver. A game-theoretic model of police enforcement proposed by Bjørnskau and Elvik (1992) suggests that the police reduce enforcement in response to a decline in violations and increase it in response to an increase in violations. If this is the case, enforcement will in the long run never become sufficient to deter all violations. Once violations drop to a low level, the police will reduce enforcement, which in turn will lead to more violations. This pattern may repeat itself many times, as there is no stable equilibrium in the game.

The objective of this paper is to test the game-theoretic model of police enforcement empirically. This is done by means of data on speeding and speed enforcement in Norway for the years 2004–2013. The game-theoretic model will first be presented. Then, data relevant for testing the model will be discussed.

2. A game-theoretic model of speed enforcement

The logic of the game-theoretic model of speed enforcement is perhaps best understood by explaining it by reference to a numerical example, taken from Bjørnskau and Elvik (1992) and reproduced in Table 1.

Table 1 shows the game in normal form. The entries are the payoffs to drivers and the police associated with the various choices.

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Table 1
A game-theoretic model of speeding and speed enforcement.

		The police	
		Enforce	Not enforce
Drivers	Violate speed limit	−10,000 −300	−20,000 50
	Not violate speed limit	−10,000 −50	0 −50

The payoff to the police is indicated in the upper right corner of each cell of the Table. The payoff to drivers is indicated in the lower left corner of each cell of the Table. Starting in the upper left cell, it can be seen that drivers can improve their payoff (from −300 to −50) by complying with the speed limit. This will result in a move to the lower left cell of the Table. However, once drivers comply with speed limits, it is seen that the police can improve their payoff (from −10,000 to 0) by not enforcing. This results in a move to the lower right cell of the Table. From that cell, it is seen that drivers can improve their payoff (from −50 to 50) by speeding. This results in a move to the upper right cell of the Table. However, when drivers are speeding, the police can improve their payoff (from −20,000 to −10,000) by enforcing. This brings the game back to the upper left cell where it started and the circle can go on forever. The game, in other words, has no solution in pure strategies.

It does have a solution in mixed strategies. A mixed strategy is to choose between the pure strategies with certain probabilities. Thus, with the payoffs used as example in Table 1, the police should enforce with a probability of 0.2857 and not enforce with a probability of 0.7143. Drivers should speed with a probability of 0.50 and not speed with a probability of 0.50. See the paper by Bjørnskau and Elvik (1992) for details regarding how the mixed-strategy solution was obtained.

What are the main implications of the game-theoretic model? The following implications are relevant for empirical testing of the model:

1. When enforcement increases, the rate of violations will be reduced.
2. When enforcement decreases, the rate of violations will increase.
3. When the rate of violations increases, enforcement will increase.
4. When the rate of violations decreases, enforcement will decrease.
5. Making sanctions more severe will have no effect on the rate of violations.
6. Making sanctions more severe will lead to less enforcement.

3. Data on speeding and enforcement

To test the game-theoretic model, data are needed about the rate of violations, the amount of enforcement and changes in these variables over time. The rate of violations is the number of offences committed divided by vehicle kilometres of travel. For most traffic offences, the rate of violations is unknown, since most violations go undetected. A few violations are, however, recorded in a sufficiently systematic manner to permit an estimation of their rate of occurrence. The focus of this study is speeding, the rate of which is defined as (Elvik and Amundsen, 2014):

$$\text{Rate of speeding} = \frac{\text{Kilometers driven while speeding}}{\text{Total kilometers of travel}}$$

The data used to estimate the rate of speeding were provided by the Public Roads Administration on an Excel spreadsheet. For each of the speed limits 50, 60, 70, 80, 90 and 100 km/h the data showed mean speed, 85 percentile speed and percentage of vehicles above the speed limit. Annual data for the years from 2004 to 2013 were provided. Three ranges of speeding were defined for the analyses reported in this paper:

1. Speeding between 6 and 10.9 km per hour above the speed limit
2. Speeding between 11 and 15.9 km per hour above the speed limit.
3. Speeding 16 km per hour or more above the speed limit.

Small violations, less than 6 km per hour above the speed limit, are tolerated. The effective risk of apprehension for speeding by less than 6 km per hour is zero.

The other key concept of the study is the amount of enforcement. Unfortunately, there is only crude summary information available about this, in the form of the total number of drivers stopped by the police each year. This number cannot be broken down according to the reason for stopping drivers, such as speeding, running red lights, etc. As a proxy for enforcement, the citation rate for speeding has therefore been used. Citation rate is measured as the number of citations per million kilometres driven while committing a violation:

$$\text{Citation rate} = \frac{\text{Numbers of citations}}{\text{Kilometers driven while speeding}}$$

Citation rate may not be strictly proportional to the amount of enforcement. Thus, as an example, if enforcement is increased by a factor of four one might expect the number of citations to increase by a factor of, for example, three if the increase in enforcement deters some violations. In Norway, however, the citation rate for speeding is extremely low, on the average only a little more than 10 citations per million vehicle kilometres driven while speeding (Elvik and Amundsen, 2014). Even if the citation rate was doubled, the probability that a speeding driver would be cited would remain very low. The citation rate for speeding in Norway is therefore probably nearly proportional to the amount of enforcement. Police statistics support this assumption. Between 2004 and 2013 the number of citations for speeding remained close to 12 percent of the total number of drivers stopped by the police, with no clear trend over time.

There are three types of citations (sanctions) for speeding in Norway:

1. Fixed penalties. These are traffic tickets with standardised amounts to be paid, issued on the spot. If the road user pleads guilty, the case is closed. They are used for speeding up to about 35 km per hour above the speed limit.
2. Fines. These are traffic tickets determined on a case-by-case basis with regard to the income of the road user. They are used for speeding by more than 35 km per hour above the speed limit.
3. Formal charges. For serious traffic offences, the police will file formal charges and the case will go to court. This is used for speeding by more than about 50 km per hour above the speed limit.

Statistics on the number of citations issued each year are kept both by the police and by the Norwegian National Collection Agency. These statistics are quite detailed and were obtained on Excel spreadsheets. Years from 2004 to 2013 were used (Elvik and Amundsen, 2014).

Estimates of the total number of vehicle kilometres of travel, kilometres driven while speeding and the number of citations for speeding are given in Table 2 for each year from 2004 to 2013. A distinction is made between speed limits up to 60 km per hour and speed limits from 70 km per hour and above. The reason for defining these two groups is that the fixed penalties for speeding are different in the two groups.