FACULTY OF ECONOMICS AND
APPLIED ECONOMIC SCIENCES
CENTER FOR ECONOMIC STUDIES
ENERGY, TRANSPORT & ENVIRONMENT

KATHOLIEKE
UNIVERSITEIT
LEUVEN

WORKING PAPER SERIES
n°2007-02

Catching or Fining Speeders: A Political Economy Approach

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May 2007

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Catching or Fining Speeders: A Political Economy Approach [1]

3/29/2007

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Abstract:

According to Becker (1968) it is best to use very high fines and low inspection probabilities to deter traffic accidents because inspection is costly. This paper uses a political economy model to analyse the choice of the fine and the inspection probability. There are two lobby groups: the vulnerable road users and the 'strong' road users. If only vulnerable road users are effective in lobbying, we find that the expected fine is higher than if only the interests of car drivers are taken into account. When we consider the choice between inspection probability and the magnitude of the fine for a given expected fine, we find that the fine preferred by the vulnerable road users is higher than socially optimal. The reverse holds if only the car drivers are effective lobbyists. The orders of magnitude are illustrated numerically for speeding and contrasted with current fines for drunk driving in the European Union.

Keywords: Political economy, enforcement, traffic safety

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[1] We thank Bruno De Borger, Erik Schokkaert, Erik Verhoef and Dirk Heremans for helpful comments on a first draft. Eef Delhaye would like to acknowledge the financial support of the Belgian Federal Science Policy research program – Indicators for sustainable development – contract CP/01/38 (Economic Analysis of Traffic Safety: Theory and Applications). Further Sandra Rousseau would like to acknowledge the financial support of the FWO project 'An economic approach to modeling enforcement of environmental regulation'.

1. INTRODUCTION

In order to increase road safety, there are different monitoring and enforcement strategies to put speed limitations into effect. In general, the public debate emphasises raising the probability of detecting speed violations rather than increasing the fines. This observation conflicts with economic theory[2] that leads to fines set at the highest possible level and minimal (costly) monitoring efforts. In Europe, we see at present large variations in the magnitude of speeding fines[3] and in the probability of detection. Think for example of the variation in enforcement strategies to deter drunk driving in the European Union, which is shown in the final section.

In this paper we look at the forces behind the monitoring and enforcement decisions for speeding. We see public policy as the outcome of a political process that is influenced by lobbying efforts of different interest groups. As an example, we mention the debate triggered by the reform of the enforcement of speed violations in Belgium (March 2006). Several interest groups held conflicting views as illustrated by the following (translated) newspaper headlines:

"The auto lobby is too aggressive" according to the Association of Parents of Road Traffic Victims (De Morgen, 29 March 2006)

"Unjust, these excessive fines. They were 'draconic measures'." according to the Flemish Automobile Association (De Morgen, 29 March 2006)

"It is perfectly defendable to limit high fines. On condition that more resources are spend on an efficient enforcement policy." E. Glorieux, Green political party (De Standaard, 31 March 2006)

We can therefore wonder whether interest groups can influence monitoring and enforcement policies. In the model of Dixit ea (1997) several principals (lobbyists) simultaneously try to control the actions of an agent (policy maker) by promising contributions in return for policy favours. Dixit ea (1997) apply the model to income taxation, while Aidt (1998) uses the model to analyse environmental policy. There might also be other reasons why policy makers opt for high monitoring efforts and low fine levels rather than the theoretically optimal high fines and low inspection probabilities. One can, for instance, use a model of voter behaviour like Barro (1973). Recently, Makowsky and Stratmann (2007) study the political economy determinants of traffic fines. They empirically estimate the influence of the incentives faced

[2] See for example Becker (1968), Polinsky and Shavell (1979) and Shavell (2004)

[3] European Commission (2004)

by police officers and their vote maximizing principals on speeding tickets. Their findings indeed show that the size of the violation is not the sole determinant of the fine and that it is also determined by the police officers' objective functions.

In this paper, we use the common agency model[4] of Dixit ea (1997) to understand the influence of different lobby groups. We only take two categories of individual agents into account: vulnerable road users and strong road users. First, we analyse the preferred expected fine, i.e. the optimal combinations of the inspection frequency and the magnitude of the fine. The socially optimal combinations serve as a benchmark. This benchmark is then compared to two lobbying equilibriums: first, when the vulnerable road users form the only effective lobby group and, secondly, when the strong road users get all the lobbying weight. We argue that vulnerable road users opt for a higher expected fine than is socially optimal because, in our model, they bear all the accident losses. The strong road users, on the other hand, prefer a very low expected fine since they have to pay the fines and see none of the benefits associated with an increase in traffic safety. Next, we determine numerically the optimal combination of the inspection and fine parameters when the expected fine is kept fixed. In that case, we find that vulnerable road users opt for high fines and a low probability of detection, while strong road users prefer a high probability of detection and low fines. The main explanation for these findings is that increasing the inspection probability is costly for society as a whole, while increasing the fine has no social costs and only affects the car drivers that violate the speed limit.

Our contribution to the existing literature is twofold. First, we use lobby groups to understand the level of the expected fine as well as the choice between the inspection probability and the level of the fine. Second, we incorporate imperfect compliance into the lobbying model.

Section two presents the theoretical model. Section three presents a numerical illustration of the factors at work. Section four concludes.

2. MODEL

The model under consideration focuses on the level of the expected fine and the trade-off between higher fines and a higher probability of detection, but it can also be used to analyse other safety policy options such as road safety investments. We examine different

[4] This model of interest groups' influence is based on the common agency model of Bernheim and Winston (1986). Grossman and Helpman (2001) provide an excellent introduction to the theoretical literature on interest group politics.

combinations of inspection frequency and fines and use the political weight of different interest groups to explain the variations in the monitoring and enforcement policy that are selected by the policy makers.

2.1. Assumptions

We assume that there are three economic agents:

- Vulnerable road users (v): children, pedestrians, bicyclists. These individuals are homogenous and have an identical value of time.
- Strong road users (c): car or truck drivers who prefer higher speeds to lower ones. They differ with respect to their valuation of time and are therefore heterogeneous.
- The government, who can take the revenue of the fines, cost of enforcement, social costs of accidents and private cost of driving into account.

The total population N consists of N_v vulnerable road users and N_c car drivers with $N = N_v + N_c$. We assume that car drivers are risk averse in their income. Polinsky and Shavell (1979) discuss the impact of risk aversion on the trade-off between the probability and the level of the fine[5]. Contrary to Becker (1968), the optimal fine level is shown to be lower than the maximal fine in the presence of risk averse individuals and measurement errors.

Car drivers are subject to an exogenously given[6] speed limit $\bar{s}$. They drive at speed s such that their utility is maximised. If drivers exceed the speed limit, they are caught with probability π. This probability of detection does not depend on the probability of having an accident[7] nor on the magnitude of the violation. As a case in point, speed cameras are not more likely to film a driver at 120 km/h than one driving at 100 km/h. The costs of

[5] Bar-Ilan (2000) has also considered the risk attitude of road users in order to analyse the behaviour of red light runners. Red light runners are shown to be risk lovers and this explains why they are not deterred by the high expected damages (injuries or even death) combined with the low probabilities of having these damages.

[6] Graves ea (1989) model the policy choice between speed limits and the probability of detection. They show that raising the level of policing is likely to have a lower social cost, at the margin, than lowering the speed limits.

[7] It would be more correct to use $\tilde{\pi} \equiv (1-p(s))[\pi] + p(s) = [\pi + p(s)(1-\pi)]$ instead of π. $\tilde{\pi}$ means that with probability $(1-p(s))$ the car driver is not involved in an accident; then he has probability π that he has to pay a fine if he speeds; with probability p(s) he has an accident and if he then speeded, the probability of a fine equals one. If a person does not speed, $\pi = \tilde{\pi} = 0$

enforcement consist of a fixed enforcement cost C_E^F (for example, the cost of a speed camera) and a variable enforcement cost C_E^V (for example, the administrative cost of writing a notice of violation). The total enforcement cost is thus an increasing and convex function of the probability of detection and the number of violators.

Once violators are caught, they face a fine $F(s) = ff + vf(s - \bar{s})$ with ff the fixed fine, vf the variable fine and $\begin{cases} F(s) = 0 \text{ if } s \leq \bar{s} \\ F(s) > 0 \text{ if } s > \bar{s} \end{cases}$. This fine is increasing with the seriousness of the infraction and linear[8]: $F'(s) > 0$ and $F''(s) = 0$.

2.2. *Modelling agents' behaviour*

In this section we discuss the behaviour of the three economic agents: vulnerable and strong road users, who are utility maximisers; and the government, which maximises an objective function for which we do not specify the origin. We model, using backward induction, the road users' reaction to the selected monitoring and enforcement policy. Next, we determine the government's preferred monitoring and enforcement strategy for a given level of lobbying activity and the previously determined reaction functions of the road users.

(a) Vulnerable road user

We assume that the utility of the vulnerable road users U_v is quasi-linear and determined by the consumption of other goods, x_v (price normalised to 1), the number of trips taken, $\overline{TR}_v$ (fixed per individual) and the expected accident costs, $p(s)h$, with $p(s)$ the probability per trip of having an accident and *h* the harm caused by the accident[9]. Note that, even though the harm is independent of speed, the expected harm is not.

Utility, which is additive in trips and consumption, then equals

$$\begin{aligned} U_v &= x_v + \overline{TR}_v \left[\gamma_v - p(s)h - \left[1 - p(s)\right]0 \right] \\ &= x_v + \overline{TR}_v \left[\gamma_v - p(s)h \right] \end{aligned} \qquad (1)$$

with a constant marginal utility of a trip γ_v for a vulnerable road user.

[8] In practice, for example in Belgium, linear fines are often used for speed violation because they are easy to communicate and to implement.

[9] Assuming that vulnerable road users are risk averse to harm does not change the results qualitatively.

The vulnerable road user maximises his utility with respect to his budget constraint

$$x_v \leq Y_v + L \tag{2}$$

The individual's consumption of other goods must be smaller than the sum of the exogenously given income Y_v and the lump sum transfer L[10].

This gives us the expression for the indirect utility

$$V_V = Y_v + L + \overline{TR}_v \left[\gamma_v - p(s) h \right] \tag{3}$$

(b) Strong road user

The strong road users differ in their value of time $t \in [t_1, t_2]$ and will, therefore, not all drive at the same speed. We assume that the value of time is continuously, uniformly distributed with probability density $\frac{1}{t_2 - t_1}$ and cumulative distribution $\frac{t - t_1}{t_2 - t_1}$.

The utility U_c of the strong road users is determined by their consumption of other goods, x_c (price equal to 1), the constant[11] number of trips they take, $\overline{TR}_c$, the constant marginal utility of a trip, γ_c, the time cost of making the trip $C_T(t,s)$ (with $\frac{\partial C_T}{\partial t} > 0, \frac{\partial C_T}{\partial s} < 0, \frac{\partial^2 C_T}{\partial t^2} = 0$ and $\frac{\partial^2 C_T}{\partial s^2} > 0$) and the disutility $R^a(F(s))$ of risking to pay a fine per trip[12]:

$$U_c = x_c + \overline{TR}_c \gamma_c - \overline{TR}_c C_T(t,s) - \overline{TR}_c \, \pi \, R^a(F(s)) \tag{4}$$

In order to implement the model of Dixit ea (1997), a quasi-linear utility function is assumed and the car driver is only risk averse with respect to the fine payments. We assume that the disutility of the fine takes a quadratic form

$$R^a(F(s)) = \alpha_c^a F(s) + \frac{\beta_c}{2} F(s)^2 \tag{5}$$

[10] We normalise the cost of taking a trip as a vulnerable road user to zero.

[11] If the number of trips is not constant then it depends also on the value of time. This assumption does not really affect our insights.

[12] We assume that the strong road users do not incur any accident losses. This can be considered as a normalisation since in accidents between strong and vulnerable road users, the losses of the strong road user will be negligible.

The car driver maximises his utility with respect to his budget constraint. The private monetary cost of driving $C_M(s)$ is a function of the speed s the driver selects. The private monetary costs include the resource cost and the fuel cost with $\frac{\partial C_M}{\partial s} \leq 0$ and $\frac{\partial^2 C_M}{\partial s^2} \geq 0$. The budget restriction thus equals[13]:

$$x_c \leq Y_c + L - \left[\pi F(s) + C_M(s)\right]\overline{TR}_c \qquad (6)$$

The car driver's indirect utility then takes the following form:

$$V_c = Y_c + L + \overline{TR}_c\left[\gamma_c - C_T(t,s) - C_M(s) - \pi R\left(F(s)\right)\right] \qquad (7)$$

With $R\left(F(s)\right) \equiv F(s) + R^a\left(F(s)\right) = \left[1+\alpha_c^a\right]F(s) + \frac{\beta_c}{2}F(s)^2 \equiv \alpha_c F(s) + \frac{\beta_c}{2}F(s)^2$.

The Arrow-Pratt measure of risk aversion for the fine equals $r = -\frac{V''}{V'}$ and thus

$$\frac{\partial V_c}{\partial F(s)} = -\overline{TR}_c\pi\left[\alpha_c + \beta_c F(s)\right]$$
$$\frac{\partial^2 V_c}{\partial F(s)^2} = -\overline{TR}_c\pi\beta_c$$

Assuming risk aversion, $r = -\frac{\beta_c}{\alpha_c + \beta_c F(s)} > 0$, imposes two conditions on the parameters α_c and β_c[14]:

$$\beta_c < 0 \quad and \quad \frac{\alpha_c}{-\beta_c} > F(s) \qquad (8)$$

We also know that, if car drivers are risk averse, they prefer a high probability of detection combined with a lower fine to a lower probability and a higher fine with the same expected value (Rothschild and Stiglitz, 1970 and 1971).

We use a two-stage approach to model the strong road users' individual reaction to the monitoring and enforcement policy adopted by the policy maker. In the first stage, the driver decides whether to comply with the speed limit or not. The decision variable is $z(t)$, which is

[13] In this model we normalise the private accident costs to zero. The results of the analysis will not change qualitatively as long as strong road users do not fully internalise total accident costs. In general, people do not take into account the full accident costs due to, among other things, insurance, judgement proof issues or the underestimation of the probability of being involved in an accident.

[14] We assume that the second condition can be met since, in practice, speed has an upper limit and therefore the possible fine that can be imposed is also limited.

one if the driver is in violation and zero if he is compliant. In the second stage, the driver decides on the speed *s* that he will drive.

Using backward induction, we first calculate the level of speed for a given compliance decision. If car drivers comply $\left(z(t)=0\right)$, their private optimal speed s^o is below or equal to the speed limit. An interior solution $\hat{s}$ is defined by

$$\left.\frac{\partial V_c}{\partial s}\right|_{z=0} = \frac{\partial C_T(s,t)}{\partial s} + \frac{\partial C_M(s)}{\partial s} = 0$$

Hence, the private optimal speed $s^o(t)$, given that the driver complies, is given by

$$s^o(t) = \begin{cases} 0 & \text{if } \hat{s}(t) < 0 \\ \hat{s}(t) & \text{if } 0 \le \hat{s}(t) \le \bar{s} \\ \bar{s} & \text{if } \hat{s}(t) > \bar{s} \end{cases} \tag{9}$$

The first order condition for drivers, who decide to ignore the speed limit $\left(z(t)=1\right)$, determines $\hat{\hat{s}}$:

$$\begin{aligned} \left.\frac{\partial V_c}{\partial s}\right|_{z=1} &= \overline{TR}_c\left[-\frac{\partial C_T(s,t)}{\partial s} - \frac{\partial C_M(s)}{\partial s} - \pi\frac{\partial R\left(F(s)\right)}{\partial s}\right] = 0 \\ \Rightarrow \frac{\partial C_T(s,t)}{\partial s} + \frac{\partial C_M(s)}{\partial s} &= -\pi\frac{\partial R\left(F(s)\right)}{\partial s} \end{aligned} \tag{10}$$

The private optimal speed $s^{oo}\left(\equiv s^{oo}(t,\pi,F) = \max\left[\hat{\hat{s}},\bar{s}\right]\right)$ is determined by equating the marginal benefit to the marginal cost of driving faster. The marginal benefit is the reduction in private costs of driving one km/h faster. The marginal cost represents the disutility of the expected change in the fine due to the increase in speed.

Using these results, we now turn to the driver's compliance decision. A driver speeds if the following condition is met:

$$z(t) = 1 \text{ if } D > 0 \;\text{ with } D = V_c\big|_{z=1} - V_c\big|_{z=0} \tag{11}$$

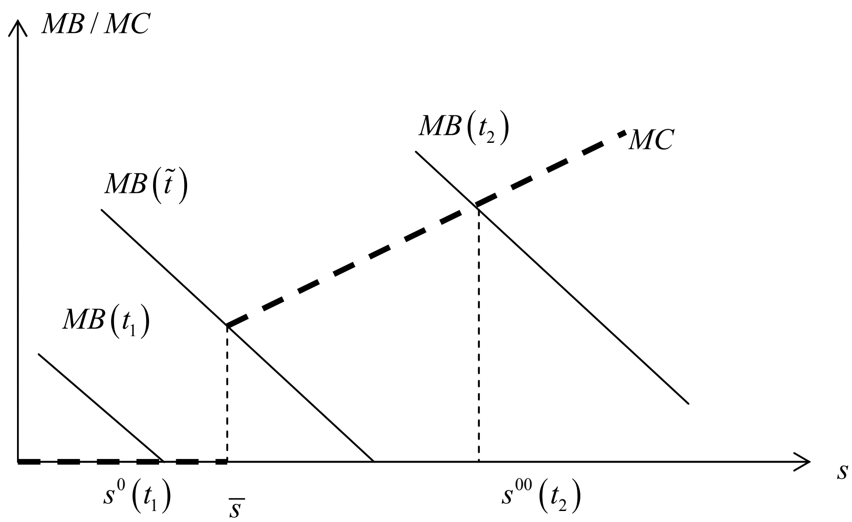
The driver will speed if the utility of complying is lower than the benefit of violating and risking the fine. There exists a certain value of time for which drivers are indifferent between speeding or not $(D=0)$. This cut-off point $\tilde{t}$ is a function of π and $F(s)$ and is defined by the equality of the net driving cost without speeding (speed s^0) and the net driving cost of speeding (speed s^{00})

$$\left[C_T\left(\tilde{t},s^o\right) + C_M\left(s^o\right)\right] - \left[C_T\left(\tilde{t},s^{oo}\right) + C_M\left(s^{oo}\right)\right] - \pi R\left(F\left(s^{oo}\right)\right) = 0 \tag{12}$$

Given that the value of time is uniformly distributed, we know that a proportion $\frac{\tilde{t}-t_1}{t_2-t_1}$ of the N_c strong road users comply and a proportion $\frac{t_2-\tilde{t}}{t_2-t_1}$ speed.

We show the speed decision in Figure 1. On the horizontal axis we denote the speed level and on the vertical axis the marginal costs and benefits. The upward sloping curve (dashed line) is the marginal cost of speeding and the downward sloping curves represent the marginal benefits for each value of time. People with a value of time $t_1 < \tilde{t}$ comply with the speed limit, while people with a value of time such as $t_2 > \tilde{t}$ speed.

Figure 1: The speed decision of the car drivers



(c) Government

The government receives the net fine revenues (probability of detection times the fine times the number of offences minus the cost of enforcement) and uses this revenue to give a lump sum *L* to all road users *N*.

$$\pi \frac{N_c}{t_2-t_1} \overline{TR}_c \int_{\tilde{t}}^{t_2} \left(F\left(s(t)\right) - C_E^V \right) dt - C_E^F = L\,N \tag{13}$$

Rewriting (12) gives the following expression for the lump sum transfer

$$L = \frac{\pi \frac{N_c}{t_2 - t_1} \overline{TR}_c \int_{\tilde{t}}^{t_2} \left(F\left(s(t)\right) - C_E^V \right) dt - C_E^F}{N} \qquad (14)$$

Note that individuals, when they decide to speed or not, do not perceive the influence of the fine they pay on the lump sum transfer, because there is a large number of car drivers N_c.

Following Dixit ea (1997), we assume that the outcome of the lobbying game can be represented by the maximum of a function that equals a weighted sum of a social welfare function (representing the pure political process before lobbying) and the utility functions of the lobbying groups.

$$OBJ\left(\theta,\lambda\right) = \theta SWF + \left(1-\theta\right)\left[\lambda N_v V_v + \left[1-\lambda\right] N_c V_c\right] \qquad (15)$$

The weights $\left(\theta \text{ and } \lambda\right)$ are determined by the lobbying game. If $\theta = 1$, lobbying has no influence on the policy decision and the regulator selects the monitoring and enforcement strategy that maximises social welfare. If $\theta = 0$, only lobbies matter and then the parameter λ determines the relative power of each lobby group. In this paper we assume that the outcome of the purely political process (SWF) corresponds to the maximum of an additive utilitarian social welfare function[15].

In the next section, we determine analytically the socially optimal probability of detection and the associated fine function. In the following section, we numerically calculate these parameters. Moreover we also numerically analyse the choice between the probability of detection and the fine function when the expected fine is given.

3. THE OPTIMAL FINE FUNCTION AND PROBABILITY OF DETECTION

We first consider the benchmark case, where the government simply maximises the objective function (14) with respect to the probability of detection π, the fixed fine ff and the variable fine vf in the absence of any lobby groups $\left(\theta = 1\right)$. Next, we examine two extreme lobbying equilibriums: one where the vulnerable road users have all the lobbying weight $\left(\theta = 0,\ \lambda = 1\right)$ and one where only the utility of the strong road users is taken into account

[15] We can take other assumptions but this would require us to model more finely the working of the political process itself.

$(\theta = 0,\ \lambda = 0)$. We show in what direction interest groups want to influence the monitoring and enforcement strategy.

(a) Benchmark: $\boldsymbol{\theta = 1}$

In the benchmark, there are no lobby groups and we assume that this results into the maximisation of an additive utilitarian social welfare function. This implies that the utility of each individual has the same weight.

$$\begin{aligned} SWF &= N_v V_v + N_c V_c = N_v V_v + \frac{N_c}{t_2 - t_1}\left[\int_{t_1}^{\tilde{t}} V_c(comply)\,dt + \int_{\tilde{t}}^{t_2} V_c(speed)\,dt\right] \\ &= N_V\left[Y_v + L + \overline{TR}_v\left[\gamma_v - p(s)h\right]\right] \\ &+ \frac{N_c}{t_2 - t_1}\int_{t_1}^{\tilde{t}}\left[Y_c + L + \overline{TR}_c\left[\gamma_c - C_T(t,s) - C_M(s)\right]\right]dt \\ &+ \frac{N_c}{t_2 - t_1}\int_{\tilde{t}}^{t_2}\left[Y_c + L + \overline{TR}_c\left[\gamma_c - C_T(t,s) - C_M(s) - \pi R\big(F(s)\big)\right]\right]dt \end{aligned} \qquad (16)$$

Using Leibnitz' rule and restricting ourselves to a linear fine function, we calculate the derivatives of social welfare with respect to π, ff and vf. These first order conditions form a system of three equations and three unknowns.

The first order condition for the inspection frequency is:

$$\frac{dSWF}{d\pi} = \left[\begin{array}{l} \underbrace{N_v\left[-\frac{dp(s)}{d\pi}h\right]\overline{TR}_v}_{\text{decreased accident cost}} \\ \underbrace{+\frac{N_c}{t_2 - t_1}\overline{TR}_c\int_{\tilde{t}}^{t_2}\left[\begin{array}{l} -\frac{dC_T(t,s)}{d\pi} - \frac{dC_M(s)}{d\pi} \\ -\pi\left[\alpha + \beta\big(ff + vf(s - \overline{s})\big)vf\frac{ds}{d\pi}\right] \\ -\left[\alpha\big(ff + vf(s - \overline{s})\big) + \frac{\beta}{2}\big(ff + vf(s - \overline{s})\big)^2\right] \end{array}\right]dt}_{\text{change trip costs}} \\ \underbrace{+\frac{N_c}{t_2 - t_1}\overline{TR}_c\left(\int_{\tilde{t}}^{t_2}\left[\big(ff + vf(s - \overline{s})\big) + \pi vf\frac{ds}{d\pi} - C_E^V\right]dt - \pi C_E^V\frac{d\tilde{t}}{d\pi}\right)}_{\text{change in government revenues from fines}} \end{array}\right] = 0 \qquad (17)$$

Using expression (10), we have:

$$\left[\begin{array}{l}\underbrace{N_v\left[-\frac{dp(s)}{d\pi}h\right]\overline{TR}_v}_{\text{decreased accident cost}} \\ \underbrace{+\frac{N_c}{t_2-t_1}\overline{TR}_c\int_{\tilde{t}}^{t_2}\left[-\left[\alpha\left(ff+vf\left(s-\overline{s}\right)\right)+\frac{\beta}{2}\left(ff+vf\left(s-\overline{s}\right)\right)^2\right]\right]dt}_{\text{disutility fine}} \\ \underbrace{+\frac{N_c}{t_2-t_1}\overline{TR}_c\left(\int_{\tilde{t}}^{t_2}\left[\left(ff+vf\left(s-\overline{s}\right)\right)+\pi vf\frac{ds}{d\pi}-C_E^V\right]dt-\pi C_E^V\frac{d\tilde{t}}{d\pi}\right)}_{\text{change in government revenues from fines}}\end{array}\right]=0 \quad \forall s\geq\overline{s}$$

The socially optimal probability of detection is determined by equating the marginal cost of increasing the probability to the associated marginal benefit. The marginal benefit equals the decrease in accident cost. If π increases for given vf and ff, the speed on the roads decreases and thus the expected accident costs decrease. The marginal cost equals the disutility of the fine. However, the change in government revenue is uncertain because two opposite effects play. Firstly, due to the relative increase in the expected fine, there are fewer speeders, the chosen speed is lower and the variable enforcement costs are higher. Hence government revenue decreases (a cost). On the other hand, additional revenue is created because the expected fine is higher and, because there are less speeders, the variable enforcement costs decrease (a benefit).

Next, the fixed fine is determined by the following expression:

$$\frac{dSWF}{dff}=\left[\begin{array}{l}\underbrace{N_v\left[-\frac{dp(s)}{dff}h\right]\overline{TR}_v}_{\text{decreased accident cost}} \\ \underbrace{+\frac{N_c}{t_2-t_1}\overline{TR}_c\int_{\tilde{t}}^{t_2}\left[\begin{array}{l}-\frac{dC_T(t,s)}{dff}-\frac{dC_M(s)}{dff} \\ -\pi\left[\alpha+\beta\left(ff+vf\left(s-\overline{s}\right)\right)vf\frac{ds}{dff}\right]\end{array}\right]dt}_{\text{change in trip costs}} \\ \underbrace{+\pi\frac{N_c}{t_2-t_1}\overline{TR}_c\left[t_2-\tilde{t}-C_E^V\frac{d\tilde{t}}{dff}\right]}_{\text{change in government revenues from fines}}\end{array}\right]=0 \qquad (18)$$

Note that the change in the trip costs equals zero (cf. equation (10)). Hence, the socially optimal ff is determined by equating the change in government revenue to the decrease in accident costs.

$$\left[\underbrace{N_v\left[-\frac{dp(s)}{dff}h\right]\overline{TR}_v}_{\text{decreased accident cost}}+\underbrace{\pi\frac{N_c}{t_2-t_1}\overline{TR}_c\left[t_2-\tilde{t}-C_E^V\frac{d\tilde{t}}{dff}\right]}_{\text{change in government revenues from fines}}\right]=0 \qquad \forall s\geq\overline{s}$$

The socially optimal variable fine vf is determined in a similar way as the fixed fine ff.

$$\frac{dSWF}{dvf}=\left[\underbrace{N_v\left[-\frac{dp(s)}{dvf}h\right]\overline{TR}_v}_{\text{decreased accident cost}}+\underbrace{\pi\frac{N_c}{t_2-t_1}\overline{TR}_c\left[\int_{\tilde{t}}^{t_2}(s-\overline{s})\,dt-C_E^V\frac{d\tilde{t}}{dff}\right]}_{\text{change in government revenues from fines}}\right]=0 \qquad \forall s\geq\overline{s} \qquad (19)$$

The three monitoring and enforcement parameters are determined by equating the marginal cost to the marginal benefits. The exact magnitudes of vf, ff and π depend on the way the speed decisions react to the change in the probability of detection, the change in the fixed fine or the change in the variable fine. These reactions depend on the degree of risk aversion.
Note that we cannot guarantee a unique solution. Several combinations of vf, ff and π will have the same effect on drivers' compliance and are therefore indistinguishable. This scenario serves as a benchmark.

(b) $\boldsymbol{\theta=0}$ and only the vulnerable road users lobby counts: $\boldsymbol{\lambda=1}$

When the government only takes the utility of the vulnerable road users into account, the objective function equals

$$OBJ(0,1)=N_vV_v \qquad (20)$$

The optimal probability of detection is then determined by

$$\frac{dOBJ(0,1)}{d\pi}=0 \;\Rightarrow\; N_v\frac{dL}{d\pi}+N_v\left[-\frac{dp(s)}{d\pi}h\right]\overline{TR}_v=0 \qquad (21)$$

$$\Rightarrow\left[\begin{array}{l}\underbrace{N_v\left[-\frac{dp(s)}{d\pi}h\right]\overline{TR}_v}_{\text{decreased accident cost}}\\ +\frac{N_v}{N}\underbrace{\frac{N_c}{t_2-t_1}\overline{TR}_c\left(\int_{\tilde{t}}^{t_2}\left[\left(ff+vf(s-\overline{s})\right)+\pi vf\frac{ds}{d\pi}-C_E^V\right]dt-\pi C_E^V\frac{d\tilde{t}}{d\pi}\right)}_{\text{change in government revenues from fines}}\end{array}\right]=0 \qquad (22)$$

For a vulnerable road user, the marginal benefits of improved monitoring are the reduction in accident costs and the (possible) increase in fine revenues of which she receives a share $\frac{N_v}{N}$ without having to pay them. The marginal costs of increased control are the higher monitoring costs. So the vulnerable road users do not take any effects on the private cost of the strong road users into account.

The fixed fine that is preferred by the vulnerable road users is determined by:

$$\frac{dOBJ(0,1)}{dff} = \left[\underbrace{N_v \left[-\frac{dp(s)}{dff} h \right] \overline{TR}_v}_{\text{decreased accident cost}} + \frac{N_v}{N} \underbrace{\pi \frac{N_c}{t_2 - t_1} \overline{TR}_c \left[t_2 - \tilde{t} - C_E^V \frac{d\tilde{t}}{dff} \right]}_{\text{change in government revenues from fines}} \right] = 0 \quad \forall s \geq \overline{s}$$

This expression is very similar to the social optimum, except that only part of the change in government revenue is taken into account.

The variable fine in this scenario is found by solving:

$$\frac{dOBJ(0,1)}{dvf} = \left[\underbrace{N_v \left[-\frac{dp(s)}{dvf} h \right] \overline{TR}_v}_{\text{decreased accident cost}} + \frac{N_v}{N} \underbrace{\pi \frac{N_c}{t_2 - t_1} \overline{TR}_c \left[\int_{\tilde{t}}^{t_2} (s - \overline{s}) dt - C_E^V \frac{d\tilde{t}}{dff} \right]}_{\text{change in government revenues from fines}} \right] = 0 \qquad \forall s \geq \overline{s}$$

Again we find a similar expression as for the social optimum but with only part of the change in government revenue taken into account.

(c) $\boldsymbol{\theta = 0}$ and only the strong road users lobby counts: $\boldsymbol{\lambda = 0}$

In this scenario, the government only cares about the strong road users. The objective function then equals

$$OBJ(0,0) = N_c V_c \tag{23}$$

The optimal probability of detection is derived from

$$\frac{dOBJ(0,0)}{d\pi} = 0$$

$$\Rightarrow \left[\begin{array}{l} \underbrace{\frac{N_c}{t_2 - t_1} \overline{TR}_c \int_{\tilde{t}}^{t_2} \left[-\left[\alpha \left(ff + vf \left(s - \overline{s} \right) \right) + \frac{\beta}{2} \left(ff + vf \left(s - \overline{s} \right) \right)^2 \right] \right] dt}_{\text{distutility fine}} \\ + \frac{N_c}{N} \underbrace{\frac{N_c}{t_2 - t_1} \overline{TR}_c \left(\int_{\tilde{t}}^{t_2} \left[\left(ff + vf \left(s - \overline{s} \right) \right) + \pi vf \frac{ds}{d\pi} - C_E^V \right] dt - \pi C_E^V \frac{d\tilde{t}}{d\pi} \right)}_{\text{change in government revenues from fines}} \end{array} \right] = 0 \quad \forall s \geq \overline{s} \tag{24}$$

The possible benefit to the strong road users of more inspections is the change in government revenue, while the cost consists of the disutility of the fine. The strong road users do not take any effect on the accident costs into account and they only consider part of the enforcement cost and the government revenues. In order to determine the fine parameters, ff and vf, they only take part of the change in government revenue into account. Thus the first order conditions for the fixed and variable fine parameters are:

$$\frac{dOBJ(0,0)}{dff}=\left[\underbrace{\frac{N_c}{N}\pi\frac{N_c}{t_2-t_1}\overline{TR}_c\left[t_2-\tilde{t}-C_E^V\frac{d\tilde{t}}{dff}\right]}_{\text{change in government revenues from fines}}\right]=0\quad\forall s\geq\overline{s}$$

$$\frac{dOBJ(0,0)}{dvf}=\left[\underbrace{\frac{N_c}{N}\pi\frac{N_c}{t_2-t_1}\overline{TR}_c\left[\int_{\tilde{t}}^{t_2}(s-\overline{s})\,dt-C_E^V\frac{d\tilde{t}}{dff}\right]}_{\text{change in government revenues from fines}}\right]=0\quad\forall s\geq\overline{s}$$

(d) Discussion

In order to compare the solutions preferred by the vulnerable and strong road users with respect to the probability of detection and the level of the fine, we need to distinguish two cases. In the first case, when the monitoring and enforcement policy is strengthened, the change in government revenue is positive or, in other words, the lump sum distributed to the individuals increases; in the second case the change in government revenue is negative and thus the level of the lump sum transfer decreases (and can even be negative if the cost of enforcement is higher than the fine revenue).

Concentrating on the probability of detection, we find that the social optimum value is higher than the probability of detection preferred by the strong road users if the government budget grows. The ordering with respect to the vulnerable road user is undetermined. For the fixed and the variable fine, we find that the social optimum value is always higher than the fine preferred by the vulnerable and the strong road user. A sufficient condition for the fixed fine preferred by the vulnerable road users to be higher than the one chosen by the strong road user is.

$$N_v\left[\frac{dp}{d\pi}h\right]\overline{TR}_v>\left(\frac{N_c-N_v}{N}\right)\frac{N_c}{t_2-t_1}\overline{TR}_c\left(t_2-\tilde{t}-\pi C_E^V\frac{d\tilde{t}}{d\pi}\right),$$

This is, the marginal benefit curve for the vulnerable road user is higher than that for the strong user. The condition for the variable fine is analogous.

In the second case, if the government revenue is decreasing, the probability of detection, the fixed and the variable fine preferred by the vulnerable road users are higher than the social optimal one. The ordering with respect to the strong road users' preference is undetermined.
In the next section we specify the different functions so that numerical simulations can help in ranking the different solutions preferred by the distinct interest groups.

4. NUMERICAL EXERCISE - ILLUSTRATION

We illustrate the theoretical analysis by means of a numerical example and investigate the impact of lobbying activity on the selection of monitoring and enforcement parameters for speed limitations for two scenarios. In the first case π, ff and vf can be set freely, in the second the expected fine is fixed. After mentioning the underlying assumptions, this section describes and discusses the results.

4.1. Assumptions

We consider interurban roads in Belgium where the current speed limit is 90 km/h. Table 1 summarizes the assumptions we make with respect to the proportion of vulnerable road users, the number of trips they make on an average day, the utility of a trip and their income per day.

Table 1: Trip parameters

	Prop. of Population	# Trips /day	Utility (€) /trip	Income (€) /day
Vulnerable road users	0,234	0,8	5,9	50
Strong road users	0,766	2,2	35	50

Source: Toint ea (2001), own calculations

The private cost of driving a car equals the sum of the resource cost, the fuel cost and the time cost. The resource cost comprises the purchase cost, the insurance, the maintenance, etc. We assume that it is independent of the level of speed and equal to 0,23551 Euro/km[16]. The fuel cost depends on the fuel price and fuel use. Both elements depend on the type of fuel. We assume that 49% of the cars drive on gasoline and 51% on diesel[17]. The price of diesel equals

[16] Own calculations based on De Borger and Proost (1997).

[17] NIS 2005 Website

1,141 Euro/litre and the price of gasoline equals 1,415 Euro/litre[18]. The fuel use depends on the fuel type and the speed. The different functions are given in Table 2 where s is the speed in km/h.

Table 2: Fuel use

Fuel type	Speed range	Fuel use (l/km)
Diesel	10-130 km/h	$0{,}1377779 - 0{,}00242356\, s + 0{,}000016279\, s^2$
Gasoline	80-130 km/h	$0{,}0395757 + 0{,}0006365\, s$

MEET project (1998), International Energy Agency (2002)

The time cost equals the value of time divided by the level of speed. We consider fifteen values of time ranging from 4 Euro/hour to 40 Euro/hour and assume that these values are uniformly distributed among the strong road users.

The expected accident cost equals the harm times the accident risk. For the harm caused by a serious accident we use a value of 2.000.000 Euro. Using the data from the FOD Economics (2006), we calculate the accident risk $\left(p(s)\right)$ per km for accidents between vulnerable and strong road users, taking into account the influence of speed on the accident risk[19]. We use the following expression:

$$p(s) = 0{,}000002154 * \left(\frac{s}{\text{speed limit}} \right)^3 \tag{25}$$

We assume that the cost of enforcement takes the following form

$$C_E(\pi) = 20500 + 410 \frac{t_2 - \tilde{t}}{t_2 - t_1} N_c \pi^2 \tag{26}$$

with the fixed enforcement cost equal to 20500 Euro and the variable enforcement costs equal to 410 Euro times the number of violators.

Remember that we use the following structure for speeding fines

$$F(s) = ff + vf(s - 90) \tag{27}$$

This means that if you speed you pay a fixed fine of *ff* Euro and an additional fine *vf* per km/h over the speed limit.

[18] www.petrolfed.be

[19] Elvik ea (2000) provides a formula which relates the accident risk to the speed.

4.2. *Results and discussion*

In this exercise, we first determine the probability of detection π, the fixed fine *ff* and the variable fine *vf* when all variables can be set freely. Secondly, we determine these parameters for a given expected fine function. In the two cases the optimal monitoring and enforcement parameters are calculated for three different scenarios: (i) the benchmark $(\theta = 1)$, (ii) the vulnerable road users' utility function is maximised $(\theta = 0 \ and \ \lambda = 1)$ and (iii) the strong road users' utility function is maximised $(\theta = 0 \ and \ \lambda = 0)$.

In the first setting, when the variables can be set freely, we use a heuristic approach to find the different optima and calculate the objective functions for 2800 different combinations of the three variables under the following conditions:

$$\begin{aligned} 0,0001 \leq & \quad \pi & \leq 0,2501 \\ 0 \leq & \quad ff & \leq 75 \\ 0,0001 \leq & \quad vf & \leq 30,0001 \end{aligned}$$

Table 3 shows the results for this scenario. As expected, we find that the vulnerable road users opt for a solution where the number of speeders is minimised whereas the strong road users opt for the minimal expected fine. The social optimum lies in between. When there are more vulnerable road users, the social optimum will involve a solution with fewer speeders than in this example. Note that in this example the solutions for the strong road users and the social optimum are unique – this is not the case for the solution favoured by the vulnerable road users. This makes sense because different combinations ensure that all comply.

Table 3: Preferred policies

	No lobby	Lobbying only by vulnerable road users	Lobbying only by strong road users
π /trip	0,0001	0,0101	0,0001
vf (€)	30,0001	6,0001	0,0001
ff (€)	45	0	0
SWF (€)	90.178	90.175	90.040
# speeders (%)	73,3	0	93,3

Own calculations.

Next we look at the speeding decisions made be car drivers. As expected, the chosen speed level rises if the driver's value of time increases (see Table 4). We also see that the selected monitoring and enforcement policy can drastically reduce the number of violators. In the private optimum without enforcement 93,3 % of the car drivers violate the speed limit, while no one does so under the policy favoured by the vulnerable road users. The social optimum still allows 73 percent of the drivers to speed despite the risk of accident.

Table 4: Speed decision in benchmark

Value of time (€/h)	Private optimal speed (no enforcement)	Speed (enforcement= social optimum)	Speed (enforcement as preferred by vulnerable users)	Speed (enforcement as preferred by strong users)
4	82,31	82,31	82,31	82,31
7	93,45	90,00	90,00	93,45
8	96,49	90,00	90,00	96,49
9	99,31	90,00	90,00	99,31
10	101,92	96,55	90,00	101,92
11	104,41	99,13	90,00	104,41
12	106,74	101,57	90,00	106,74
14	111,06	106,06	90,00	111,06
16	115,00	110,16	90,00	115,00
18	118,64	113,93	90,00	118,64
20	122,03	117,44	90,00	122,03
25	129,65	125,31	90,00	129,65
30	136,34	132,19	90,00	136,34
35	142,33	138,36	90,00	142,33
40	147,80	143,98	90,00	147,80

Own Calculations

In the second scenario, we use non-linear programming in order to select the monitoring and enforcement parameters that maximise the different objective functions under the restriction of a constant expected fine function. Following Polinsky and Shavell (2000), the expected fine function is determined exogenously as the sum of the change in the expected harm plus the variable enforcement cost. Remember that we can not calculate a unique socially optimal expected fine function. This is

$$\left(\pi F(s)\right)^* = \Delta\, p(s) \cdot harm \cdot \left(s - 90\right) + ve \qquad (28)$$

The results are summarised in Table 5.

Table 5: Preferred policies when the expected fine is fixed

	No lobby	*Lobbying only for vulnerable road users*	*Lobbying only for strong road users*
π /trip	0,0677	0,04	0,54
vf (€)	1,29	2,18	0,16
ff (€)	590	1000	73
SWF (€)	90.160	90.160	90.160
# speeders (%)	0	0	0

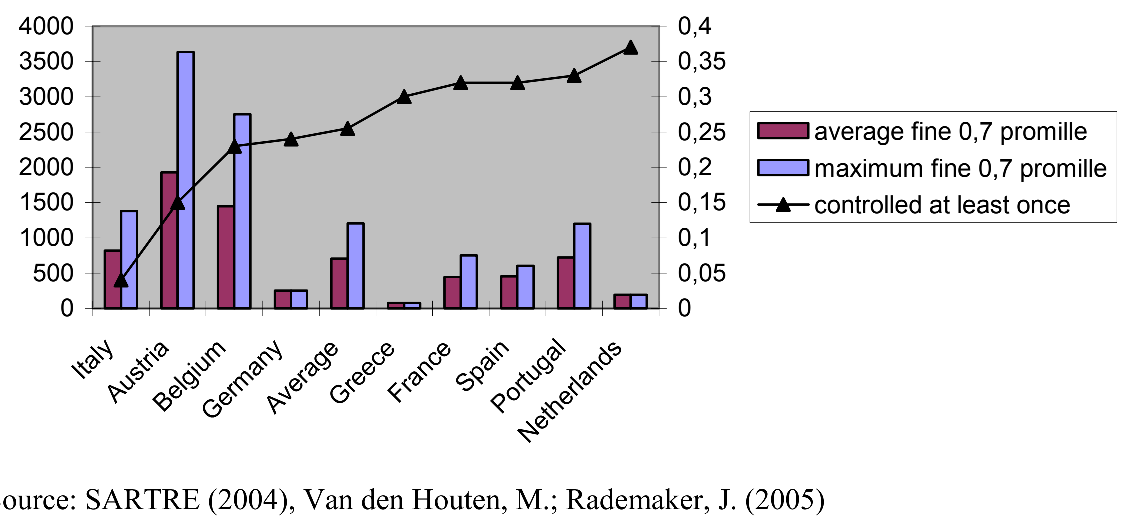
Own Calculations

This illustration corresponds with the second case discussed for the theoretical model. In line with our expectations, we indeed see that the strong road users opt for a lower fine function and a higher probability of detection than the vulnerable road users. After all, the strong road users are the only drivers to pay the fines while the burden of increasing the inspection probability is shared with the vulnerable road users. Without lobbying, the social optimum lies, as expected, in between these two extremes.

5. CONCLUSION AND SOME EMPIRICAL EVIDENCE

In the context of road safety and more specifically speed limits, we develop a model that represents the preferences of different lobby groups. In the model, the lobby groups can select different combinations of inspection probability and fine level. We show – both theoretically and numerically - that, in general, vulnerable road users (cyclists, pedestrians) prefer a higher expected fine than strong road users (car and truck drivers). If we focus on the choice between the magnitude of the fine and the inspection probability for a given fixed expected fine, we find that the vulnerable road users prefer a higher fine and a lower inspection frequency than the strong road users. This model can not only be used to explain current policy in one country but it could also serve to clarify differences in policy between countries or regions. As a case in point, traffic safety stands high on the political agenda in Flanders, a region in Belgium, and many resources are spent to improve traffic safety. This is less the case in Wallonia, another region in the same country. For example, Flanders wants to lower the speed limit on interurban roads to 70 km/h, while Wallonia wants to keep the 90 km/h speed limit. A possible approach to investigate the variation in regional policies could be, for example, to look at the shares of vulnerable and strong road users and the type of enforcement policy in place and calculate the correlation coefficient. One could also perform an econometric analysis to determine the exact influence of the interest groups. However, there are two problems: there are too little observations and information on the probability of detection is often lacking. Another illustration is the enforcement strategy chosen by nine European countries. **Error! Not a valid bookmark self-reference.** shows the average and the maximal fines for drunk driving (blood-alcohol level between 0.5 and 0.7) for some European Countries.

Figure 1 : Probability of detection and fines for alcohol infractions



Source: SARTRE (2004), Van den Houten, M.; Rademaker, J. (2005)

The percentage of people who have been checked at least once for drunk driving serves as an indicator for the probability of detection. We make three observations. Firstly, there is a lot of variation in the enforcement strategies. Secondly, in general the fines decrease as the probability of detection increases. In Table 6 we confront the enforcement strategy with the relative importance of vulnerable road users. We see that in countries where there are relatively many vulnerable road users, the fines are higher and the probability of detection lower (except for Germany and the Netherlands). This is our third observation.

Table 6 : Importance of vulnerable road users

Country	**Relative number of km travelled by vulnerable road users compared to European average**
Greece	0,6656
Spain	0,696
Portugal	0,7568
France	0,8224
average	1
Italy	1,0032
Austria	1,0208
Germany	1,16
Belgium	1,2336
The Netherlands	2,0736

Eurostat (2007)

Furthermore, note that the analysis is not restricted to the setting of fines and probability of inspections for speeding and drunk driving. The analysis is also not limited to vulnerable versus strong road users. Other types of (road) users such as freight versus passenger transport, pedestrians versus cyclist, etc. can be discussed as long as their objective functions can be clearly defined. It can also provide additional insights into the political processes that determine the monitoring and enforcement strategies for, for example, environmental legislation.

Note that we did not discuss the political process behind the objective function of the government as this is beyond the scope of this paper. Furthermore, we did not take into account any equity effects the enforcement policy may have; nor did we consider the case where all users are – to some extent – risk averse. Finally, we assumed that the fine revenues were redistributed in a lump sum fashion. In reality, these revenues are often earmarked. If, for example, all revenue is used for investments in traffic safety, this lowers the general accident risk and hence creates an additional incentive for the vulnerable road users to set the expected fine at revenue maximising levels.

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