Minor offences are often punished with a fine. Up to 2007 the number of fines in the Netherlands was increasing but 2008 saw a decline. At the same time fines were raised significantly. The question is whether the raise in fines caused the decline in the number of fines. To answer this question a database containing administrative fines for speeding on the motorway over the period 2007–2010 is analyzed. Two categories are compared: speeding offences detected by average speed measuring systems (ASMS) and speeding offences detected by police officers. For each category the elasticity of fines is estimated. It turns out that the elasticity of fines detected by an ASMS is small but differs significantly from both 0 and −1. If fines are raised by 1%, the offence rate, that is, proportion of fines detected by an ASMS, will decline by 0.14%. For fines handed out by police officers we see no such effect: the estimated elasticity of the number of fines is positive and does not significantly differ from zero. The conclusion is that motorists make moderate adjustments in their behavior when fines are raised but only if the risk of being caught is high.

1. Introduction

Becker [1] argues that when the risk of apprehension (and punishment) is fixed and assumed 100%, the optimal fine only depends on the marginal harm to society and the cost of enforcement. Social harm associated with speeding offences depends on the number of accidents which may result. It follows that by raising the fines the number of offences can be reduced and thus the harm. The size of this effect is measured by the so-called elasticity of fines. On the other hand, if fines are fixed and the risk of apprehension is subject to control, then the optimal fine depends on the marginal net damage to society, the cost of enforcement, and the risk of apprehension. It follows that by raising the risk of apprehension the number of offences can be reduced. If both the risk of apprehension and the fines are subject to control, then the optimal fine and apprehension rate depend on the offender's attitude towards risk.

Recent developments in the Netherlands with respect to fines provide a unique opportunity to test Becker’s theory. After a long period of no change the Dutch Ministry of Security and Justice has raised the fines several times in the past five years. These raises were partly meant to counteract the effects of inflation and partly to induce a reduction in the number of offences. In addition technological developments meant that the risk of getting caught for speeding offences has increased significantly in the past seven years. In an ex ante study, Significant [2] used a simulation model to assess the effect of the planned increase in fines. They predicted that a 20% increase in fines would lead to a 20% decrease in the number of fines but that this effect would be temporary and last no longer than one year, because motorists would get used to the higher fines and fall back into their old driving behavior.

The question is whether the Ministry was successful in achieving its goal. The number of major and minor offences (including traffic offences) has declined over the past five years, but it is unclear to what extent this decline is caused by the higher fines, changing risk of getting caught, or other circumstances such as the economic downturn, problems with technical equipment, and changes in police priorities. To pinpoint the cause of the decline this paper focusses on fines for speeding offences on the motorway because this is a large group of homogenous minor offences, committed by ordinary people from all walks of life and not just criminals. Two categories are compared to account for the perceived risk of being caught: speeding offences detected by average speed measuring systems (ASMS) and speeding offences detected...
by police officers. For each category the elasticity of fines is estimated using regression analysis on a dataset covering the period 2007–2010. The main question being answered is whether people react differently to a raise in fines when they are fined by an ASMS (with a high perceived risk of getting caught) or by a police officer (with a low perceived risk of getting caught). It is also checked if young drivers react differently and what effect the recent economic downturn and changes in police priorities have on the elasticity of fines.

The structure of the paper is as follows. Section 2 describes the literature on fines for traffic offences. Section 3 provides a brief description of the Dutch situation. Section 4 explains how an ASMS works, while Section 5 gives information on fines handed out by police officers. In Section 6 the theoretical model and the methodology used to estimate the elasticity of fines are explained and in Section 7 the results are presented. Section 8 ends with a summary and conclusion.

2. Previous Research on Fines for Traffic Offences

There is not a lot of literature on the relationship between the amount of the fine and the number of traffic offences, in particular speeding. Most of the available literature comes from the area of road safety and looks at the relationship between the severity of the penalty and road accidents, in particular more severe punishment of driving under the influence (for an overview see Wilmsetal. [3]). For motorists there is a tradeoff between greater accident damage (at higher speeds) and average journey times. For the police there is a tradeoff between the costs of managing accidents and the costs of enforcing speed limits. Briscoe [4] found that doubling the punishment for driving under the influence in New South Wales in Australia in 1998 did not lead to fewer offences or less accidents. Mathijssen [5] found similar results for the Netherlands in 1992. Wagenaar et al. [6] found that drunk drivers in various American states did not adjust their behavior when possibly faced with a prison sentence. Moffat and Poynton [7] could not establish a relationship between the fine or the duration of a driving ban and the risk of reoffending.

Even less is known on the relationship between speeding offences and increases in fines. A Norwegian study by Elvik and Christensen [8] showed that a 100–150% increase of speeding fines over a ten-year period did not lead to a change in motorist's behavior. In Finland warning letters are more sensitive to a change in fine. Lawpoolsri et al. [20] found that young people and people with older motor vehicles are more sensitive to a change in fine. Lawpoolsri et al. [20] found that young drivers and male drivers were more likely to receive a speeding citation.

3. Fines in the Netherlands

In the Netherlands fines are a common form of sanctioning. After several years of no adjustments to fines, on April 1st 2008 fines were raised with 20% on average. This increase applied to all types of fines, but fines for minor offences were raised less than fines for major crimes. The average rise of 20% is an unweighted average. If weighted with actual volume, then the actual average rise will be lower. On January 1st 2010 the fines were raised again, this time with an average of 4%, which was considered to be an inflation correction. Since then fines are raised with a correction for inflation on the 1st of January each new year (see Table 1).

In the Dutch legal system there is a variety of fines. Administrative fines are fines for very common and not so serious offences, such as traffic violations. They are usually handed out by the police or by automated computer systems. Out-of-court settlements are proposals by the Public Prosecutor or the police on behalf of the Public Prosecutor for all kinds of minor (and a few major) offences. The suspect may decline the proposal in which case the Public Prosecutor has to make a decision on how to proceed. In 2008 penal orders were introduced. Eventually these are meant to replace most of the out-of-court settlements. The difference with out-of-court settlements is that penal orders are not a proposal but a final decision. The last type of fines is fine sentences imposed by a judge. In the case of penal orders or court fines the suspect's wages or other assets may be seized if he does not pay the fine.

The number of administrative fines has increased rapidly during the last decade. In 11 years' time the overall increase was 25% (see Figure 1). At the same time out-of-court settlements increased by 27% and fine sentences by 9%.

| Date               | Average increase (unweighted) |
|--------------------|-------------------------------|
| 1st April 2008     | 20%                           |
| 1st January 2010   | 4%                            |
| 1st January 2011   | 15%                           |
| 1st January 2012   | 15%                           |
| 1st January 2013   | 2%                            |
However, the largest increase took place in the early part of the decade. In fact, the number of out-of-court settlements and fine sentences is decreasing since 2003/2004 along with crime rates, while the number of administrative fines started to decrease in 2008. Because the administrative fines are the largest part of the fines the revenue from fines kept on rising until 2009 (see Figure 2). All fine revenues go to the National Treasury and not to the police.

It is worth noting that the raise in fines took place against the background of a changing economic climate. After years of economic growth, the Netherlands officially went into recession by the end of 2008 with a slight revival in 2010. Because transport is a big economic sector in the Netherlands, this directly affects the number of motor vehicles on the road. Indirectly, less economic activity leads to less traffic from commuters and thus also to a drop in mobility (see Figure 3).

Administrative fines can be roughly split into three groups: offences detected by average speed measuring systems (ASMS), offences detected by individual (mobile) cameras or radar, and offences detected by police officers.

The number of offences detected by police officers depends highly on where and when the police officers are at work and on priorities made by the head of the police department. In general the risk of getting caught is not high. To a lesser extent this is also the case for individual (mobile) cameras and radars. When these devices are in operation they will detect almost all offences they are meant to detect, but whether and where they are in operation is often also a matter of police priorities. The ASMS, on the other hand, are not subject to police priorities. If they are in operation almost all speeding offences are detected. In order to find out what influences the number of fines and how sensitive motorists are to changes in fines, administrative fines for offences detected by ASMS are analyzed. In addition the administrative fines for offences detected by police officers are also analyzed. The next section explains how the ASMS works; the section after that gives some information on fines for motorists pulled over by police officers.

4. Automatic Speed Detection

So how does the ASMS work? Multiple cameras are installed along a fixed section of the motorway. At the beginning of this section there are sensors in the road surface which detect whether a motor vehicle is passing by. If a motor vehicle is detected the digital camera above the road photographs the motor vehicle and puts a time stamp on the photograph. The same thing happens at the end of the section. Using automatic number plate recognition (ANPR) software the number plate can be recognized and matched to a motor vehicle in the database of all number plates issued. Based on the number plate the type of motor vehicle (trailer, bus, truck, motor, or passenger car) can be identified. Based on the time stamp of the photographs and the distance between the cameras, the average speed of each motor vehicle can be calculated (see Figure 4). If the average speed exceeds the speed limit for that particular type of motor vehicle at that particular section of
the road, then the ASMS sends its data to a specialized unit of the Public Prosecutor. If not, the data are not recorded. As long as it is not a matter of excessive speeding the computers at this specialized unit automatically notify the national fine collection agency. This agency sends out a notification with a request for payment to the registration holder. Fines are fixed and increase with the actual speed. For example, a speeding violation in excess of 4 km/h with a passenger car when there are no road works was 23 euros in 2012 while a violation in excess of 39 km/h was 390 euros. Speed violations of less than 4 km/h are not fined. This is a legal correction to take into account any bias in speed measuring systems. For trucks and busses the fines are higher. If there are road works, the fines are also higher. The registration holder is always liable even if he or she was not the actual person driving. Because the registration holder may not be the actual person who committed the offence, no record is kept after the fine has been paid. Exceeding the speed limit by more than 40 km/h on the motorway (or 30 km/h on other roads) is considered to be excessive speeding. In this case the Public Prosecutor determines the fine. In the period 2007–2010 there were 16 ASMS in operation. Most of them were introduced during 2006 (see Figure 5). To avoid any noise from the introduction period, our analysis is limited to the period 2007–2010.

The only factors influencing the number of fines generated by ASMS are the number of motor vehicles passing by, the percentage of recognized number plates, and the number of days that the system is in operation. There is no influence from the availability of police officers or priority of police forces. In fact, if the system is functioning perfectly, the risk of being caught is 100%. In practice though, the risk of being caught is less than 100%. During road works lanes are narrowed and moved aside. Consequently the sensors in the road surface are no longer able to detect whether a motor vehicle is passing by and the ASMS will not function properly. Also the system is calibrated for a certain speed limit. If the speed limit is changed, then the system needs to be recalibrated; otherwise, the evidence from the ASMS will not be admissible in court (in case the registration holder decides to contest the fine). The system is not always able to recognize the number plates, especially in the case of foreign number plates. Fog, snow, or other bad weather conditions may blur the camera’s vision. At sun rise or sun set the sun may shine directly into the camera also causing its vision to be blurred. Snow and ice may also cause the sensors in the road surface to malfunction or even damage these sensors. High vehicles may obscure the camera’s vision of the car right behind the high vehicle. Cars changing lanes right at the camera position are sometimes not detected. Number plates may be smudged so that they cannot be recognized by the system. And general wear and tear of the ASMS may also cause malfunctions. Maintenance is done by (third party) technicians, not by police officers. Table 2 shows some statistics.

The number of fines for speeding offences detected by average speed measuring systems has decreased by 59% between 2007 and 2010 (see also Figure 5). A simple decomposition analysis (Moolenaar et al. [21]) shows that 35% of this decrease can be attributed to the behavioral effects of motorists. The behavioral effects are not so much caused by the increase in the fine rate but more by an increased awareness of the probability of being caught and fined when driving past an ASMS. About 32% can be attributed to the number of days that the average speed measuring system is out of order due to planned or unplanned road works and/or weather conditions. About 7% of the decrease is caused by
Table 2: General descriptives of ASMS.

|                          | 2007  | 2008  | 2009  | 2010  |
|--------------------------|-------|-------|-------|-------|
| Recognition rate         | 61.7% | 61.6% | 55.6% | 48.7% |
| Offence rate\(^a\)       | 0.96% | 0.70% | 0.65% | 0.67% |
| Number of fines per 1,000 motor vehicles passing by | 5.9   | 4.3   | 3.6   | 3.3   |
| Number of motor vehicles passing by | 411,842,123 | 429,071,480 | 412,906,536 | 314,297,314 |
| Number of fines          | 2,401,580 | 1,807,870 | 1,477,411 | 991,030 |
| Average number of days that an ASMS is in operation | 279   | 265   | 264   | 261   |
| Average number of motor vehicles passing by per operational day | 1,476,137 | 1,619,138 | 1,564,040 | 1,204,204 |
| Average number of fines per operational day | 8,608 | 6,822 | 5,596 | 3,797 |

\(^a\)This is the number of fines divided by the number of matches. See Section 6 for further explanation.

Source: LPTV/CJIB.

a reduction in traffic due to the economic crisis and/or weather conditions and about 22% is caused by general wear and tear of the average speed measuring systems. The remaining 3% is due to unknown causes. Not only has the number of fines and settlements decreased but also the average speed limit transgression.

5. Offences Detected by Police Officers

The Dutch authorities do not solely rely on ASMS for enforcing the speed limit. Most ASMS are in the southwestern and southern parts of the Netherlands. On motorways (and other roads) where there are no ASMS police officers enforce the speed limit, either by setting up (mobile) cameras or radar equipment or by patrolling the roads. How much time and effort is put into these activities depends highly on local priorities and may vary across police forces. It also depends on perceived safety of the roads within a police department. Figure 6 shows that in the period 2003–2010 the total number of hours spent by police officers on enforcing the speed limit (on all roads) has declined slightly with the introduction of the ASMS but remains fairly constant the last couple of years. Because all fine revenues go to the National Treasury, there are no monetary incentives for police forces to change priorities.

If police officers see a motorist commit an offence they apprehend him or her. This need not be a traffic offence. Once apprehended the police officer will determine whether the committed offence is eligible for an administrative fine, an out-of-court settlement, or a penal order or whether the offence is so serious that a notification is sent to the Public Prosecutor. If the offence is eligible for an administrative fine, out-of-court settlement, or penal order the police officer issues a ticket stating the fine. Unless you are a nonresident you do not have to pay immediately. Instead the national fine collection agency is notified and they send out a notification with a request for payment.

Between mid-December 2007 and mid-March 2008 there was labor dispute between the regional police forces and the government. The police protests took on the form of a relay race: each day another police force was on protest. The protests mainly consisted of only doing what was absolutely necessary. Writing out tickets did not belong in that category. This can be clearly seen in Figure 7. Also until October 2010 police officers had to write out a certain number of tickets per year. These targets were abolished in November 2010, which led to an immediate drop in the number of fines.

In order to make the comparison with the ASMS we need to exclude all nonadministrative fines from our analysis. Because the ASMS does not work during road works, fines issued by police officers during road works are also excluded. Because there are only ASMS on the motorways, fines issued by police officers on all other roads are excluded as well. Because the ASMS only detects speeding offences, fines issued for other offences than speeding offences are excluded. This leaves us with a subsample of administrative fines issued by police officers that is comparable to the fines generated by the ASMS.

6. Methodology

To estimate the response of motorists to a change in fines data from the national fine collection agency is collected on fines for speeding detected by an ASMS categorized by type of motor vehicle, the exceeded number of kilometers per hour,
week of the year, region, and local speed limit. Fines may vary by speed and type of motor vehicle. The speed limit varies by type of motor vehicle and location (and sometimes even by time of day). Also data on the number of cars passing by and the number of recognized number plates is available. Monthly or quarterly data on the state of the economy is added to the data set.

Let $A_{a,kmh}$ be the number of fines in speeding category $s$ in period $t$ for type of motor vehicle $k$ with speed limit $m$ at ASMS $h$, $P_{th}$ the number of cars passing by ASMS $h$ in period $t$, and $M_{th}$ the number of recognitions in period $t$ at ASMS $h$.

If the recognition rate is 100% the offence rate would be the number of fines divided by the number of cars passing by. However, because the recognition rate is not 100% we need to correct it for the number of cars not recognized. The implicit assumption here is that the unrecognized cars behave the same as the recognized cars. Although motorists can avoid recognition by intentionally smudging their number plates, most of the nonrecognition is due to technical problems and weather circumstances, which makes the assumption likely. Thus, the offence rate $O_{a,kmh}$ in speeding category $s$ in period $t$ for type of motor vehicle $k$ with speed limit $m$ at ASMS $h$ is defined as

$$O_{a,kmh} = \frac{A_{a,kmh}/P_{th}}{M_{th}/P_{th}} = \frac{A_{a,kmh}}{P_{th}} \frac{P_{th}}{M_{th}} = A_{a,kmh}. \tag{1}$$

Now let $F_{stk}$ be the fine in constant prices for speeding category $s$ in period $t$ for type of motor vehicle $k$ with speed limit $m$. Then, the theoretical model is

$$\ln(O_{stk}) = c_0 + c_1 \ln(F_{stk}) + c_2 \ln(U_t) + c_3 \ln(GDP_t) + c_4 Y_t + \sum_{i=2}^{4} c_i SE_i + c_6 MV + \sum_{m=1}^{3} c_m MAX_{stk}$$

$$+ \sum_{h=2}^{16} c_h LOC_h + V_{stk}, \tag{2}$$

where

(i) $U_t$ is the number of unemployed people in period $t$. It is an indicator of the economic circumstances. Unemployment is actually measured monthly so all the weeks in a particular month get the same number of unemployed.

(ii) GDP is the gross domestic product (GDP) in constant prices in period $t$. This is also an indicator of the economic circumstances. GDP is measured quarterly so all the weeks in a particular quarter get the same GDP.

(iii) $Y$ is the year in which the offence was committed.

(iv) $SE_i$ is a seasonal dummy. For example, $Season_1 = 1$ if it was summer and zero elsewhere. The seasons are proxies for weather circumstances. Spring is the reference category.

(v) $MV$ is a type of motor vehicle dummy; $MV = 1$ if the offence was committed with a truck, bus, or motor vehicle with a trailer weighing over 750 kg and zero elsewhere.

(vi) $MAX_{stk}$ is a speed limit dummy in period $t$ for type of motor vehicle $k$. For example, $MAX_{stk} = 1$ if the speed limit in period $t$ for type motor vehicle $k$ is 80 km/h and zero elsewhere. There are 4 categories of speed limits: 80, 90, 100, and 120 km/h. 120 km/h is the reference category.

(vii) $LOC$ is a location dummy. Location 1 is the reference category. There are 16 locations in total.

(viii) $V$ is an error term.

The coefficient $c_2$ estimates the elasticity of a fine. This is defined as the relative change of the offence rate as a consequence of the relative change in the fines. In this case, we have

$$c_2 = \frac{dO_{stk}/O_{stk}}{dF_{stk}/F_{stk}} = \frac{dO_{stk}}{dF_{stk}} \frac{F_{stk}}{O_{stk}} = \frac{d \ln(O_{stk})}{d \ln(F_{stk})}. \tag{3}$$

So if the fine increases with 1%, the offence rate for speeding violations will change with $c_2$ %, if all other factors remain constant.

Equation (2) models the relationship between the fine and the offence rate. The question is whether this is to be interpreted as a causal effect. To give this interpretation the fine has to be more or less coincidental. In other words, people that get a high fine should be comparable to people with a low fine, controlling for all other variables. This is not likely. Thus, the fine is probably endogenous and depends on personal characteristics that may or may not be observed, like income, education, family size, and, in particular, driving skills and risk aversion. In other words, people that get high fines are likely to differ from people with low fines. If this is case it is not clear whether the estimated effect is because of the fine or the difference between people with high fines and low fines.
One way of avoiding this problem is to see if there was an exogenous shock to the system. In fact this shock is available: the increase in fines on April 1st 2008 and January 1st 2010. These shocks can be used as instrumental variables, which are correlated with the exogenous variables but uncorrelated with the error term. Equation (2) should then be estimated in two stages using Two Stage Least Squares (TSLS). In the first stage the fine is regressed on the instrumental variables, in this case the two exogenous shocks and other exogenous variables that may explain the fine. In the second stage the fitted fines are included as an exogenous variable in the estimation of the offence rate. Thus, the theoretical model for the fine amounts looks like

\[
\ln (F_{stkm}) = b_0 + b_1 D_{2008} + b_2 D_{2010} + b_3 Y_t + b_4 \text{MV} + \sum_{m=1}^{3} b_{8m} \text{MAX}_{stkm} + \sum_{s=5}^{40} c_{10s} \text{SC}_s + E_{stkm},
\]

where \(F_{stkm}, Y_t, \text{MV},\) and \(\text{MAX}_{stkm}\) are as before and

(i) \(D_{2008}\) and \(D_{2010}\) are dummy variables for the increase in fines on April 1st 2008 and January 1st 2010, respectively. The dummy variables are 1 if the offence took place after the increase and zero elsewhere.

(ii) \(\text{SC}_s\) is a speeding category dummy. For example, \(\text{SC}_{10} = 1\) if the speed limit is exceeded by 10 km/h and zero elsewhere. There are 37 categories ranging from 4 km/h to 40 km/h. No speeding (i.e., <4 km/h) is the reference category. Exceeding the speed limit by less than 4 km/h is not fined. But for estimation purposes zero fines are set to one eurocent to avoid zeros under the logarithm. Exceeding the speed limit by more than 40 km/h on the motorway is considered to be excessive speeding. Excessive speeding cannot be handled administratively. These cases are sent to the Public Prosecutor and are not included here.

(iii) \(E_{stkm}\) is an error term.

In order to isolate the effect of the exogenous shocks the exogenous variables in (2) and (4) need to overlap perfectly except for the two dummy variables representing the exogenous shocks. Thus, the full model to be estimated becomes

\[
\ln (O_{stkm}) = c_0 + c_1 \ln (\bar{F}_{stkm}) + c_2 \ln (U_t) + c_3 \ln (\text{GDP}_t) + c_4 Y_t + \sum_{i=2}^{4} c_{5i} \text{SE}_i + c_6 \text{MV} + \sum_{m=1}^{3} c_{7m} \text{MAX}_{stkm} + \sum_{h=2}^{16} c_{8h} \text{LOC}_h + \sum_{s=5}^{40} c_{9s} \text{SC}_s + V_{stkm},
\]

where \(O_{stkm}\) is the fitted value from the equation

\[
\ln (O_{stkm}) = b_0 + b_1 D_{2008} + b_2 D_{2010} + b_3 \ln (U_t) + b_4 \ln (\text{GDP}_t) + b_5 \text{MV} + \sum_{m=1}^{3} b_{8m} \text{MAX}_{stkm} + \sum_{h=2}^{16} b_{9h} \text{LOC}_h + \sum_{s=5}^{40} b_{10s} \text{SC}_s + \sum_{p=2}^{27} b_{12p} \text{FP}_p + \sum_{s=5}^{40} c_{13s} \text{SC}_s + V_{stkm},
\]

The advantage of using data on ASMS is that speeding offences detected by the ASMS are independent of the number of available police officers and police priorities. We can also look at offences detected by police officers to see if motorists respond differently when the human factor is involved. To make it comparable with the ASMS analysis we limit ourselves to speeding offences on the motorway. A similar analysis can be made, but because the data source is different some of the exogenous variables have slightly different definitions.

Assume that \(A_{stkm}\) is the number of speeding tickets handed out by police officers on the motorway for speeding category \(s\), in period \(t\), for type of motor vehicle \(k\), in region \(p\), for gender \(g\) and age category \(l\) and that \(F_{stkm}\) is the fine in fine category \(s\) and period \(t\) for type of motor vehicle \(k\). Then, the equation to be estimated with TSLS is

\[
\ln (A_{stkm}) = c_0 + c_1 \ln (\bar{F}_{stkm}) + c_2 \ln (U_t) + c_3 \ln (\text{GDP}_t) + c_4 \ln (\text{POP}_{tp}) + c_5 Y_t + \sum_{i=2}^{4} c_{6i} \text{SE}_i + c_7 \text{MV} + \sum_{g=2}^{3} c_{8g} \text{SEX}_g + \sum_{l=2}^{5} c_{9l} \text{AGE}_l + c_{10} \text{FP} + \sum_{m=1}^{3} c_{11m} \text{ST}_m + \sum_{p=2}^{27} c_{12p} \text{PF}_p + \sum_{s=5}^{40} c_{13s} \text{SC}_s + V_{stkm}.\]

where \(\bar{F}_{stkm}\) is the fitted value from the equation

\[
\ln (F_{stkm}) = b_0 + b_1 D_{2008} + b_2 D_{2010} + b_3 \ln (U_t) + b_4 \ln (\text{GDP}_t) + b_5 \ln (\text{POP}_{tp}) + b_6 Y_t + \sum_{i=2}^{4} b_{7i} \text{SE}_i + b_8 \text{MV} + \sum_{g=2}^{3} b_{9g} \text{SEX}_g.\]
Table 3: Effect of a raise in fines on the number of fines for speeding on the motorway, detected by an ASMS.

| Variable                          | Coefficient | \(t\)-Statistic |
|-----------------------------------|-------------|-----------------|
| Constant                          | 324.575**   | 30.039          |
| Fine amount                       | -0.139*†    | -1.812          |
| Unemployment                      | -0.142**    | -5.809          |
| GDP                               | -1.032**    | -10.131         |
| Yearly trend                      | -0.155**    | -28.903         |
| Season\(^a\)                      |             |                 |
| Summer                            | 0.073**     | 10.592          |
| Autumn                            | -0.212**    | -31.464         |
| Winter                            | -0.067**    | -10.440         |
| Truck, bus, or trailer            | -3.628**    | -166.403        |
| Maximum speed\(^b\)              |             |                 |
| 80 km/h                           | 2.307**     | 146.976         |
| 90 km/h                           | 1.044**     | 52.432          |
| 100 km/h                          | 0.823**     | 56.882          |
| +15 location dummies\(^c\)       |             |                 |
| +37 dummies for the number of kilometers with which the speed limit was exceeded\(^d\) | | |
| Number of observations            | 116,812     |                 |
| Adjusted \(R^2\) 1st stage       | 0.998       |                 |
| Adjusted generalized \(R^2\) 2nd stage\(^d\) | 0.925       |                 |

\(^a\) Significantly different from 0 at 90% level.
\(^b\) Significantly different from 0 at 95% level.
\(^†\) Significantly different from -1 at 95% level.
\(^a\) Spring is the reference category.
\(^b\) 120 km/u is the reference category.
\(^c\) The results for all the dummy variables are available upon request.
\(^d\) See Pesaran and Smith [23].

\[ \begin{align*}
&+ \sum_{i=2}^{5} b_{10i} \text{AGE}_i + b_{11} \text{FP} + \sum_{m=1}^{4} b_{12m} \text{ST}_m \\
&+ \sum_{p=2}^{27} b_{13p} \text{PF}_p + \sum_{s=5}^{40} b_{14s} \text{SC}_s + E_{15bmn},
\end{align*} \]

(6b)

where the variables \(F_{1bnm}, D_{2008}, D_{2010}, U_t, \text{GDP}_t, Y_t, \text{SE}_t, \text{MV}, \) and \(\text{SC}_s\) are as defined before. In addition, we have the following.

(i) \(\text{POP}_p\) is the number of inhabitants in period \(t\) in region \(p\).

(ii) \(\text{SEX}_p\) are gender dummies: male, female, and unknown. Male is the reference category.

(iii) \(\text{AGE}_i\) are age category dummies. There are 5 categories: \(\geq 18\) years and \(<30\) years, \(\geq 30\) years and \(<50\) years, \(\geq 50\) years and \(<70\) years, and \(\geq 70\) years and age unknown. Age \(\geq 18\) years and \(<30\) years is the reference category.

(iv) \(\text{FP}\) is a dummy for a change in fining policy in November 2010.

(v) \(\text{ST}_j\) are dummies for the months that the police were on strike (December 2007 until March 2008). No strike is the reference category.

(vi) \(\text{PF}_p\) are dummies for the (regional) police forces. In the estimation period there were 25 regional forces, 1 national police force, and 1 military police force. The national police force is the reference category, which is also the largest category.

Again the coefficient \(c_1\) estimates the elasticity of a fine. That is, if the fine increases with 1%, the number of fines for speeding violations will change with \(c_1\)% if all other factors remain constant.

There are some obvious differences between (5a)-(5b) and (6a)-(6b). An important difference is that the number of cars passing by is not available, so instead the analysis is performed on the number of fines instead of the offence rate. And while the ASMS are more or less located in the same area, speeding offences detected by police officers on the motorway are located all over the country. Thus, the regional population is added as an indication of the size of the region and thereby the size of the police force. Because the offenders were actually pulled over additional information on gender and age is available. This makes it possible to do partial analysis on the group aged 18–30 years to test the hypothesis...
Table 4: Effect of a raise in fines on the number of fines for speeding on the motorway, detected by police officers.

| Coefficient | t-Statistic |
|-------------|-------------|
| Constant    | 10.747      | 0.591        |
| Fine amount | 0.154       | 1.264        |
| Unemployment| −0.021      | −0.562       |
| GDP         | −0.717**    | −5.536       |
| Population  | 0.960       | 1.174        |
| Yearly trend| −0.009      | −0.863       |
| Season\(^a\)\) |            |             |
| Summer      | −0.012      | −1.506       |
| Autumn      | −0.031**    | −3.786       |
| Winter      | −0.026**    | −2.902       |
| Truck, bus, or trailer | −0.384**    | −11.504      |
| Gender\(^b\)\) |            |             |
| Female      | −0.381**    | −12.160      |
| Unknown     | −0.482**    | −57.327      |
| Age\(^c\)\) |            |             |
| >30 years, <50 years | 0.128**    | 20.577       |
| ≥50 years, <70 years | −0.200**    | −24.229      |
| >70 years   | −0.574**    | −16.033      |
| Unknown     | −0.706**    | −13.902      |
| Less restrictive fining policy |            |             |
| Strike\(^d\)\) |            |             |
| Dec 2007    | −0.071**    | −2.706       |
| Jan 2008    | −0.105**    | −3.430       |
| Feb 2008    | −0.054*     | −1.927       |
| Mar 2008    | −0.070**    | −2.629       |
| +15 location dummies\(^e\) \+36 dummies for the number of kilometers with which the speed limit was exceeded\(^f\) |            |             |
| Number of observations | 42,450 | 1.000 |
| Adjusted \(R^2\) 1st stage |             |             |
| Adjusted generalized \(R^2\) 2nd stage\(^f\) | 0.307 | 0.307 |

\(^a\) Significantly different from 0 at 90% level.
\(^b\) Spring is the reference category.
\(^c\) Male is the reference category.
\(^d\) No strike is the reference category.
\(^e\) The results for all the dummy variables are available upon request.
\(^f\) See Pesaran and Smith [23].

that young (and thus often inexperienced) drivers behave differently from the total group of motorists (see Polinsky and Shavell [16, 17] and Garoupa [18]).

7. Results

Becker [1] argued that raising the fines, while holding the risk of apprehension fixed, should reduce the number of fines. Here, the elasticity of fines detected by an ASMS is estimated to be −0.14 which differs significantly from both 0 and −1 (see Table 3). This result differs slightly from Moolenaar et al. [21] who performed a similar analysis on the same dataset. However, Moolenaar et al. [21] did not include the recognition rate in the equation nor did they include the number of cars passing by the ASMS without committing an offence.

So there is a small effect: if the fine increases by 1%, then the offence rate detected by an ASMS will decline by 0.14%. This is in line with the results of Bar-Ilan and Sacerdote [19] who found an elasticity of −0.20 for red light offences. Interestingly Levitt [22] found a similar elasticity for total crime. However, the results do not concur with the outcomes...
Table 5: Effect of a raise in fines on the number of fines for speeding on the motorway, detected by police officers; young drivers only.

|                                | Coefficient | t-Statistic |
|--------------------------------|-------------|-------------|
| Constant                       | 12.586      | 0.422       |
| Fine amount                    | 0.206       | 1.025       |
| Unemployment                   | -0.106*     | -1.749      |
| GDP                            | -0.919**    | -4.301      |
| Population                     | 0.563       | 0.422       |
| Yearly trend                   | -0.005      | -0.295      |
| Season a                       |             |             |
| Summer                         | -0.009      | -0.699      |
| Autumn                         | -0.030**    | -2.205      |
| Winter                         | -0.021      | -1.394      |
| Truck, bus, or trailer         | -0.553**    | -9.747      |
| Gender b                       |             |             |
| Female                         | -0.366**    | -6.714      |
| Unknown                        | -0.451**    | -33.547     |
| Less restrictive fining policy | -0.013      | -0.504      |
| Strike c                       |             |             |
| Dec 2007                       | -0.055      | -1.289      |
| Jan 2008                       | -0.110**    | -2.181      |
| Feb 2008                       | -0.051      | -1.089      |
| Mar 2008                       | -0.027      | -0.610      |
| +15 dummies for the number of kilometers with which the speed limit was exceeded d | 1.038 | 0.232 |
| Number of observations         | 14,511      | 1.000       |
| Adjusted $R^2$ 1st stage       |             | 0.314       |
| Adjusted generalized $R^2$ 2nd stage e |             |             |

a Significantly different from 0 at 90% level.
** Significantly different from 0 at 95% level.

Spring is the reference category.
Male is the reference category.
No strike is the reference category.
The results for all the dummy variables are available upon request.
See Pesaran and Smith [23].

of an ex ante simulation model by Significant [2] which suggested that a 1% increase in fines would lead to a temporary decrease of 1% in the number of fines. It is also not in line with the hypothesis of Bjørnskau and Elvik [15] who argue that, under the assumption that both the enforcer and the motorists are maximizing utility, raising fines has no effect on motorist’s behavior. This may be because the amount of police enforcement plays a crucial role in their hypothesis, while the amount of police enforcement is virtually nonexistent in the case of ASMS, as pointed out earlier.

The regression analysis also shows that besides the raise in fines the increased number of unemployed and the GDP had a negative effect on the offence rate. On the one hand, there are less people travelling to and from work; on the other hand, there is less economic activity and thus less transport of resources and products. As expected, bad weather in autumn and winter leads to a lower offence rate. Trucks, busses, and cars with trailers also offend less than ordinary motor vehicles. The lower the speed limit is, the higher the offence rate is.

For fines handed out by police officers there is no such effect: the estimated elasticity is positive and does not significantly differ from zero (see Table 4). Economic developments and population have no influence on the number of fines. The police strikes from December 2007 until March 2008 and the change in fining policy in November 2010 had a significant negative effect. In autumn and winter there are significantly less fines than spring probably due to bad weather. Drivers between 30 and 50 years old get significantly more fines than drivers under 30. This is surprising but may have to do with the fact that motor vehicle ownership is lower for people under 30. Fortunately as people get older they seem to get wiser: drivers over 50 get significantly less fines than people under 30. Women and trucks, busses, and cars with trailers also get significantly less fines. Finally, Table 5 shows that the elasticity for the subsample for young motorists does not significantly differ from zero either. These results seem to support the hypothesis of Bjørnskau and Elvik [15] that raising fines has no effect on motorist’s behavior because the police will reduce their amount of enforcement.
The results imply that motorists only adjust their behavior if the risk of being caught is high, as is the case with ASMS, and even then the adjustments are moderate. The adjustments do seem to be structural. Young drivers are not more responsive to increases in fines than other age groups.

8. Summary and Conclusion

Becker [1] suggests that raising the fines while holding the risk of apprehension fixed reduces the number of offences, which is measured by the elasticity of fines. On the other hand, if fines are fixed and the risk of apprehension is subject to control, then raising the risk of apprehension reduces the number of offences. Recent developments in the Netherlands with respect to fines provide a unique opportunity to test Becker’s proposition. After a long period of no change the Dutch Ministry of Security and Justice has raised the fines several times in the past five years. In addition, technological developments meant that the risk of getting caught for speeding offences has increased significantly in the past seven years.

The first part of Becker’s proposition is supported by the outcomes of a regression analysis on Dutch data on automated speed measuring systems which have a high perceived risk of apprehension. A raise in fines leads to a significant albeit small effect on the offence rate taking into account any other factors that may influence the number of fines, such as weather conditions, the economy, and system malfunctions. The estimated elasticity is −0.14%.

The second part of Becker’s proposition is harder to investigate, since very little is known on the perceived and actual risk of apprehension. However, the results from “high risk” dataset can be compared with the results from a “low risk” dataset. Performing more or less the same regression analysis on fines handed out by police officers in the same period on the same type of road for the same type of offences, no significant effect is found from raising the fines. Thus, when fines are raised, motorists make a moderate adjustment in their behavior, but only if the perceived risk of being caught is high.

Polinsky and Shavell [16, 17], Garoupa [18], and Bar-Ilan and Sacerdote [19] found that young drivers have a higher elasticity than older drivers. But this is not so in the Netherlands. Young drivers do not react differently from older drivers, at least not when there is a low perceived risk of apprehension.

The question remains how successful the Ministry’s policy was. The raises in fines were partly meant to counteract the effects of inflation and partly to induce a reduction in the number of offences. Obviously they have succeeded in counteracting the effects of inflation, but they have only partially succeeded in reducing the number of offences. The reduction in the number of speeding offences, which account for a large part of the fines, can only be slightly explained by the raise in fines. Other factors, such as the economic downturn and not properly functioning ASMS, have had more impact. The economic downturn led to less road traffic; there was a lot of general wear and tear in the average speed measuring systems and many of the average speed measuring systems were out of order due to planned and unplanned road works. The raise in fines may have had a different effect on other types of offences though. This is left for further research.

Conflict of Interests

The author declares that there is no conflict of interests regarding the publication of this paper.

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