UNIVERSITÀ DELLA CALABRIA

Dipartimento di Economia e Statistica
Ponte Pietro Bucci, Cubo 0/C
87036 Arcavacata di Rende (Cosenza)
Italy
http://www.ecostat.unical.it/

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Maria De Paola
Dipartimento di Economia e Statistica
Università della Calabria
Ponte Pietro Bucci, Cubo 1/C
Tel.: +39 0984 492459
Fax: +39 0984 492421
e-mail: m.depaola@unical.it

Vincenzo Scoppa
Dipartimento di Economia e Statistica
Università della Calabria
Ponte Pietro Bucci, Cubo 1/C
Tel.: +39 0984 492464
Fax: +39 0984 492421
e-mail: v.scoppa@unical.it

Mariatiziana Falcone
Dipartimento di Economia e Statistica
Università della Calabria
Ponte Pietro Bucci, Cubo 1/C
e-mail: mariatiziana.falcone@unical.it

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The Deterrent Effects of Penalty Point System in Driving Licenses: A Regression Discontinuity Approach

Maria De Paola, Vincenzo Scoppa, Mariatiziana Falcone ♦ *

Department of Economics and Statistics, University of Calabria

Abstract: Using data on road accidents, traffic fatalities and driving offences taking place in Italy over the period 2001-2005, we estimate the effects of the introduction on July 2003 of a penalty point system for driving offences. To identify the causal effect of the penalty point system on road safety we use a Regression Discontinuity Design. It emerges that, controlling for weather conditions, police patrols, speed cameras, gasoline price, the introduction of the penalty point system has led to a reduction of about 10% of road accidents and of about 25% of traffic fatalities. These findings are robust to different specifications of the model and different time windows. Moreover, it emerges that the driving offences for which the introduction of the new regime has determined a sharp change in the sanction scheme have reacted more than offences for which the change was less relevant.

JEL classification: K320; K420; R410; R480; C230.

Keywords: Law Enforcement; Deterrence; Safety and Accidents; Panel Estimations..

1. Introduction

On 1st July 2003, following the experience of many other countries, a penalty point system for driving offences has been introduced in Italy. Under this system, drivers are sanctioned, in case of traffic violations, with the loss of a number of points (according to the severity of the offences) from a total of 20 points assigned initially. If a driver loses all the points, in case of repeated traffic violations, the driving license is revoked and he/she has to pass a new exam – after a compulsory deprivation period – to get his/her license back.

In practice, the penalty point system, in addition to the traditional monetary sanctions (fines), imposes non-monetary sanctions on drivers consisting in the withdrawal of the driving license. The rationale of this mechanism is that drivers – in part because they are protected by the auto insurance coverage or because they are unable to evaluate the accidents' consequences – fail to fully internalize the social costs of the accidents that they might provoke.

♦ Mariatiziana Falcone is responsible for Section 2; Maria De Paola and Vincenzo Scoppa are jointly responsible for all the other Sections.

* Department of Economics and Statistics, University of Calabria, 87036 Arcavacata di Rende (CS), Italy. E-mail: m.depaola@unical.it; v.scoppa@unical.it. mariatiziana.falcone@unical.it. We would like to thank Simona Benedettini, Antonio D'Agostino, Antonio Nicita, Michela Ponzo for useful comments and suggestions. The usual disclaimers apply.

The aim of the penalty points system – representing a sharp increase in the severity of sanctions for reckless drivers and inappropriate driving behaviour – was to induce drivers to behave more carefully, promote safety and address the intolerable levels of fatalities and serious injury on Italian roads: about 7,000 people died in car accidents in Italy in 2002 while 370,000 were seriously injured. Road accidents are the leading cause of death for people under 45 years.

Bourgeon and Picard (2007) have recently proposed a theoretical model showing that non-pecuniary sanctions (such as the suspension or withdrawal of the driving license) for traffic violations may be more effective than monetary sanctions. In fact, the efficacy of fines may be limited for drivers with a higher income; moreover, the withdrawal of the driving license has the advantage to prevent chronically reckless drivers through incapacitation effect.

The aim of this paper is to show whether the increased level of deterrence determined by the penalty points system has proven successful in reducing the number of road accidents and fatalities in Italy. Our straightforward hypothesis is that if the penalty point system induces individuals to drive more safely, a lower number of crashes will follow and, in addition, the severity of crashes should be lower, leading to a lower number of fatalities and injuries.

We use a panel dataset providing information on a daily basis on road accidents, traffic fatalities and injuries, and driving offences over the period 2001-2009. Data are from the Italian National Police (Polizia di Stato). To recover the causal effect of the penalty point system on road accidents and related fatalities we use a Regression Discontinuity Design exploiting the fact that the assignment to the treatment is determined by time being on the right hand side of the fixed threshold 1st July 2003. Jumps in the relationship between road accidents and time in the period close to the introduction of the penalty point systems are taken as evidence of a treatment effect. In fact, even if time may itself affect our outcome of interest, for example because cars become safer or people become more aware of traffic risks, this association should be smooth. A similar approach, using time as a forcing variable in a regression discontinuous design model, has been followed by Davis (2008) in examining the effects of driving restrictions imposed in Mexico City in 1989 on air quality.

Our estimation results show that, controlling for seasonal effects (month of the year and day of the week), number of police patrols and speed cameras, weather conditions, gasoline price (an exogenous proxy for traffic intensity), the introduction of the penalty point system has determined a significant reduction in the number of road accidents and of related fatalities and injuries. In our basic specification, considering a symmetric two year window around the implementation of the penalty point system (1st July, 2001 – 1st July, 2005), it emerges that the new regime has reduced road accidents of about 10%, while the effect on the number of traffic injuries and fatalities is stronger, showing a reduction of respectively 15% and 25%. These findings are robust to different polynomial time trends and to the use of interaction terms between the treatment variable and the temporal trend. A negative and highly statistically significant impact on all our variables of interest emerges also when we focus on a narrow time window, considering, for example, a year before and a year after the implementation of the new system or a six month window.

In addition, thanks to the availability of information on the number of per day driving offences detected by public authorities, we have analyzed the effect of the new regime on this variable. As regards this variable, we are able to exploit both changes occurring over time (before and after 1st July 2003) and across different types of offences. In fact, the penalty point system introduced in Italy in 2003 did not modify in a homogeneous way sanctions for all types of driving offences. For some types of offences, the new system has determined a significant change, exposing the driver to the risk of having withdrawn the driving license, while for other types of offences the change was less relevant, since these were already punished under the old system with the suspension of driving privileges. From our analysis, it emerges that the impact of the penalty point system has been very strong for the first type of offences, while a weaker effect is found for those offences that were already punished harshly by the old system. This heterogeneous impact on offences, according to the change in the sanction scheme introduced by the penalty point system, reassures us that the effects we have estimated are not driven by other factors that may have occurred simultaneously to the implementation of the new scheme.

Our paper is related to the growing literature investigating the effects of automobile safety regulations on traffic accidents and related fatalities. Traynor (2009) examines the concomitant impact of three different policies that some U.S. states have implemented to induce safer behaviour of drivers and passengers. Empirical findings support the hypothesis that these policies, by imposing restrictions on teen driving and driving under the influence of alcohol, have produced a statistically significant impact on traffic safety reducing annual fatality rates. On the other hand, the law imposing the use of seat belts does not seem to have played any relevant role. This result may be due to the well known Peltzman (1975) effect: drivers wearing seat belt feel more secure and drive less carefully increasing total fatalities. However, there are a number of other works showing that seat belt use reduces the fatality risk among car occupants. Cohen and Einav (2003) use state panel data for the period 1983-1997 to evaluate mandatory seat belt law and conclude that these laws are effective in reducing traffic fatalities. In a similar vein, Levitt and Porter (2001*a*) analyse the effectiveness of seat belts and air bags in preventing deaths in motor vehicle crashes. Using data for fatal crashes occurring in the years 1994-1997 in U.S., they find that seat belts are more effective in reducing the risk of death than air bags.

Among the main determinants of traffic fatalities many scholars have focused on the effects of maximum speed limits. Results are not conclusive: while some studies show that higher limits result in an higher number of traffic fatalities, other works support the so called "speed spillover hypothesis", that is higher speed limits on rural interstates produce additional hazards on other roadway types. Houston (1999), using data for U.S. states, suggests that higher speed limits have negative safety consequences on roads directly affected by these limits, but produce a reduction in accidents and related fatalities taking place on other roads.

Road accidents are strongly influenced also by the driver behaviour, for example in terms of alcohol or drug use, phone usage while driving, car maintenance. Levitt and Porter (2001*b*) estimate the likelihood of a fatal crash for drinking drivers, using data on fatal accidents in U.S. They find that drinking drivers are at least seven times more likely to cause fatal crashes than sober drivers. Their results suggest that policies focused on stopping erratic drivers might be successful. Similarly, Grabowski and Morrisey (2001) find that increasing the minimum legal drinking age decrease fatalities among younger drivers.

Using state-level panel data on mobile phone ownership, hands-free laws and traffic fatalities, Kolko (2009) finds that mobile phones are positively correlated with traffic fatality rates, while hands-free laws are associated with lower fatality rates.

Poitras and Sutter (2002) have tested the effectiveness of safety inspections on vehicles – inducing drivers to improve mechanical condition of vehicles and to increase the level of maintenance. They find that inspections do not increase maintenance and mechanical soundness of cars on the road. Furthermore, in inspecting states the number of old vehicles declines but casualties do not.

The paper is organized in the following way. In Section 2 we present the institutional framework and the data we use. Section 3 carries out the empirical analysis considering the effect of the penalty point system on road accidents and related fatalities and injuries. Section 4 analyses the effect on different types of driving offences. Section 5 concludes.

2. Institutional Setup and Data

2.1. The Driving License Point System in Italy

Punishments for infringements of road regulations belong to two categories: monetary sanctions and license deprivation as suspension or withdrawal. Major traffic offences, such as driving under the influence of alcohol or drugs, often carry a mandatory suspension of driving license and drivers may incur other serious penalties like imprisonment. Less severe traffic violations are recorded in many countries through a penalty point system according to which authorities subtract points to drivers on conviction for road traffic offences.[1] Notwithstanding the implementation of the penalty point system varies among countries, the general operating principles are the same.

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[1] Depending on the particular system in use, points may either be added until a threshold is reached (the so-called Demerit Point System typically used in the US) or be subtracted from a given score until zero (the so-called Penalty Point System adopted in many European countries).

On 1st July 2003 a Penalty Point System (PPS hereafter) for driving offences was introduced in Italy (Law no. 214/03). Each driver is credited with an initial driving score of 20 points. This score is reduced by deducting a number of points when the driver commits traffic violations. The number of points deducted varies according to the severity of the offences. For example, ignoring a red traffic light is punished with 6 points of penalty, driving under the influence of alcohol or drug is punished with 10 points, overcoming the speed limit of 40 Km/h with 10 points, failing to wear a seatbelt or using a mobile phone with 5 points, and so on.[2] The loss of points comes in addition to monetary sanctions. When the number of points reaches zero, the driving license is withdrawn and the driver must take a new driving test.

The introduction of this new system has determined an increase in the penalties for traffic violations that is not homogenous across different offences. Whereas it has determined a severe increase in the punishment of some types of violations, the change was relatively less relevant for other types of offences. On the one hand, for offences such as driving at a dangerous speed,[3] driving without wearing some safety devices (seat belts and helmets), which were punished under the old system only with monetary sanctions, the new regime has added a non-pecuniary penalty (the loss of a certain number of points), exposing the driver to the risk of suspension of his driving license.[4] On the other hand, for offences such as driving at an excessive speed, driving under the influence of alcohol or drugs, which were already harshly punished under the old systems (with the mandatory suspension of driving license and imprisonment),[5] the new system, adding to those sanctions the subtraction of 10 points, has determined a relatively minor change.

2.2. Data

This section briefly describes the data used in our empirical analysis and their source.

In Italy, police departments are required by law to submit detailed information on each automobile crash. Three different bodies are in charge for accidents taking place on Italian roads: a) the Municipal Police ("Vigili Urbani") for accidents occurring in urban areas (65% of the total); b) the National Police and c) the "Carabinieri" (another Italian military force) for accidents occurring in other areas (35%).

The National Police maintains a database of road accidents and driving offences, freely available at http://www.poliziadistato.it/pds/stradale/archivio, which covers about 20% of the

[2] The penalty points are doubled if a driver commits traffic violations in the first three years after passing his driving test. The driver may reconstitute all or part of his score by committing no further breaches for a period of two years. Every 2 years drivers receive a bonus of 2 points until a maximum of 30 points.

[3] Driving at a dangerous speed concerns a number of driving behaviours, such as driving at a very low speed, not maintaining safe distances from other vehicles, etc., and is very different from offences related to driving at an excessive speed.

[4] The Law no. 214/03, introducing the penalty point system, has also doubled the monetary fines for violation regarding the use of helmets on motorcycles and the use of seat belts.

[5] Excessive speeding was punished with the mandatory suspension of driving privileges when the speed limit was exceeded by more than 40 Km/h.

total number of accidents. Notwithstanding these data do not cover the entire universe of accidents, they constitute a representative sample and accidents recorded in this dataset represents a nearly constant proportion of the total number occurring over time (see ISTAT, 2009). Unfortunately, data recorded by the Municipal Police and by the "Carabinieri" are not publicly available.

The dataset at hand provides information on a daily basis of road accidents, traffic fatalities and injuries occurring on highways and other roads over the period 1st March 2001-31st December 2009 and on different types of traffic violations detected by the National Police during the same period of time. Even though we have data from 2001 to 2009, as we explain in Section 3, in our main specifications we focus on a symmetric two year time window before and after the introduction of the PPS (from 1st July 2001 to 30th June 2005). Data are recorded separately for main highways and other roads and, as a consequence, we have two observations for each day. We use a dummy variable *Highways* to denote events occurring on highways.

Table 1 shows the descriptive statistics for the main variables used in the analysis (in this Table we add up data occurring on highways and other roads). The number of per day road accidents has significantly decreased after the introduction of *PPS*, from 309.6 to 255.4. A sharp reduction is observed also for traffic injuries (passing from 228.4 to 180.5) and fatalities (passing from 7.1 to 5.2).

This reduction in the number of road accidents and related fatalities is consistent with national data provided by ISTAT which show that the total number of accidents has changed from 263,100 in 2001 to 240,011 in 2005, while fatalities has decreased from 7,096 to 5,818.

As explanatory variables we use an indicator of weather conditions obtained averaging the daily precipitations (provided by the European Climate Assessment & Dataset ECA&D)[6] in 10 Italian cities located across different geographical areas (North-East, North West, Center, South and Islands). To control for traffic intensity, we consider monthly gasoline prices (Ministry of Economic Development), which should be exogenous, instead of using the gasoline sales that might be endogenous.

We also have information on the monthly number of police patrols and speed cameras operating respectively on highways and other roads,[7] which allows us to control for the effort made by public forces to detect and then avoid traffic violations. In Table 1 it is possible to see that both the number of police patrols and of speed cameras has increased in the period following the introduction of the *PPS*.

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[6] Data are available at http://eca.knmi.nl. See Klein *et al.* (2002).

[7] The dataset we use provides information of the number of police patrols starting from September 2004. Data on police patrols and on speed cameras for the period going from March 2001 to September 2004 were kindly provided by Antonio Nicita, who obtained the data from the Traffic Police Directorate (Direzione della Polizia Stradale).

Table 1. Descriptive statistics. Daily data: 1st July 2001 to 30th June 2005

Variable	Mean	Sd	Min	Max	N
		Before the introduction of PPS			
Road Accidents	309.608	53.146	204	611	730
Injuries	228.404	64.709	95	548	730
Fatalities	7.063	3.658	0	23	730
Police patrols	297887.3	20359.07	266402	340572	730
Speed cameras	3156.24	624.4372	2390	5161	730
		After the introduction of PPS			
Road Accidents	255.371	38.950	149	399	731
Injuries	180.510	49.951	75	443	731
Fatalities	5.157	3.086	0	27	731
Police patrols	334679.7	18544.77	303510	369059	731
Speed cameras	3459.159	581.1021	2686	5110	731
		Other Controls – 2001-2005			
Precipitations	21.365	42.459	0	348	1461
Gasoline Price	1.083	0.057	0.992	1.220	1461
Holiday	0.033	0.178	0	1	1461

Sources: Italian National Police, European Climate Assessment & Dataset ECA&D, Ministry of Economic Development.

In the next section, to better understand the effects of the *PPS* on the outcome variables we use a regression discontinuity design to disentangle the effects of the *PPS* from other possible confounding factors.

3. Regression Discontinuity Estimates of the Effects of the Penalty Point System

The aim of our analysis is to empirically investigate whether the introduction of the *PPS* for driving license has determined a reduction of road accidents and fatalities in Italy, assuming that the frequency of road crashes and fatalities is strictly related to the drivers' behavior: when inappropriate and dangerous behavior are sanctioned more harshly, we expect that drivers tend to drive more safely, respect signals and speed limits, wear seat belts or helmets, do not take alcohol or drugs, etc. This, in turn, will determine a minor number of accidents and will help at reducing the negative consequences of accidents.

Formally, we define the dummy variable PPS_t equal to one for observations after the introduction of the penalty point system at time $t_0 = 1^{st}$ July 2003 and 0 otherwise:

$$PPS_t = \begin{cases} 1 \ \ if \ \ \mathrm{t} \geq 1^{st} \ \ July\ 2003 \\ 0 \ \ if \ \ \mathrm{t} < 1^{st} \ \ July\ 2003 \end{cases}$$

To recover the effect of PPS_t on the number of per day road accidents and related casualties we use a Sharp Regression Discontinuity Design in which the treatment status PPS_t is a deterministic and discontinuous function of time (Imbens and Lemieux, 2008; Angrist and Pischke, 2009). Following most of the papers in the literature, we use a parametric approach.

In general, sharp regression discontinuity design compares the outcomes of units just above the threshold with the outcomes of units just below the threshold. Therefore, we compare the road accidents and fatalities just before and after the cutoff date of 1st July 2003. Obviously, traffic accidents might be related to time for a variety of reasons: technological progress making cars safer; road maintenance and investments in safe road infrastructures; an increasing drivers' awareness of traffic risks; population aging, since older people tend to be more careful, and so on. However, the effects of time can be controlled using temporal trends. Under the assumption that the relationship between the outcome variables and time is continuous in a neighborhood of t_0, any jump in the dependent variable in proximity of the cutoff point can be interpreted as evidence of a treatment effect.

We model the number of per day road accidents and fatalities using the following model:

[1] $$Y_t = \phi PPS_t + \beta X_t + f(t) + \varepsilon_t$$

where Y_t is our outcome of interest (alternatively, *Accidents*, *Injuries* and *Fatalities*), ϕ measures the effect of the penalty point system, X_t is a vector of control variables including month of the year, day of the week, an indicator for holidays, the monthly number of police patrols and speed cameras, average daily precipitations, average monthly gasoline price, a dummy for highways, $f(t)$ is a flexible functional form for the effect of time, $f(t) = \gamma_1 t + \gamma_2 t^2 + ... + \gamma_p t^p$, which, in our main specifications, we model with a fifth grade polynomial, and ε_t is an error term.

Our main estimates focus on the period July 2001-July 2005, a two year window around the implementation of the PPS.[8] The chosen period of analysis is due, on the one hand, to the need to avoid longer time spans during which other institutional changes might have taken place (for example, in 2006 a number of other laws concerning road traffic safety have been implemented). On the other hand, in the Regression Discontinuity Design approach (see Imbens and Lemieux, 2008; Davis, 2008) it is recommended to focus on observations distributed within a distance Δ on either side of the threshold t_0: $[t_0 - \Delta, t_0 + \Delta]$. Therefore, we focus on a symmetric time window and, due to the lack of data before 2001, we are constrained to a two year maximum symmetric window.

As a robustness check, in section 3.1, we estimate our model focusing on alternative time windows. In all estimates, standard errors are robust to heteroskedasticity and arbitrary correlations within 7 lags.

[8] Estimating a standard regression on a window of width Δ on both sides of the cutoff point amounts to a non-parametric estimation method using a rectangular kernel (Imbens and Lemieux, 2008).

In columns (1), (2) and (3) of Table 2 are shown OLS estimates of equation [1] for, respectively, *Accidents*, *Injuries* and *Fatalities*. It emerges that, controlling for temporal trends and covariates, the introduction of the *PPS* has led to a reduction in the number of daily accidents of 13.9, that is, a reduction of about 8.8%. The coefficient is statistically significant at the 1 percent level. Similar effects emerge also in columns (2) and (3): the *PPS* is associated with a reduction of about 20.9 injuries (–18%) and with a reduction of about 1 fatality per day (nearly –28%).

Table 2. RD estimates of PPS effects - 1st July 2001 – 30th June 2005

	OLS			Poisson		
	(1) Accidents	(2) Injuries	(3) Fatalities	(4) Accidents	(5) Injuries	(6) Fatalities
Penalty Point System	-13.9921***	-20.8851***	-1.0062***	-0.1033***	-0.2163***	-0.3528***
	(3.4434)	(3.5997)	(0.3364)	(0.0231)	(0.0283)	(0.0990)
Holiday	-8.8324***	21.7648***	0.4844**	-0.0613***	0.1981***	0.1547**
	(2.9942)	(4.2162)	(0.2388)	(0.0225)	(0.0337)	(0.0693)
Precipitations	0.3021***	0.1556***	0.0002	0.0019***	0.0014***	0.0000
	(0.0166)	(0.0149)	(0.0012)	(0.0001)	(0.0001)	(0.0004)
Gasoline Price	32.1300	-6.5495	-0.5002	0.3122*	0.2524	0.2408
	(25.8986)	(27.1321)	(2.4352)	(0.1842)	(0.2374)	(0.7922)
Police patrols	-0.0000	0.0000	0.0000	-0.0000	0.0000	0.0000
	(0.0001)	(0.0001)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Observations	2922	2922	2922	2922	2922	2922
(Pseudo) R-squared	0.5844	0.8056	0.3672	0.3512	0.6992	0.1810
Log-likelihood				-15467.8	-15755.4	-5802.0

Notes: The Table reports RD estimates. All specifications are for July 2001-July 2005 and include a fifth order polynomial time trend, indicator variables for month of the year, day of the week and for accidents occurring on highways. Standard errors (reported in parentheses) are corrected for heteroskedasticity and autocorrelations (up to 7 lags). The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at the 1, 5, and 10 percent level.

In order to take into account that our dependent variables take non-negative discrete values, we have also used a Poisson estimator. Estimation results, reported in columns (4)-(6), are widely consistent with OLS estimates, but the magnitude of the effects is significantly larger. It emerges a reduction of about 10.3% in road accidents (*t*-stat=–4.48), of 21.6% in traffic injuries (*t*-stat=–7. 64) and of 35.3% in traffic fatalities (*t*-stat=–3.56).[9]

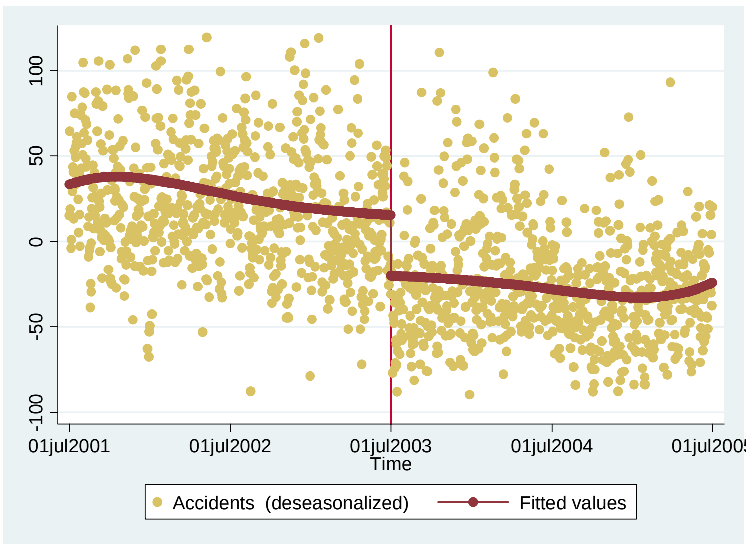
As regards control variables, it emerges that road accidents and related casualties follow a seasonal pattern, with peaks in July and December; they are more frequent on Saturdays and on Sundays, probably because of drunk-driving, which is more common during weekends, especially among young people (dummies for month of the year and day of the week are not reported to save space). Drunk driving may also explain the coefficient on the dummy *Holydays,* which is negative when considering road accidents, implying that during holidays the number of road accidents reduces, probably because of a lower traffic intensity, but is positive on the number of traffic injuries and fatalities, suggesting that the pool of drivers tend to be less careful leading to more serious consequences when an accident occurs. Weather conditions play

[9] Very similar results are obtained using a negative binomial estimator.

a very relevant role both in explaining the number of accidents and the number of injuries, which increase with precipitations, while they are not statistically significant in explaining the number of traffic fatalities. Gasoline price and the number of police patrols are not statistically significant as regards all our outcome variables. Finally, the dummy variable *Highways* shows that the number of accidents occurring on highways is smaller.

One of the main advantage of Regression Discontinuity Design is that it allows a transparent graphical analysis. We first deseasonalize our dependent variables by regressing them on dummies for month of the year and day of the week. The deseasonalized values plotted against time are shown in Figure 1 (panel a: *Accidents*; b: *Injuries*; c: *Fatalities*). In this Figure are also represented the predicted values from a fifth order polynomial trend estimated separately on each side of the cutoff point. The vertical line at the 1st July 2003 denotes the day in which the *PPS* was introduced. In the three panels of Figure 1, it clearly emerges a jump in the relationship between the outcomes and the time variable in the proximity of our threshold point.

Figure 1. Daily accidents, injuries and fatalities and predicted values



panel (a)

panel (b)

panel (c)

The estimates reported in Table 2 are based on a sample composed of 2 observations per day, the first for accidents occurring on main highways and the second for accidents taking place on local roads. In Table 3 are reported Poisson estimates separately for each types of road. From these estimates it emerges that the *PPS* has reduced accidents and related fatalities occurring both on highways and on local roads.[10] However, the effect is higher in magnitude on accidents occurring on local roads.

[10] As an alternative, we have summed up observations for highways and local roads, obtaining the total number of daily traffic accidents. Estimates using this sample are very similar to those shown in Table 2.

Table 3. RD estimates for accidents and casualties occurring on Local Roads and Highways (Poisson estimates)

	Roads			Highways		
	(1)	(2)	(3)	(4)	(5)	(6)
	Accidents	Injuries	Fatalities	Accidents	Injuries	Fatalities
Penalty Point System	-0.1673***	-0.2503***	-0.3722***	-0.0367*	-0.1489***	-0.2271*
	(0.0238)	(0.0325)	(0.1147)	(0.0216)	(0.0392)	(0.1369)
Observations	1461	1461	1461	1461	1461	1461
Pseudo R-squared	0.3468	0.4580	0.0936	0.2049	0.2985	0.0400
Log-likelihood	-6939.7	-8043.9	-3263.3	-7279.5	-7315.1	-2503.9

Notes: The Table reports RD estimates of PPS. All specifications are for July 2001-July 2005 and include a fifth order polynomial time trend, indicator variables for month of the year and for day of the week, dummies for holiday, monthly number of police patrols, precipitations, gasoline price. Standard errors (reported in parentheses) are corrected for heteroskedasticity and autocorrelations (up to 7 lags). The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at the 1, 5, and 10 percent level.

3.1. Robustness Checks 1: Different Polynomial Time Trends

The consequences of the misspecification of the functional form in terms of biased estimates of the treatment effect are particularly serious in RD design contexts. Following Angrist and Pischke (2009) who suggest to verify the robustness of results to different polynomial trends, in Table 4 we replicate the same specifications shown in Table 2, considering different polynomial time trends, from the first to the eighth order.[11] Across all the time trend specifications, it emerges a clear effect of the *PPS* on all our outcome variables.

Table 4. Sensitivity of RD estimates to the polynomial time trend order (Poisson estimates)

Polynomial time trend	Accidents	Injuries	Fatalities
First order	-0.0891***	-0.1526***	-0.2234***
	(0.0199)	(0.0439)	(0.0749)
Second order	-0.0892***	-0.1535***	-0.2292***
	(0.0197)	(0.0439)	(0.0753)
Third order	-0.0796***	-0.1552***	-0.2752***
	(0.0243)	(0.0528)	(0.0884)
Fourth order	-0.0757***	-0.1552***	-0.2704***
	(0.0241)	(0.0529)	(0.0903)
Sixth order	-0.1114***	-0.2233***	-0.3601***
	(0.0302)	(0.0667)	(0.1155)
Seventh order	-0.1114***	-0.2207**	-0.3638**
	(0.0410)	(0.0931)	(0.1661)
Eighth order	-0.1078***	-0.2175**	-0.3649**
	(0.0412)	(0.0935)	(0.1663)
Observations	2922	2922	2922

Notes: The Table reports RD estimates of PPS. All specifications are for July 2001-July 2005 and include indicator variables for month of the year and day of the week, dummies for holiday and highways, monthly number of police patrols, precipitations, gasoline price. Standard errors (reported in parentheses) are corrected for heteroskedasticity and autocorrelations (up to 7 lags). The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at the 1, 5, and 10 percent level.

[11] We do not report the fifth order already presented in Table 2.

In order to not impose any restriction on the underlying conditional forms, we include among controls interaction terms between the polynomial time trend and our treatment variable With the aim to interpret the coefficient on PPS_t as the treatment effect, the terms of the time trend have been defined as $\tilde{t} = t - t_0$. Therefore, we estimate the following model:

[2]
$$Y_t = \phi PPS_t + \beta X_t + \left(\gamma_1 \tilde{t} + \gamma_2 \tilde{t}^2 + \ldots + \gamma_p \tilde{t}^p\right) + \\ + \left(\gamma_1 \tilde{t} PPS_t + \gamma_2 \tilde{t}^2 PPS_t + \ldots + \gamma_p \tilde{t}^p PPS_t\right) + \varepsilon_t$$

In Table 5, in which are reported only Poisson estimates,[12] it emerges that estimates of ϕ turn out to be very similar to those discussed above, but the effects become larger in magnitude when the polynomial order increases. In all specifications, and for all our outcome variables, the effect of *PPS* is negative and highly statistically significant.

Table 5. RD estimates with interaction terms (Poisson estimates)

Polynomial time trend	Accidents	Injuries	Fatalities
First order	-0.0910***	-0.1566***	-0.2328***
	(0.0154)	(0.0199)	(0.0632)
Second order	-0.0877***	-0.1741***	-0.3006***
	(0.0200)	(0.0248)	(0.0866)
Third order	-0.1181***	-0.2508***	-0.4399***
	(0.0320)	(0.0397)	(0.1425)
Fourth order	-0.0992***	-0.1968***	-0.4286**
	(0.0385)	(0.0469)	(0.1751)
Fifth order	-0.1202***	-0.2140***	-0.5259**
	(0.0449)	(0.0530)	(0.2123)
Sixth order	-0.1510***	-0.2737***	-0.5128**
	(0.0481)	(0.0562)	(0.2360)
Observations	2922	2922	2922

Notes: The Table reports RD estimates of PPS. All specifications are for July 2001-July 2005 and include indicator variables for month of the year and day of the week, police patrols, precipitations, gasoline price, dummies for holiday and highways, interaction terms between the terms of the time trends and PPS_t. Standard errors (reported in parentheses) are corrected for heteroskedasticity and autocorrelations (up to 7 lags). The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at the 1, 5, and 10 percent level.

3.2. Robustness Checks 2: Different Time Windows

Following Imbens and Lemieux (2008), we now look only at data in a neighborhood around the discontinuity. The comparison of average outcomes in a small enough neighborhood to the left and to the right of the threshold value should estimate our effect of interest in a way that does not depend on the correct specification of the model for the conditional expected function.

We experiment focusing on three different time intervals: the first including a year before and a year after t_0, the second considering six month before and after t_0 and the last focusing on a three months window. In Table 6 are reported results obtained from our local

[12] OLS estimates are very similar, but not reported to save space.

linear regressions. In all specifications, the *PPS* produces a reduction of road accidents and related fatalities but the effect becomes smaller in magnitude as the time interval is shortened.

When we consider a three month interval, the effect of *PPS* is imprecisely estimated and it becomes not statistically significant for traffic fatalities. However, given the importance of seasonal effects for our outcome variables (road accidents tend to be more frequent during summer), estimates obtained when focusing on very short time windows, where it is not possible to control for seasonal factors, may be downward biased.

Table 6. RD estimates with alternative time windows (Poisson estimates)

Time window	(1) Accidents	(2) Injuries	(3) Fatalities
01 July 2002 – 30 June 2004	-0.1451***	-0.2095***	-0.2562***
	(0.0098)	(0.0130)	(0.0427)
Observations	1462	1462	1462
01 Jan 2003 – 31 December 2003	-0.0786***	-0.1126***	-0.1863***
	(0.0124)	(0.0164)	(0.0519)
Observations	730	730	730
01 April 2003 – 30 September 2003	-0.0586***	-0.0417*	-0.1322
	(0.0210)	(0.0237)	(0.0848)
Observations	366	366	366

Notes: The Table reports RD estimates of PPS. All specifications include indicator variables for day of the week, dummies for holiday and highways, monthly number of police patrols, precipitations, gasoline price. The specification focusing on 1st July 2002 – 30th June 2004 time window also includes dummies for month of the year. Standard errors (reported in parentheses) are corrected for heteroskedasticity and autocorrelations (up to 6 lags). The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at the 1, 5, and 10 percent level.

As a further robustness check we extend the analysis to the entire period covered by our data, going from 1st March 2001 to 31st December 2009. As shown in Table 7, also for this large temporal span, the PPS has proven effective in increasing road safety. The impacts on road accidents (-10%), on injuries (-15%) and on fatalities (-24.5%) are very close to estimates obtained in other specifications of our model.

Table 7. RD estimates for accidents occurring on Local Roads and Highways. 1st March 2001 – 31 December 2009 (Poisson Estimates)

	(1) Accidents	(2) Injuries	(3) Fatalities
Penalty Point System	-0.0972***	-0.1538***	-0.2450***
	(0.0150)	(0.0194)	(0.0618)
Observations	6394	6394	6394
Pseudo R-squared	0.3704	0.6738	0.1835
Log-likelihood	-32425.8464	-33532.5881	-12057.4584

Notes: The Table reports RD estimates. All specifications include indicator variables for month of the year and for day of the week, dummies for holiday and highways, monthly number of police patrols, precipitations, gasoline price and a fifth order polynomial trend. Standard errors (reported in parentheses) are corrected for heteroskedasticity and autocorrelations (up to 8 lags). The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at the 1, 5, and 10 percent level.

In Figure 2 we plot the deseasonalized values of accidents and the predicted values from a fifth order polynomial trend against time. From the Figure it clearly emerges a marked jump in proximity to the introduction of the PPS. The temporal trend of road accidents is decreasing and the *PPS* seems to have produced a shift in the intercept.

Figure 2. Daily accidents and predicted values from 2001 to 2009

4. The Heterogeneous Effect of the PPS on Different Types of Traffic Offences

The introduction of the *PPS* has determined an increase in penalties for traffic violations, which is not homogenous across different types of offences. In fact, while it has determined a severe increase in the punishment of some types of violations, for other offences the change was relatively less relevant. Offences such as driving without seat belts or helmets and driving at a dangerous speed (*Type A Offences*) were punished only with a monetary sanction under the old system and the *PPS* has added to the fine a non-pecuniary sanction – the loss of a certain number of points – which exposes the driver to the risk of driving license withdrawal. For other infringements – such as driving under the influence of alcohol or drugs and driving at an excessive speed (*Type B Offences*) – the increase in penalty was less dramatic, since these offences were already punished very harshly under the old system (mandatory suspension of driving privileges and imprisonment in addition to pecuniary penalties). The *PPS* has added to these sanctions the subtraction of a number of points.

Therefore, for *Type A Offences* the new system has determined the passage from a pecuniary sanction scheme to a more complex scheme involving the risk of withdrawal of the driving license. On the other hand, for *Type B Offences*, the withdrawal of the driving license was already in force under the old system, and the change introduced by the *PPS* was less relevant.

To analyze whether the impact of the *PPS* was heterogeneous across different type of offences, we exploit the fact the our dataset also provides detailed information on the number of traffic offences detected by the National Police each day. For the period we consider (a symmetric two year window around the implementation of the *PPS*), data are available for six different type of offences[13]: driving at a dangerous speed (*Dangerous Speed*), driving without seat belts (*Seat Belts*), riding a motorcycle or a scooter without a helmet (*Helmet*), excessive speeding (*Excessive Speeding*), driving under the influence of alcohol (*Alcohol*), driving under the influence of drug (*Drug*). Since in this analysis we use many interaction terms, for the sake of simplicity we added up observations for highways and other roads ending up with one observation per day.

As shown in Table 8, in which some descriptive statistics are presented, the introduction of *PPS* is associated to a drastic reduction of the number of detected offences for driving at a dangerous speed and driving without safety devices, while offences related to driving at an excessive speed and under the influence of alcohol or drugs have increased after July 2003.

Table 8. Descriptive Statistics for Detected Road Offences. Daily data: 1st July 2001 – 30th June 2005

Variable	Mean	Sd	Min	Max	N
Before the introduction of PPS					
Dangerous speed (Type A)	221.662	40.074	75	456	730
Helmet (Type A)	189.856	119.446	10	583	730
Seat belts (Type A)	684.837	167.919	66	1505	730
Excessive speeding (Type B)	1772.877	984.545	198	9018	730
Alcohol (Type B)	57.518	40.652	13	311	730
Drugs (Type B)	3.338	4.254	0	61	730
After the introduction of PPS					
Dangerous speed (Type A)	178.927	34.611	54	356	731
Helmet (Type A)	47.260	33.431	2	225	731
Seat belts (Type A)	299.528	71.559	30	744	731
Excessive speeding (Type B)	2463.312	914.529	125	8807	731
Alcohol (Type B)	63.341	50.902	14	377	731
Drugs (Type B)	4.164	3.730	0	37	731

Sources: Italian National Police.

In the following we undertake an econometric analysis to disentangle the impact of *PPS* on traffic offences, controlling for a number of potential determinants.

To this aim, we stack observations referring to each type of offence obtaining a dataset composed of 8,766 units (1,461 daily observations times 6 different types of offences) in order to statistically test – using interactions terms – the impact of *PPS* on offences of different type. We estimate the following model:

[2] $$A_{tj} = \mu_j + \phi_j\left(\mu_j \cdot PPS_t\right) + \beta X_t + f\left(t\right) + \varepsilon_t$$

[13] Starting from September 2004 data are available also for offences related to unauthorized speed competitions, to vehicle lighting system use and to headphone and speaker phone system use.

where A_{tj} are detected road offences of type *j* committed in day *t*, μ_j are dummies to denote each type of offence and the interaction terms $(\mu_j \cdot PPS_t)$ allow to estimate separately the coefficients ϕ_j, representing the specific impact of *PPS* on each type of offence, X_t is a vector of control variables, including all the regressors used in the previous analysis, $f(t)$ is a fifth grade polynomial for temporal trends, and ε_t is an error term.

As shown in column (1) of Table 9, once we control for weather conditions, traffic intensity, seasonal factors, monthly number of police patrols, from Poisson estimates it emerges that the *PPS* has reduced on average of about 39% the number of traffic offences. To analyze whether the effect has been heterogeneous across different types offences, in column (2), we add among regressors interaction terms between the different types of offences and the dummy *PPS*, leaving as reference category offences for *Excessive Speeding*. Estimates show that the effect has been very relevant for those offences, such as *Seat Belts*, *Helmets* and *Dangerous Speed*, for which the new system has determined a major change in the sanction scheme, while a weaker effect emerges for offences, such as *Alcohol*, *Drugs* and *Excessive Speeding*, for which non pecuniary sanctions were already in force before the introduction of the *PPS*. For the reference category, which includes offences for driving at a speed exceeding 40 Km/h the limit (already punished under the old scheme with the withdrawal of the driving license), the effect is negative, but not statistically significant.

Table 9. The Impact of PPS on Driving Offences. 1st July 2001 – 30th June 2005 (Poisson Estimates)

	(1)	(2)	(3)
Penalty Point System	-0.3949***	-0.1082	-0.1149*
	(0.0635)	(0.0682)	(0.0677)
PPS*Dangerous Speed		-0.5431***	
		(0.0246)	
PPS*Seat Belts		-1.7195***	
		(0.0415)	
PPS*Helmet		-1.1559***	
		(0.0254)	
PPS*Alcohol		-0.2325***	
		(0.0486)	
PPS*Drug		-0.1079*	
		(0.0621)	
PPS*Type A Offences			-1.0572***
			(0.0245)
Observations	8766	8766	8766
Log-likelihood	-441834.8	-309572.3	-327049.7

Notes: The Table reports RD estimates. All specifications include indicator variables for the type of offences, month of the year and for day of the week, dummies for holidays, monthly number of police patrols, precipitations, gasoline price and a fifth order polynomial time trend. Standard errors (reported in parentheses) are corrected for heteroskedasticity and autocorrelations (up to 7 lags). The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at the 1, 5, and 10 percent level.

To better understand whether the effect of the *PPS* was significantly different for different types of offences, in column (3), we jointly consider *Type A Offences* and leave as reference category *Type B Offences*. The coefficient on the *PPS* dummy is negative and statistically significant at 5 percent level, suggesting that the introduction of the new system has led to a reduction of about 11% of *Type B Offences*. The coefficient on the interaction term *Type A Offences**PPS* is negative and highly statistically significant, suggesting a much stronger impact of *PPS* on *Type A Offences*.

Similar findings emerge when we experiment with different polynomial time trends, when we use interaction terms between the treatment variable and the temporal trend and focusing on different time windows.

These heterogeneous effects imply that the *PPS* has been more effective in reducing those offences for which it has determined a radical change in the sanctioning scheme and give further support to the finding that the *PPS* has helped at increasing traffic safety in Italy.

4. Concluding Remarks

This paper analyzes whether the increased level of deterrence determined by the penalty points system introduced in Italy in July 2003 has proven successful in reducing the number of road accidents and related fatalities.

Our analysis is based on a rich dataset, from the Italian National Police, providing daily information on the number of road crashes, traffic fatalities and driving offences. We use a Regression Discontinuity Design and compare traffic accidents and related fatalities before and after the introduction of the *PPS*. Controlling for seasonal factors, weather conditions, traffic intensity, number of police patrols, polynomial time trends, it emerges that the *PPS* has produced a relevant negative effect on all our outcomes of interest. The introduction of the *PPS* has reduced road accidents of about 10%, while the effect on the number of traffic injuries and fatalities has been, respectively, of about 15% and 25%. These findings are robust to different polynomial time trends and to the use of different time windows.

From our analysis it also emerges that the *PPS* has determined a reduction of the number of per day driving offences detected by the National Police. Since we control for monitoring intensity (police patrols and speed cameras) we interpret these findings as the causal effect of the increased deterrence determined by the introduction of PPS.

In addition, we show that the effect of the *PPS* is heterogeneous across different types of offences. The new regime has determined a strong reduction of those offences for which a main change occurred in the sanctioning scheme, while the effect has been weaker for those offences which were already punished under the old system with non pecuniary sanctions, such as the withdrawal of the driving license. This heterogeneous impact on different types offences reassures us that the positive effect of the *PPS* on traffic safety is not driven by other factors that may have occurred simultaneously to the introduction of the *PPS*.

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