Rational Drivers, Irrational Enforcers, and Road Safety

S.Benedettini[1], and A.Nicita[2]

Abstract

Italy shows one of the highest level of road fatalities across European countries. Speeding is ascertained to be the first cause for motorways fatal accidents. In order to increase road safety, in 2001 the Italian Parliament enabled the Government to review the traffic code in force and to adopt, in addition to the already existing monetary sanctions, a penalty system based on demerit points, which would have come into force on July 2003.
Using Italian data, this article presents an econometric investigation of the effects the latter produced on speeding infractions and mortal accidents.
Our main finding is that the coming into force of the Italian DPS produced only a temporary and weak effect on the drivers' speeding behavior, as well as on the number of fatal accidents, while the announcement of the decision of the Italian Government to introduce it produced a stronger and more lasting deterrent effect on the former. The coming into force of the Italian DPS has been prevented by exerting a lasting deterrent effect on speeding behaviors because drivers' learning about the effective probability of being detected made them perceive the new measure's sanctioning aims less credible. Data on the implemented generic enforcement support this hypothesis. In addition, we claim that the credibility of the new point license system has been also treathened by the Italian DPS's specific functioning modalities.

Introduction

Road traffic injuries represent the ninth cause of the global burden of disease and injury and it is supposed to become the third main determinant in 10 years (1). In Italy, road accidents account for the 2% of the total number of deaths and they appear to be the first motive of decease for people between 25 – 29 (2). Among European countries, Italy shows one of the highest level of annual road fatalities (3) with motorways displaying a rate of mortality (number of deaths every 100 accidents) triple than that occurring on urban roads (4). Actually, Italy also exhibits the greatest number of outside urban roads' deaths due to car and motorcycle accidents with speeding accounting as the major reason of decease (4).

In order to increase road safety, in 2001 the Italian Parliament enabled the Government to review the traffic code in force (5) and to adopt, in addition to the already existing monetary sanctions, a penalty system based on demerit points, which would have come into force on July 2003 (6).

Likely, the main reason underlying the widespread adoption of a DPS relies on the idea that there exists a positive correlation between the propensity to lose demerit points and accident likelihood. Actually, many empirical works show that the higher is the number of accumulated demerit points in a given period, the greater is the likelihood to be involved in a crash in a subsequent period (7,8,9,10). This is particularly true for speeding offenses which show a strong correlation with the likelihood of future collisions (10,11,12). Moreover, many country analyses show that the introduction of a DPS, by focusing especially on certain violations and by tracking recidivist violators, is an effective measure to increase compliance with the traffic laws (13, 14,15,16), and to improve road safety (17,18,19).

Therefore, given its ability to influence drivers' behavior, the demerit points mechanism provides, if effectively implemented, an unique opportunity to prevent dangerous violations and, consequently, to save lives.

Methodology

Data
We collected monthly observations of the number of motorways' speeding infractions and mortal accidents, as well as of the number of deployed police patrol cars, during the period March 2001 - September 2008 (included). Specifically, data come from the dataset published on the website of the Italian police which reports daily evidence

1 Department of Economics, University of Siena. E-mail address: nicita@unisi.it
2 Department of Economics, University of Siena. E-mail address: benedettini5@unisi.it

on the number of: (i) administrated sanctions; (ii) accidents; and (iii) employed police patrol cars (20).

Speeding infractions refer to the number of registered sanctions due to exceeding the speed limit. For Italian motorways the latter is equal to 130 Km/h and represents the highest limit among European countries (21). The Italian traffic code defines four types of speeding infractions: (i) exceeding the speed limit up to 10 Km/h (for which just a fine is established); (ii) between $10 - 40$ Km/h; (iii) between $40 - 60$ Km/h; and (iv) more than 60 Km/h (for these three latest types of offenses the points'curtailment is also established). However, data are available only for the four types of violations combined.

Mortal accidents concern those accidents involving at least one vehicle and at least one killed person regardless the injury severity of any other involved persons.

The number of monthly police patrols cars on duty is used as a proxy of the implemented level of enforcement of the traffic rules. Actually, the literature on speeding enforcement provides evidence that police patrol cars are a striking tool to deter speeding behaviors (22,23), even unmanned (24), and are moreover associated with a greater self - reported compliance to speed limits than mobile and fixed speed camera (25).

Finally, the extent of the considered period allows to study the trend of the speeding infractions before and after the coming into force of the Italian DPS, occurred on July 1st, and thus to infer whether the changes occurred in the sanctioning system produced any effects on the drivers' behavior.

Analysis (26)
We estimate the dynamics over time of the number of motorways' speeding violations and mortal accidents in order to investigate whether they have been influenced by the coming into force of a DPS.

To the aim, we perform a nonparametric estimation. Precisely, we perform a local linear regression based on the Kernel approach.

The reason why we perform a nonparametric estimation is essentially related to the specific advantages that these methods provide if compared to the traditional ones. When there is not a prior knowledge on the type of relationship we are interested to analyze, or when one does not want to make any assumptions on the type of function describing the latter, nonparametric methods are an useful and straightforward tool to investigate and represent it, and to detect the eventual existence of statistically significant nonlinearities.

The implemented nonparametric estimation performs a linear least squares regression to localized subsets of the data. The size of the latter is defined by the so called bandwidth. The bandwidth deterimines the smoothing of the estimated function. The larger is the bandwidth the more smoothed is the function, whereas the smaller it is the more the function fits to the data.

When the dependent variable is a time series and, thus, the independent variable is represented by a generic function of time, as it is the case for the dynamics of the speeding offenses and mortal accidents, it is praxis to take into account the possible presence of autocorrelated errors which can influence the smoothing of the data. To this aim, it is a usual procedure, before the implementation of the local linear regression, to compute the optimal level of the shaping parameter, which has to be used for the estimation of the relationship we are interested in, by means of the so called *Cross Validation Criterion*. Precisely, we use the *Direct Cross Validation Criterion* which is that we use in our analysis.

In order to test the statistical signficance of the relationship emerging from the performed nonparametric estimation, we use the linear model as a reference. In other words, we test the null hypothesis of linearity of the resulting function, against the alternative hypothesis of nonlinearity. The shaded area appearing in the graphic representing the function coming out from the nonparametric estimation is thus the reference band for the linear model. This band suggests where the estimated relationship should lie if the null hypothesis is not rejected. Therefore, if the resulting estimated function lies outside the reference band, this means that the null hypothesis is rejected and that the displayed nonlinearities are statistically significant.

All the estimations are performed using the *sm* package of the statistic software R.

Results

The performed estimation (see Fig. 1) suggests that, in Italy, the coming into force of a DPS to back traffic violations produced only a short and weak effect on the dynamics of the speeding offenses (see *Event 2*). Actually, we observe that the indefinitely increasing trend started at the beginning of 2002 stopped only after about July 2003, when the DPS became effective and the dynamics of the speeding offenses experienced a statistically significant nonlinearity in the form of a temporary decreasing trend. After that, the documented speeding violations start again to indefinitely increase and to reach, at the end of the examined period, almost their initial level.

Differently, what appears straightforwardly evident is the statistically significant nonlinearity occurred in correspondence to the period March 2001 – December 2001 (see *Event 1*). Indeed, departing from March 2001, the recorded speeding infractions experienced a vertical reduction which culminated in a global maximum in December 2001, when they began to indefinitely raise.

In March 2001 the Italian Parliament enabled the Government to review the traffic code in force and to introduce a new sanctioning system based on demerit points (5). This decision received great attention from the Italian mass media which, when the enabling act was still in debate in the Parliament and thus it was not official, gave the news of the upcoming tightening up of the traffic sanctions, (see the web links to the main national newspapers (27)).

In our opinion, the media' s announcement of the Parliament's decision to harsher sanctions by introducing a license point system is strongly related to the steep reduction in the number of the recorded speeding infractions, in the following way.
Actually, the media's clamour and the anticipated Government's announcement about the upcoming change in the sanctioning system, made drivers anticipate an increase in the perceived exepected sanction due mainly to a correspondent expected increase in the probability of being detected, they believed would have immediately followed such announcement. This, in turn, made individuals pay more attention to their driving behavior thus determining the observed progressively reduction in the number of recorded speeding infractions.

It can be argued that the mentioned nonlinearity in the dynamics of the speeding offenses could be a physiological consequence of a corresponding increase in the number of police patrol cars on duty, and thus of an increased ability of the traffic police to back offenses. However, the available data show that during the period March 2001 – December 2001 the number of police patrol cars on duty remained costant and didn't change significantly with respect to previous months. Moreover, if a temporary meaningful change in the controls' extent would have to be occurred, then it reasonably would had occurred in July 2003 when the DPS became effective, and not when the review of the traffic code has just been announced.
Therefore, the evidence on the performed traffic law enforcement supports the hypothesis that the vertical reduction experienced by speeding offenses, since March 2001, is essentially the consequence of a change in drivers' perceptions.

The fact that the level of controls remained substantially unchanged, with respect to the period prior to the Government's announcement, also contributes to explain the dramatic and indefinitely increasing trend experienced by speeding infractions departing from December 2001. As claimed before, when the Parliament's willingness to introduce a point license system has been disclosed, drivers' perceived expected sanction increased, consequently enhanching their level of compliance with the traffic law, and determining the observed reduction in the number of documented speeding offenses. However, as time went by, they also learned, from their and other drivers' activity (28), that the probability of being detected remained unchanged with respect to the period previous the reform's announcement. In addition, given that the actual probability of being detected remained substantially unchanged with respect to past periods, drivers' perceived probability of detection approximated almost exactly the actual one (30). Consequently, they rationally and progressively adapted their driving behavior to the acquired information, by progressively returning to the pre-announcement level of compliance with the traffic law and, thus, causing the progressive increase in the number of speeding infractions we observe departing from December 2001.

Moreover, the estimated dynamics of the number of police patrols cars on duty, over the whole analyzed period, supports the mentioned interpretation of the results. Actually, the estimation does not show the existence nor of a decreasing, neither, especially, of an increasing trend of the number of employed police patrols cars. Rather, it shows a substantially costant trend with some oscillations of the dependent variable around an average value of about 19000 units. This evidence strengths the hypothesis that the estimated dynamics of the recorded speeding offenses is mainly addressed by the changes occurred in the drivers' perceptions concerning the expected sanction rather than to an increased ability of the Police to bak offenses.

In our opinion, the fact that no meaningful changes occurred in the level of the implemented enforcement when the reform of the driving license system has been emphasizely announced is the main reason to be responsible for the loss of credibility of the deterrent purposes of the new measure, but not the only one. Actually, some of the peculiarities of the Italian point license system also contributed to threatened the credibility of the latter's deterrent aims and to prevent it to exert a lasting positive effect on drivers' behaviors when it came into force. Precisely, we refer to mechanisms like: (i) the periodically accredit of points to those drivers that for two consecutive years have not committed points consuming offenses, and (ii) the fact that when the loss of the total endowment of points occurs does not occur the license's automatic suspension (actually, drivers are just forced to attend a driving course and to pass a written and practical test within thirty days from the zeroing of their points' endowment. The suspension occurs if and only if, within these thirty days, they miss to attend the driving course). These peculiarities undoubtely make drivers perceive points as an easily renewable resource further weakening the sanctioning extent of the Italian DPS.

If the DPS would have been not prevented by exerting a credible sanctioning and thus deterrent effect, probably its coming into force would have produced a more lasting influence on motorways mortal accidents as well. Actually, we observe (see Fig. 2) that when the DPS became effective the dynamics of the fatal accidents experienced a statistically significant nonlinearity (see *Event 2*) in their decreasing trend. Precisely, we observe that the rate at which mortal accidents decrases became faster. Indeed, the number of mortal accidents switched from a decrease at a costant rate to a decrease at a decreasing rate. However, once the DPS stopped to exert its positive effect on the speeding behavior we also observe that the rate at which mortal accidents decreased slowed down too by returning to its previous costant rate of decrease.

Our estimation confirms the latest years virtous dynamics of the number of mortal accidents, and accidents in general, Italy is experiencing. Obviously, this virtous process results from the concurrence of many factors which go further the role of driving behavior, like e.g. traffic education and safety program, the improvement in road maintenance, the introduction of more advanced vehicle traffic devices, etc. However, it is undeniable that drivers' behavior matters, that Italy's road traffic injuries are the highest among those of others European countries, and that the coming into force of a DPS affected their dynamics. Therefore, if the credibility of the deterrent goals of the latter would have been not wakend, likely, they would have produced a more lasting effect on the dynamics of the mortal accidents too. Precisely, we would have observed a more lasting accelerated reduction in the number of mortal accidents which in turn would have bring Italy's road safet more fastly close to the European standards, consequently saving more lives than the actual.

Discussion

Speeding is considered the second key factor responsible for road traffic injuries, across the world (1). Thus, appropriate measures aimed at reducing the incidence of such dangerous driving behavior on road safety appear desiderable. In Italy, a DPS to back traffic infringements has been introduced in 2003 with the esplicit goal to improve road safety.

Our results show that the coming into force of the new license system has been prevented by exerting a lasting effect on both the dynamics of speeding offenses and, similarly, on that of the mortal accidents. In our opinion, the scarce effectiveness of the new sanctioning mechanism has reference to the lack of an appropriate implementation of a corresponding level of enforcement. We claim that if, immediately after the announcement of the new measure, controls would have been increased such to prevent the observed drivers' learning process about the discrepancy

between the actual and the perceived probablity of being detected, likely the DPS would have benefitted by more credibility and thus it would have produced a more lasting effect on offenses and accidents.

Actually, many works show that a corresponding increase in the implemented level of controls is an essential factor for the success of road safety programs (29,16,23) as well as for producing positive spillovers also on those driving behaviors not directly affected by the specific program (29). Moreover, it has been argued that a parallel increase in the level of the general enforcement is a more effective measure to the aim, than an equivalent increase in the level of the specific enforcement (29).

We also claim that the credibility of the deterrent purposes of the Italian DPS has been threatened, in addition, by the peculiarities characterizing its actual implementation which made drivers perceive point license as a very easily renewable resource.

Our analysis has limitations. Aggregate data deserve caution in the inference of a precise evidence on individual behavior (in (30) we are considering micro data). Secondly, we are aware of the fact that our data represent only a fraction of the total amount of recorded offenses, but data collected from other Italian police forces, like *Vigili Urbani* and *Carabinieri* are not publicly available.

In the light of our results, we suggest the following countermeasures aimed at increasing the credibility of the deterrent goals of the Italian DPS, and thus at raising, in a more effective way, the costs of undertaking dangerous driving behaviors: (i) to increase the amount of curtailed points for those offenses, like speeding, ascertained to be among the main causes of accidents, in those periods characterized by a higher rate of mortalitiy (e.g. August, the weekend, and the night (4)); (ii) to introduce more costly mechanisms of attainment of points bonus like for example extending the period after which obtain extra points, or to eliminate them at all; (iii) to introduce the automatic driving license 's suspension in case drivers loose all the points them available.

It stands to reason that to make these eventual countermeasure effectively working, they must be accompanied by a corresponding appropriate increase in the performed level of enforcement. Only in this way sanctioning mechanisms preserve their credibility and may effectively affect drivers' behavior thus contributing to save lives.
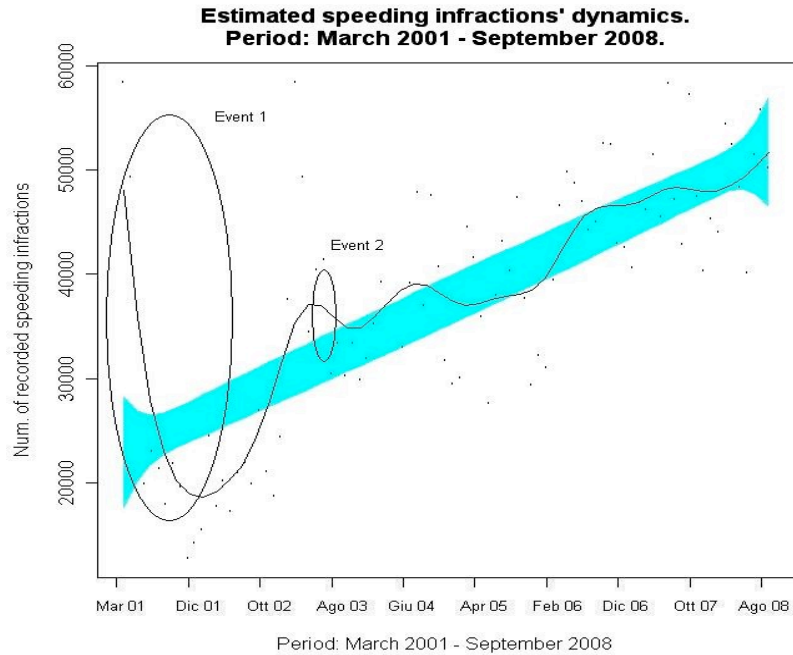
**Estimated speeding infractions' dynamics.
Period: March 2001 - September 2008.**

Period: March 2001 - September 2008

Figure 1:*Total num. of speeding infractions recorded onmotorways.Period: March 2001 - September 2008. Smoothing parameter: 3.57. The shaded area represents the reference band for the linear model. Test of linear model: significance = 0*
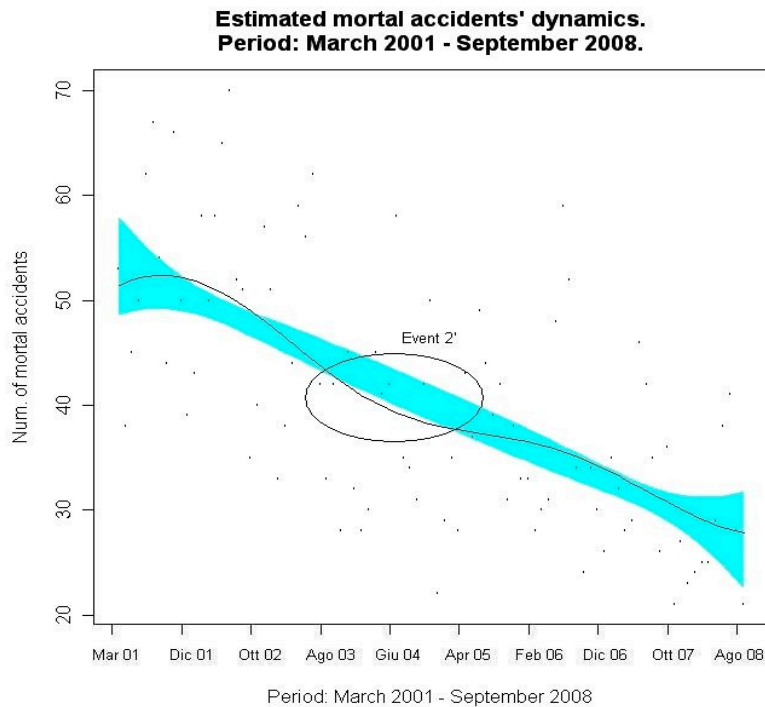

**Estimated mortal accidents' dynamics.
Period: March 2001 - September 2008.**

Period: March 2001 - September 2008

Figure 2: Total num. of motorways mortal accidents.Period: March 2001 - September 2008. Smoothing parameter: 10. The shaded area represents the reference band for the linear model. Test of linear model: significance = 0.301

References

1. Peden M., R. Scurfield, D. Sleet, D. Mohan, A. A. Hyder, E. Jarawan, and C. Mathers, (2004). "World report on road traffic injury prevention", World Health Organization, Geneva.

2. Osservatorio Nazionale sulla Salute nelle Regioni Italiane , (2008). "Rapporto Osservasalute 2008" (in Italian), Università Cattolica del Sacro Cuore, Rome.

3. European Road Safety Observatory, (2008). "Annual Statistical Report 2008", http://www.erso.eu/safetynet/fixed/WP1/2008/SafetyNet%20Annual%20Statistical%20Report%202008.pdf (accessed December 2008).

4. Italian Institute of Statistics – ISTAT, (2008). "Incidenti Stradali, Anno 2007" (in Italian), http://www.istat.it/salastampa/comunicati/non_calendario/20081120_00/testointegrale20081120.pdf (accessed January 2009).

5. Italian Parliament, (2001). Legge 22 Marzo 2001, n.85. "Delega al Governo per la revisione del nuovo codice della strada", Italian Official Bulletin n. 76 (in Italian). http://www.parlamento.it/leggi/01085l.htm (accessed October 2008) .

6. Italian Government, (2003). Decreto Legge 27 Giugno 2003, n. 151. "Modifiche ed integrazioni al codice della strada", Italian Official Bulletin n. 149 (in Italian), www.parlamento.it/parlam/leggi/decreti/03151d.htm (accessed October 2008).

7. Chipman, M.L., and P. Morgan (1975). "The role of driver demerit points and age in the prediction of motor vehicle collisions", *British Journal of Preventive & Social Medicine*, Vol. 29 (3).

8. Chen, J., P. Cooper, and M. Pinili, (1995). "Driver accident risk in relation to the penalty point system", *Journal of Safety Research*, Vol. 26 (1).

9. Diamantopoulou, K., M. Cameron, D. Dyte, and W. Harrison, (1997) ."The relationship between demerit points accrual and crash involvement", Monash University Accident Research Centre, Report No. 116.

10. Redelmeier, D.A., R.J. Tibshirani, and L. Evans, (2003). "Traffic-law enforcement and risk of death from motor-vehicle crashes: case-crossover study", *Lancet* ,Vol. 361 (9376).

11. Liu, C., C.-L. Chen, R. Subramanian, and D. Utter, (2005). "Analysis of speeding-related fatal motor vehicle traffic crashes", National Highway Traffic Safety Administration, Report n. DOT HS-809-839,Washington,DC.

12. Williams, A.F., S. Y. Kyrychenko, and R. A. Rettinga, (2006). "Characteristics of speeders", *Journal of Safety Research*, Vol. 37 (3).

13. Haque, M. O., (1990). "Evaluation of the Demerit Point System in Deterring Traffic Offenses", Evaluation Review, Vol.14 (1).

14. Zaal, D. (1994) . "Traffic law enforcement: a literature review", Monash University Accident Research Centre, Report No. 53.

15. Vaa, T. (2000) "Effects of police enforcement measures on accidents and levels of injury", Oslo, Institute of Transport Economics (TOI), Working paper n. SM/1104/2000.

16. Zambon, F., U. Fedeli, G. Milan, S. Brocco, M. Marchesan, and S. Cinquetti (2008). "Sustainability of the effects of the demerit points system on seat belt use: A region-wide before-and-after observational study in

Italy", *Accident Analysis and Prevention*, Vol. 40 (1).

17. Poli de Figueiredo, L. F., S. Rasslan, V. Bruscagin, R. Cruz Jr, and M. Rocha e Silva (2001). "Increases in fines and driver licence withdrawal have effectively reduced immediate deaths from trauma on Brazilian roads: First-year report on the new traffic code", *Injury*, Vol. 32 (2).

18. Papaioannou, P., G. Mintsis, C. Taxiltaris, and S. Basbas, (2002). "Enforcement and Traffic Accidents: Recent Experience from Greece", Proceedigs of the 15ᵗʰ International Cooperation on Theories and Concepts in Traffic Safety.

19. Hussain, O. T., M.S. Nayyar, F.A. Brady, J.C. Beirne, and L. F. A. Stassen, (2006). "Speeding and maxillofacial injuries: Impact of the introduction of penalty points for speeding offences", *British Journal of Oral and Maxillofacial Surgery*, Vol. 44 (1).

20. Italian traffic police. "Incidenti e contravvenzioni giorno per giorno" (in Italian), http://www.poliziadistato.it/pds/stradale/archivio/index.php (accessed October 2008).

21. Directorate General for Energy and Transport, (2009). "EU energy and transport in figures. Statistical Pocketbook 2009", http://ec.europa.eu/transport/publications/statistics/doc/2009_energy_transport_figures.pdf (accessed April 2009).

22. Vaa, T., (1997). "Increased Police Enforcement: Effects on Speed", *Accident Analysis and Prevention*, Vol. 29(3).

23. Davis, J.W., L.D. Bennink, D.R. Pepper, S.N. Parks, D. Lemaster, and R. Townsend, (2006). "Aggressive Traffic Enforcement: A Simple and Effective Injury Prevention Program", *Journal of Trauma-Injury Infection & Critical Car*e, Vol. 60 (5).

24. Kaplan, J.L., M.J. Wright, L. Lazarus, N. Congemi, K. duTreil, R. Arnold, D. Mercante, J.H. Diaz, M. Vrahas, and J.P. Hunt, (2000). "Use of an Unmanned Police Car to Reduce Traffic Speed", *Journal of Trauma-Injury Infection & Critical Care,* Vol. 49 (1).

25. Soole, D.W., A.J. Lennon, and B.C. Watson, (2008). "Driver perceptions of police speed enforcement: differences between camera-based and non-camera based methods: results from a qualitative study". In: Australasian Road Safety Research, Policing and Education Conference, 10-12 November 2008, Adelaide, South Australia

26. Bowman, A.W., and Azzalini A. (1997). "Applied Smoothing Techniques for Data Analysis: The Kernel Approach With S-Plus Illustrations", Oxford University Press.

27. *La Repubblica* (1 febbraio 2001). "La nuova patente", (in Italian), available at: http://ricerca.repubblica.it/repubblica/archivio/repubblica/2001/02/01/la-patente.html (accessed December 2008);
Il Corriere della Sera (8 marzo 2001). "Nuovo Codice della strada, oggi il voto. Arriva la targa personalizzata Patente a punti e corsi a scuola per i motorini", (in Italian), available at: http://archiviostorico.corriere.it/2001/marzo/08/Nuovo_Codice_della_strada_oggi_co_0_0103086017.shtml (accessed December 2008);
La Stampa (7 marzo 2001). "Oggi voto al Senato Codice della strada: ecco le novità", (in Italian), available at: http://archivio.lastampa.it/LaStampaArchivio/servlet/CreaPdf?ID=3038001 .

28. Sah, R.J., (1991). "Social Osmosis and Patterns of Crime", *The Journal of Political Economy*, Vol. 99 (6).

29. Tay, R. (2005). "General and Specific Deterrent Effects of Traffic Enforcement: Do We Have to Catch Offenders to Reduce Crashes? ", *Journal of Transport Economics and Policy*, Vol. 39 (2).

30. Basili, M., S. Benedettini, and A. Nicita (2009). "Compliance and Deterrence in a Demerit Point System: Theory and Evidence.", in progress.