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Multilevel modelling for the regional effect of enforcement on road accidents

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Abstract

This paper investigates the effect of the intensification of Police enforcement on the number of road accidents at national and regional level in Greece, focusing on one of the most important road safety violations: drinking-and-driving. Multilevel negative binomial models are developed to describe the effect of the intensification of alcohol enforcement on the reduction of road accidents in different regions of Greece. Moreover, two approaches are explored as far as regional clustering is concerned: the first one concerns an ad hoc geographical clustering and the second one is based on the results of mathematical cluster analysis through demographic, transport and road safety characteristics. Results indicate that there are significant spatial dependences among road accidents and enforcement. Additionally, it is shown that these dependences are more efficiently interpreted when regions are determined on the basis of qualitative similarities than on the basis of geographical adjacency.

Keywords: Road accidents; Alcohol enforcement; Negative binomial models; Multilevel analysis; Cluster analysis

1. Introduction

Road accidents and related casualties presented an increasing trend during the past decade in Greece, mainly due to insufficient maintenance of the road network, inappropriate behaviour of the road users and lack of efficient and systematic enforcement. Since 1998, an important effort was devoted to the improvement of this situation in Greece, expressed in an intensification of enforcement. More specifically, in 1998 the Greek Traffic Police started the intensification of road safety enforcement, having set as general target the gradual increase of roadside controls for the two most important infringements: speeding and drinking-and-driving, aiming to improve driver behaviour.

This road safety enforcement intensification could be one of the two basic reasons (the other one may be congestion) that may explain the important decrease observed in the number of road accidents, persons killed and injured during the last 5 years in Greece. Previous research on enforcement assessment has indicated that only a significant increase in enforcement level may affect the number of accidents (Bjørnskau and Elvik, 1992). Additionally, very little validation of enforcement effect at national level has been available in international literature. In particular, most evaluation attempts concern a temporary increase in local resources or concentrated enforcement efforts in a selected area (ESCAPE, 2003).

Several longitudinal studies on road accidents trends include the effect of Police enforcement. A recent research (Welki and Zlatoper, 2007) examined several explanatory variables to describe the decrease of road accidents in Ohio, USA during the period 1973–2000 and found that the introduction of a drink-driving arrests law and its enforcement had a significant, though short term, positive effect on injury accidents. A relevant research in the Netherlands (Mathijssen, 2005) showed that each intensification of alcohol enforcement within the period 1970–2000 resulted in a short-term drink-driving decrease.

In general, intensification of road safety enforcement is considered to affect both drivers' behaviour and the road safety outcome, in terms of road accidents and casualties, those two parameters being examined separately in most relevant studies. Goldenbeld and van Schagen (2005) report a significant decrease in road accidents and a significant modification of drivers speeding behaviour, as a result of an intensification of speeding enforcement on the rural network of a large area in the Netherlands. Chen et al. (2002) also report a significant effect of

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speed cameras on both drivers speeding behaviour and accidents occurrence. De Waard and Rooijers (1994) evaluated different types and intensities of speeding enforcement and found a significant, preventive rather than repressive, effect on drivers' behaviour.

Several studies also focus on the possible variations of the effect of the various types of enforcement over time or in space. In a research investigating the effect of speed radars (Chen et al., 2002) showed that a significant effect was obtained not only on and around the radars locations, but also along the entire enforcement corridor. Hauer et al. (1982) report both a "time halo" effect of enforcement and a spatial dispersion (upstream and downstream the enforcement sites). Vaa (1997) shows a significant effect of road section speed enforcement on drivers' behaviour, as well as an important temporal variation, with a specific decrease of the effect during the morning peak hours. Another relevant research (Tay, 2005) evaluating drinking-and-driving enforcement and publicity campaigns revealed a significantly higher effect on "high alcohol hours".

A research on drinking-and-driving among college students in the US (Wechsler et al., 2003) showed that the occurrence of drinking-and-driving differs significantly according to the policy environment at local and regional levels and the enforcement of those policies. Moreover, the results of a drinking-and-driving survey in Belgium (Vanlaar, 2005) are analyzed according to the geographical hierarchical structure of the survey, and significant differences in drinking-and-driving among different survey sites are found. Finally, Hakkert et al. (2001) evaluated the regional effect of a general road safety enforcement project in Israel, by means of a grouping of geographic zones according to Police enforcement intensity, and found a significantly different regional effect.

As far as Greece is concerned, the measures were implemented at national level, and a systematic enforcement covering most types of violations was achieved, resulting to a significant reduction of road accidents and related casualties, as shown in Table 1, which presents the basic road safety related trends in Greece.

However, because of the lack of specific quantitative targets in the intensification of enforcement, the increase of Police roadside controls was not carried out in a uniform or fixed way across the administrative regions of Greece, unlike most relevant enforcement projects (e.g. Goldenbeld and van Schagen, 2005; Hakkert et al., 2001). In particular, both the amount and the intensification rate of the enforcement activity presented significant differences in different regions; consequently, the resulting decrease in the number of road accidents could not be assessed under a common framework for all regions. Moreover, important differences among individual regions, such as demographic characteristics, transport systems infrastructure and operation and road safety related attitudes and behaviours further complicate the interpretation of the effects of Police enforcement. Summarizing, the efficiency assessment of a spatially varying Police activity over regions with significantly different characteristics is an interesting yet complex issue.

2. Objectives and methodology

The objective of this research is the quantification of the national and regional effect of Police enforcement on road safety in Greece. In particular, it is assumed that the effect of enforcement on road safety may depend on (either or both):

- the administrative structure of the Police, which follows a strictly geographic regional hierarchy, resulting to different practices and amounts of enforcement, and
- the spatial variations of the socioeconomic and traffic characteristics, which reflect another hierarchy, both spatial and qualitative, resulting to different effects of enforcement.

On that purpose, a hierarchical modelling approach shall be used, in order to capture the spatial dependences rising from the hierarchical nature and structure of the parameters examined. In particular, a multilevel modelling technique is applied, allowing for the investigation and quantification of significant effects at all levels of the hierarchical structure (Rasbash et al., 2000).

In the present analysis, aggregate accident data are examined, and therefore a Poisson-family distributed response vector (O) of observed cases is assumed (Langford et al., 1999; Lord et al., 2005), by introducing a log link function in the classical two-level model, as:

$$O \sim \text{Poisson}(\pi_{ij})$$
$$\log(\pi_{ij}) = \log(E_{ij}) + \beta_{0j} + \beta_{1j}x_j + e_j$$
$$\beta_{0j} = \beta_0 + u_{0j}$$
$$\beta_{1j} = \beta_1 + u_{1j}$$

where E_{ij} represents the expected numbers of cases for each level-1 unit (Rasbash et al., 2000).

The Poisson distribution is therefore used to model the (lowest) level-1 variance and random parameters at higher levels are assumed to be multivariate normal (Rasbash et al., 2000).

Table 1
Basic trends of road safety and enforcement in Greece (1998–2002)

	1998	1999	2000	2001	2002	Five-year change (%)
Injury road accidents	24,819	24,231	23,127	19,710	16,852	−32
Persons killed	2,182	2,116	2,088	1,895	1,654	−24
Vehicles (×1000)	4,323	4,690	5,061	5,390	5,741	33
Speed infringements	92,122	97,947	175,075	316,451	418,421	354
Drink and drive infringements	13,996	17,665	30,507	49,464	48,947	250
Drink and drive controls	202,161	246,611	365,388	710,998	1,034,502	412