The Road against Fatalities:
Infrastructure Spending vs. Regulation?

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Abstract

The road safety literature is typified by a high degree of compartmentalization between studies that focus on infrastructure and traffic conditions and those devoted to the evaluation of public policies and regulations. As a result, few studies adopt a unified empirical framework in their attempts at evaluating the road safety performance of public interventions, thus limiting our understanding of successful strategies in this regard. This paper considers both types of determinants in an analysis of a European country that has enjoyed considerable success in reducing road fatalities. After constructing a panel data set with road safety outcomes for all Spanish provinces between 1990 and 2009, we evaluate the role of the technical characteristics of infrastructure and recent infrastructure spending together with the main regulatory changes introduced. Our results show the importance of considering both types of determinants in a unified framework. Moreover, we highlight the importance of spending in maintenance given its effectiveness in reducing fatalities and casualties in the current economic context of austerity that is having such a marked impact on investment efforts in Spain.

Keywords: Road Safety; Infrastructure spending; Regulation; Transportation, Public Policy Impacts.

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1. Introduction

Road safety today is a major concern and an increasingly important objective for public authorities in charge of the transport sector. This is particularly the case in developed economies. In fact, involvement in road accidents is one of the three leading causes of death and hospital admission for European Union (EU) (12) inhabitants (together with cancer and coronary heart diseases), and it is leading cause of death for EU citizens under 50 years old (ETSC, 2003). These rankings clearly highlight the importance of traffic accidents as a public health threat.

Apart from these public health concerns, there are also economic motives that make road safety an important goal for any country. Estimates indicate that the economic costs associated with road accidents are as high as 2% GDP in EU economies.[1] Only in Europe these costs are as high as 180 billion euro, twice the annual EU budget. In Spain, FITSA (2008) estimated in 2008 that total costs places a burden on the economy of 16,000 euro, about the 2% of GDP. The economic value of a lost live in a road crash was estimated in 858.000 euro. Beyond Europe, the WHO (2004) report estimated worldwide road accident costs at 518$ billion. These costs include vehicle and other damages, health expenditures and wasted production.

It is, therefore, hardly surprising that road safety concerns have led public authorities to devote increasing interest to active public policies aimed at improving safety outcomes. Two of the most common policies adopted include the provision of new or better infrastructure (infrastructure spending) and the enactment and enforcement of public measures (regulation). The extant road safety literature has extensively examined the effectiveness of both these paths to reducing fatalities. However, the research conducted has tended to be compartmentalized – either examining the role of investments and infrastructure or testing the impact of regulatory changes – so it is difficult to find studies in which both sets of policies are considered simultaneously. An exception is Noland (2003), which accounts and shows the relevance of including both safety measures – infrastructure and regulation – to determining changes in crash related injuries and deaths for the US. Albalate (2008) and Albalate and Bel (2012) also tried to capture the effect of regulatory measures and infrastructure quality in Europe, but only based on general road characteristics (% motorways, % primary network, etc.). Others, as Mitra and Washington (2012) among others, conducted extensive research in the introduction of omitted variables related with geometric data, traffic data, spatial variables or weather conditions, but neglect changes of regulation.

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[1] Source: European Commission. Socio-economic costs and the value of prevention. Available on http://ec.europa.eu/transport/road_safety/specialist/knowledge/postimpact/the_problem_road_traffic_injury_consequences/socio_economic_costs_and_the_value_of_prevention.htm Retrieved on 01/02/2013.

Hence, the first contribution of this paper is its use of a unified framework to compare the relative effectiveness and impact of two different groups of policy measures included in the same econometric model. Therefore, we build on the approach by Noland (2003) in introducing regulatory changes besides infrastructure characteristics, which, in any case, are the main focus of our analysis. On the one hand, we consider the infrastructure and investment dimension as the efforts made by governments as they fulfill their duty to provide safer infrastructure. On the other hand, we also incorporate government regulatory programs, which may take the form of general laws and traffic rules or regulations. The objective of focusing on both policies is to measure how these strategies can help reduce road fatalities and casualties.

The second contribution is the evaluation it makes of public investment in Spain. Given the current economic context typified by austerity policies and budget constraints, road maintenance investment has been downgraded in recent years. This paper examines the safety performance of two different types of public investment: construction spending vs. maintenance spending. The interest on both relies on the fact that during the last years Spain has devoted huge efforts in increasing the motorway network, while some criticism recently claims for the lack of maintenance of roads.

The rest of this article is organized as follows. The next section is devoted to reviewing the previous literature on road safety distinguishing between studies that seek to understand the role played by infrastructure and spending and those that evaluate the impact of traffic regulations. Section 3 describes the patterns and main characteristics of road safety in Spain, the country in which we test our hypothesis. The empirical model is explained in section 4 and we provide our main results in section 5. Finally, in section 6 we present our main conclusions.

2. Literature review

The amount of literature on road safety has grown markedly in recent decades, with a broad range of studies being conducted in the fields of transportation, economics, public policy and health. This surge is indicative of the increasing awareness among academics, practitioners and policy makers of the importance of this issue in terms of its economic implications and its threat to public health. In particular, the study of the determinants of road accidents and their severity has acquired special relevance within this literature.

The approaches adopted in identifying the factors that might account for road safety are diverse. Here, two main groups of study can be distinguished. On the one hand, there are those that base their analysis on characteristics of the infrastructure and their improvement or on those of traffic conditions, including levels of congestion and vehicle mix. This group of studies typically employs field-specific data on road sections and count data regression models to estimate the impact of several infrastructure factors on fatality or injury counts.

The infrastructure factors considered include investments; physical characteristics such as curves, width or type of pavement; and the number of intersections and junctions. In examining traffic conditions, the studies focus on traffic flow and the share of different types of vehicles. Generally, these elements cannot be controlled by the road user and are external influences on his/her driving.

On the other hand, the second group of studies examines the impact of regulatory measures and institutional frameworks on safety outcomes – also including their enforcement-. As such, this line of literature is more closely concerned with behavioral attitudes and exposure to the risk. This is the case of the large number of studies analyzing the impact of changes in speed limits, mandatory seat-belt laws, blood alcohol content limits and those that focus on enforcement intervention effectiveness. In this group we can also include studies devoted to assess the importance of compulsory and periodic technical vehicle inspection tests and the mandatory use of particular in-vehicle safety devices. Most of these studies typically employ time series and cross sectional time series analyses with aggregate data. They generally conduct pooled (OLS), fixed effects estimations (within and between group estimators) or just negative binomial regression models accounting for fixed effects.

However, given both sources of road safety, it is quite surprising that the two bodies of literature have virtually ignored each other. Thus, each line has conducted its work without taking advantage of the advances obtained by the other. For instance, studies that can be classified as belonging to the first group neither consider regulatory variables nor take into account legislative changes even when employing cross sectional time series (i.e. different jurisdictions monitored during a period of time). At the same time, studies belonging to the second group usually focus solely on evaluating the impact of a policy, and overlook the role played by the infrastructure in road safety outcomes, which usually biases their estimates as relevant variables are omitted.

Since both groups of factors seem relevant as a source of road (un)safety, we consider it essential to consider the findings from both lines of literature jointly so that we can proceed in our attempt to build a complete model that assesses both infrastructure/traffic conditions and regulatory interventions as determinants of road safety outcomes. This brief review should serve to show how both literatures have tended to ignore each other and as a result have told only one side of the story.

2.1 Infrastructure characteristics and traffic conditions

The literature on physical road characteristics presents mixed findings, although most studies do show the importance of having better infrastructure. This variation in findings is probably attributable to the fact that the impact of infrastructure critically depends on the individual case being studied and on the different infrastructure variables that are taken into account. However, some regularity is found and it can be concluded that certain aspects of infrastructure and traffic conditions need to be taken into consideration when modeling the determinants of road (un)safety.

The first point to stress is the role played by road type. Most papers highlight the benefits of providing better quality roads, a determinant captured by road type (motorways, conventional roads, urban roads, etc.), the number of traffic lanes, the pavement, and the median shoulder and lane width (Abdel-Aty and Essam-Radwan 2000; Flahaut, 2004; Noland, 2003; Noland and Oh, 2004; Anastasopoulos, Tarko and Mannering, 2008; Park et al. 2012). Others, adhering to the Peltzman (1975) compensating effect, claim that these enhanced properties have just the opposite impact and increase the level of risk taken by drivers in the light of the better infrastructure endowment. Indeed, a number of studies report no benefit from programs designed to improve road conditions for this reason (Noland, 2003). This offsetting effect seems most apparent in the case of the increase in the number of lanes, but it is not so consistently reported when other infrastructure characteristics are enhanced (see, for example, Vitalino and Held, 1991; Milton and Mannering, 1998; and Martin, 2002).

The number and type of curves, additional turning lanes, the number of intersections and junctions, and better signals are other commonly considered variables in models of this kind. These network features also seem to have a significant impact on road safety outcomes, as reported in several detailed studies, including Feber, Feldmeier and Crocker (2003) and Meuleners et al. (2008).

Most studies examining traffic flows conclude that traffic conditions and vehicle mix are two of the most important determinants of accidents (Vitalino and Held, 1991; Dickerson, Peirson and Vickerman, 1998; Hayness et al. 2008). Yet, congestion is usually associated with lower numbers of road fatalities (Albalate and Fernández-Villadangos, 2010), although some studies show that congestion, while reducing mortality, might increase the number of non-severe road accidents (Noland and Quddus, 2005). The literature examining vehicle mix seems to suggest that the number of motorcycles, trucks, sport utility vehicles and vans tends to increase the frequency of fatal crashes, while the number of cars and buses reduces this number (Tay, 2003).

In **Appendix A** we summarize some of the most important studies on road safety focusing their attention on infrastructure characteristics and traffic conditions to explain safety outcomes since year 2000. As can be seen, we highlight the variables used in each study, distinguishing between those concerned with regulatory measures and those concerned with infrastructure or traffic characteristics in order to stress the two paths taken by the literature.

2.2 Laws, regulation and enforcement

One of the most influential studies in the literature examining the impact of regulatory measures and behavioral treatments is Peltzman's (1975) seminal work. Based on his findings and those reported in similar papers, the literature has coined the well-known term of 'offsetting behavior' (also known as the Peltzman or the compensating effect) to account for the fact that safety improvements – either to roads or vehicles – may have an inverse effect on final safety outcomes.[2] The origin of this contradiction lies in the fact that individuals tend to adjust their behavior by taking more risks or being more careless and, as a result, they generate the same number of accidents as before or even more. Thus, behavior must be placed in the baseline of any regulatory policy enacted to fight road accidents, since infrastructure improvements or better performance of in-vehicle safety devices are not sufficient on their own to alleviate the problem. Clearly, the willingness to comply with the law is an essential element for ensuring policy effectiveness (Vereek and Vrolix, 2007).

Several policies have been evaluated in recent decades. Speed limits, mandatory seat-belt devices, minimum legal drinking age and blood alcohol content levels are probably the most widely covered in the literature. In the case of speed limits, the literature presents mixed findings. However, there is some consensus in the literature regarding the fact that what is actually important here is not the average speed, but rather the variation in speed. In fact, speed limits do seem to have an effect on both, but it is not clear to what extent. Some of the most influential papers examining this issue are Lave (1985), Garber and

[2] See Peterson, Hoffer, Millner (1995) for an excellent example of this type of study for air-bag equipped cars, and Sen (2001) for the case of mandatory seat belts.

Graham (1990), Lave and Elias (1994), McCarthy (1994, 2005) and Dee and Sela (2003). It should be stressed that most papers evaluating regulatory measures examined changes in speed limits as a key control variable. Also, number of works made their contribution on the speed limits enforcement.

The literature on mandatory seat belt devices is mixed on the effectiveness of this measure in reducing the number of traffic victims, perhaps because it also depends on enforcement. The main contributions on mandatory seat-belt regulations are Loeb (1995, 2001) and Cohen and Einav (2003), all of which report significant impacts on road safety. However, others found little evidence of effectiveness, as Derrig et al, (2002), Garbacz (1991); Harvey and Durbin (1986), etc.

Changes to the minimum legal drinking age have also produced some interesting studies, usually reporting the effectiveness of such measures in reducing young road fatalities. Influential examples in this line of research include Cook and Tauschen (1984), Asch and Levy (1990), DuMouchell, Williams and Zador (1987) and Saffer and Grossman (1987). Among more recent studies, Carpenter and Stehr (2008) stress just how effective such regulatory measures can be.

The final policy measures to be evaluated by this group of the literature are the reductions in legal blood alcohol content (BAC) level and the introduction of licenses based on points (demerit points system). As is shown in Dee (2001), Eisenberg (2003), Kaplan and Prato (2007) and Albalate (2008), among others, enacting and lowering legal limits of BAC can have an effective impact on road safety outcomes. However, the impact does not seem to be immediate and can provide heterogeneous impacts among victim groups.

In spite of all these policies, changes in laws or new regulations need to be accompanied by their enforcement. Tay (2005), for instance, shows the effectiveness in reducing crashes of anti drink-driving enforcement and awareness campaigns when they are activated independently, while their interaction does not seem to offer complementarities as believed. Also anti-speed enforcement has been tested in Tay (2009, 2010), which report enforcement had a significant impact on total crashes and injuries. Similarly, Harrison and Pronk (1998) and Zaal (1994) already found positive effects of speed limits enforcement on the road safety outcomes. Also Guria (1999) finds that safety programs such as enforcement and advertising campaigns against drink-driving, speeding or seatbelt wearing produce high incremental returns of the investments in safety programs. As for drink-driving enforcement, Delaney et al. (2006) find that existing enforcement efforts have successfully contributed to reductions in casualty crashes at all severity levels.

Indeed, several studies stress that policy impacts are heterogeneous depending on the driving population examined. This point applies to the case of speed limits (Dee and Sela, 2003), mandatory seat belt laws (Carpenter and Stehr, 2008) or changes in illegal blood alcohol levels (Albalate, 2008). In the case of driving licenses based on demerit points systems, recent studies, including Castillo-Manzano, Castro-Nuño and Pedregal (2010) and Castillo-Manzano and Castro-Nuño (2012), find strong initial positive impacts that then fade quickly, highlighting the limitations of this strategy for public authorities given the absence of complementary enforcement.

In **Appendix B** we summarize some of the most important studies on road safety focusing their attention on regulatory determinants. As can be seen, in addition to describing the main results of each paper, we again highlight the variables used in each study, distinguishing between those concerned with regulatory measures and those concerned with infrastructure or traffic characteristics. As the reader will observe, only one considers of the latter variable type.

In short, infrastructure characteristics and traffic conditions, on the one hand, and regulatory measures affecting behavioral attitudes, on the other, seem to contribute to determine road (un)safety outcomes. However, the literature has tended to tackle each of these problems separately, ignoring the lessons provided by the other line of research.

3. Road safety in Spain.

As this study seeks to analyze the impact of various strategies aimed at promoting road safety in Spain, it is essential that we first consider the main trends in safety outcomes, in road network development – characteristics and investments, and in the type of regulations and laws enacted to achieve better safety performance. This review should serve to justify why the Spanish experience is of particular interest.

3.1 Spanish trends in road safety outcomes

Spanish strategies aimed at fighting the number of road fatalities can be considered a success if we consider the decreasing trends in the number of total fatalities or in the fatality rate per million population. In 1991 within EU(15), Spain formed part of those countries with fatality rates above the average, but in 2010 was in the group of countries with rates below the average **(Table 1)**. Indeed, Spain is the country that has experienced the largest fall in terms of this fatality ranking within the EU15 between these two years –

the first and the last in the CARE database - and in its overall percentage change. Being this said the decline was not linear, living episodes of stagnation in the total number of fatalities, or even increase in the case of the number of casualties during the second half of the 90's. A closer analysis of the trends is displayed in **Figure 1,** which shows that the actual number of casualties or total injury crashes has remained more or less constant over time, after an initial stage of rapid decline in the early 1990s. Thus, a reduction in fatality rates appears to be one of the key determinants of Spain's success. On the basis of these figures, it is easy to justify the importance of studying the role of investments and regulations for the promotion of road safety in the Spanish case.

<< Insert figure 1 about here >>

<< Insert table 1 about here >>

In spite of these encouraging outcomes, it is worth mentioning that the same trend is not found in all Spanish territories. As **Table 2** shows, there is significant variation and heterogeneity in road safety outcomes across the provinces. Thus, while some provinces, such as Álava, Lugo and Ourense, report reductions of more than 50% in the number of injury crashes between 1996 and 2010, others, such as Cadiz, Girona and Cáceres, present increases of 61%, 42% and 59%, respectively, for the same period. Thus, despite positive outcomes nationally, road safety outcomes in Spain differ significantly across the territory. However, we should be able to exploit this variability in order to understand the contributors of safety outcomes in Spain, by paying particular attention to the role of infrastructure, investments and regulations.

<<Insert table 2 about here >>

3.2 Infrastructure and investments

The Spanish road network has changed significantly in recent decades. This change, however, is not one based on absolute kilometer extensions, since the network has only increased by 6.15% in 20 years - between 1990 and 2010. On the contrary, the transformations have been made in terms of improvements to the quality of the existing infrastructure. In this respect, successive Spanish governments have sought to expand the proportion of motorways while reducing the share of narrow roads in the total road network. **Table 3** shows this network growth and also describes the trends taken by the respective shares of each road type in relation to the total road network between 1990 and 2010.

<< Insert table 3 about here >>

As is shown, the motorway network increased from 156,172 km to just 165,787 km in 20 years. Indeed, the share of motorways in the overall network has almost tripled, growing from 3.8% in 1990 to 9.63% in 2010. The same is true of all other roads with a width greater than 7 meters. As the last column in **Table 3** shows, roads of these dimensions have increased their share in the total network from 18.9% in 1990 to 38.43% in 2010, while roads with a width of less than 7 meters have fallen from 77.7% to 61.57% during the same period. As a result, we can affirm that generally, road quality has improved over the last 20 years in Spain and, as such, we expect a significant positive impact of these improvements on road safety.

The extension of the motorway network as well as the improvements made to the other road types must necessarily reflect investment efforts. Indeed, road investment has increased in recent decades. **Table 4** shows the growth in, and the distribution of, road investments implemented by the public administration and motorway companies for the period 1990-2010. In the table we also distinguish by type of investment (maintenance and construction). As can be seen, the highest proportion of investment efforts has been devoted to network construction, receiving around three quarters of total investments (made by the public administration). This category is devoted not only to extending the network but also to building better accesses, wider lanes and new connections. In spite of the lower amounts involved, maintenance investment has increased in terms of its share of total investments, but indicates that greater efforts need to be dedicated to improve and maintain mature consolidated networks.

A further interesting fact is that motorway companies (almost all of which today are privately owned) increased their investments at the end of the 90s and the beginning of the new century. This increase can be explained in terms of the new concessions awarded by the Spanish government to build and operate greenfield projects for toll motorways.[3]

<<Insert table 4 about here >>

3.3 Road safety regulations and laws

Investments and infrastructure improvements are not the only strategy that can be followed in tackling road fatalities. The decreasing trend in Spanish fatalities (see above) might also be attributed to regulatory and public interventions of a broad and diverse

[3] A greenfield project lacks any constraints imposed by prior work so construction can take place without any need to remodel or demolish existing structures. In our context, this represents a new road or an extension of a currently operating network. A brownfield project, by contrast, involves investment and construction work on existing roads and networks, generally to improve quality.

nature. Below we discuss some of the most relevant interventions in this regard that have served to promote road safety by reducing the risk of accidents.

Until 1992, Spanish traffic was still regulated by a traffic code that had been drafted and enacted by the Second Spanish Republic in 1934. The growth in traffic volume in the intervening years and its incidence on mortality rates convinced new democratic governments to overhaul the code and to adapt Spanish legislation to modern times. Thus, Law 18/1989 was passed, laying the foundations of the future Royal Decree 339/1990 on traffic regulation and the eventual traffic rules established by Royal Decree 17/1992. Thus, Spanish traffic regulations had become outdated by 1992, and new regulations introduced important changes in the scope of public intervention in matters of road safety.

These regulations remained unchanged for almost 15 years, but a new campaign to reduce road accidents, targeting above all traffic offenders, led to a major reform of traffic rules in 2005. The main change introduced by the new traffic regulations (Law 17/2005) was the use of a 'demerit points license', which has been in force since mid 2006.[4] Moreover, the government made significant amendments to the penal code to increase sanctions on traffic offenders in Law 15/2007. All these measures formed part of a public intervention program designed to promote road safety by increasing driver awareness.

In addition to these basic regulations, other specific interventions and measures have been made over the last three decades. For instance, new rules were introduced regarding compulsory technical vehicle inspection tests, which were introduced in 1985 and reformed in 1994. The first initiative, established by Royal Decree 2344/1985, specified the type and frequency of inspection tests in Spain, while the second initiative, introduced by Royal Decree 2042/1994, brought these regulations into line with the stricter controls applied in the EU.

In 1994, the Spanish government introduced another measure relate to vehicle safety by subsidizing fleet renewal under the RENOVE program, which consisted of a grant for car owners who withdrew an old passenger car from circulation and bought a new one. One of the main objectives of RENOVE was to enhance safety thanks to the improved attributes in this respect of modern vehicles. In 1997, a second stage was initiated in the program, when the newly elected government extended this program to commercial vehicles and

[4] A *points license* is a driving license based on a penalty points system whereby severe infractions of traffic rules result in a specific number of points being deducted from the offender's license. In Spain, drivers have 15 points unless they are novice drivers, who are awarded just 8 points. If drivers lose points they can take courses to recover in part these points. However, if a driver loses all his points he must wait six months to take a new training course and a driving test that enables him to recover 8 points.

motorcycles. The program was terminated in 2008, but the government came under pressure from the automobile sector to establish a new plan. The Ministry of Industry, therefore, implemented the VIVE program designed to keep encouraging the withdrawal of the oldest and most polluting vehicles (at least 15 years old).

Objectives of a different type were pursued by regulatory measures designed to have an impact on drivers' behavior. For instance, the legal blood alcohol content limit (BAC) was lowered in 1999 to 0.5mg/ml from the previous level of 0.8mg/ml. in order to fight drunk driving, the main cause of road fatalities in Europe. This measure was recommended by European institutions, specifically under their program for the "Promotion of Road Safety in the European Union 1997–2001".[5] Several countries decided to amend their rules along similar lines.

A subsequent program recommending measures and policies to reduce road fatalities within the European Union – the European Road Safety Action Plan 2003-2010 – led to the introduction of one of the most important recent measures: a directive enforcing seat-belt use in all seats of a vehicle. Until then, Spain had only enforced the use of seat-belts in front-seats, while rear-seats had been exempt. The new measure came into force in 2006.

An additional measure, probably of secondary importance in comparison with those described above, and one concerned with promoting mobility in large cities, may have had an impact on motorcycle road safety. In 2004 the Spanish authorities decided to adhere to European Directive 91/439/CEE, which allowed national governments to determine whether holders of car driving licenses could also be allowed to drive small motorcycles.[6]

As described above, therefore, the Spanish authorities have been engaged in the promotion of road safety via public interventions since the early nineties. In the last decade, they have been particularly active reforming traffic laws and increasing the severity of sanctions on offenders. **Table 5** summarizes the main policies and programs of intervention designed by Spanish or European authorities.

4. Methods and data

This article considers two groups of road safety strategies in a unified framework. Thus, we apply an empirical strategy that involves the construction of an econometric model that

[5] COM(97)131.

[6] This change to the regulations allowed holders of car driving licenses with more than three years' experience, to drive motorcycles – up to 125 cc. The measure led to a dramatic rise in the number of registered motorbikes, while the number of accidents also experienced a significant upturn.

includes both public investment/infrastructure and traffic regulation enactments in Spain, a successful country in the fight against road fatalities. In order to check the omitted variable biased incurred, we first estimate models without regulatory measures and, subsequently, full models with all relevant variables.

Based on the information made available by the Spanish Ministries with responsibility for Transportation we have constructed a panel data model explaining road safety outcomes across provinces and over time. Overall, we exploit a panel with fifty provinces monitored between 1990 and 2010 (1050 observations).[7] Our model contains variables that capture features of the infrastructure and its maintenance and construction spending, as well as of traffic rules and other controls. In order to test the importance of these two groups of determinants on road safety we have employed two estimation methods. First, a one-way, fixed effects model with a time trend and error term following an autoregressive structure in order to correct serial correlation. The model, therefore, takes the following form:

$$log\, Y_{it} = \alpha + \beta X_{it} + \delta I_{it} + \gamma R_{it} + s_i + \varepsilon_{it} \qquad (1)$$

$$\varepsilon_{it} = \rho \varepsilon_{i,t-1} + u_{i,t} \qquad (2)$$

where y_{it} is the fatality or casualty rate (both measures of safety outcome are considered) in province i in year t. As determinants of road safety we consider X_{it}, which contains a vector of time-varying variables, I_{it} is a vector of the infrastructure and investment variables and R_{it} a vector of policies and traffic regulations. The fixed effects property is provided by s_i, which denotes a province-specific fixed effect that controls for time-invariant, province-specific omitted variables. The time trend controls for time patterns affecting safety outcomes, and captures the effect of better technology and the public's higher safety concerns. Finally, the error term ε_{it} follows a first order autoregressive disturbance (AR1), as shown in equation 2.

In the case of safety outcomes, we consider the rate of fatalities per 100,000 inhabitants and the rate of casualties per 100,000 inhabitants. Both variables provide two important dimensions of road safety: on the one hand, the fatality rate captures the severity of accidents by considering the number of deaths; on the other, the casualty rate treats road safety as a more general concern by including the other victims of road accidents.

[7] The autonomous cities of Ceuta and Melilla on the North Africa coast are not considered.

It is also possible to construct dependent variables by distinguishing between urban and non-urban areas. Since most infrastructure characteristics and investments are concerned with non-urban environments – given that most infrastructure spending is in charge of public authorities, which are supramunicipal governments concerned with interurban roads-, here we focus on interurban road safety, although we provide aggregate results for the rate of fatalities.

The second method of estimation is a Negative Binomial fixed effects model (Hausman et al. 1984). This count data method fits better the generation of traffic-related fatalities (Karlaftis and Tarko, 1998; Lord and Mannering, 2010), accounts for heterogeneity and allows for an offset exposure variable, in our case the number of vehicles in each province.[8] In this case, our dependent variables are counts for deaths (during 30 days after the crash) and casualties in road accidents.

Data for the regressors are collected from different sources. On the one hand, the infrastructure and spending variables are obtained from the *Spanish Ministry of Transportation*. Among these variables are the investment executed in the last two years distinguishing between construction and maintenance per 100,000 inhabitants, the proportion of the province's road network occupied by motorways and the percentage share of the rest of roads according to their width. We are aware that using a two-year lag for accumulated investments is arbitrary. However, this decision does not change the results when compared with those obtained with a longer time consideration and it serves to minimize the loss of observations in the sample. On the other hand, data for demographic characteristics and motorization are provided by the *Spanish National Institute of Statistics* (INE) and the *General Traffic Directorate* (DGT), respectively.

Finally, laws and regulations are considered in the year in which they were enacted. However, an important point should be made here. Given the significant number of measures adopted in Spain (see **Table 5)**, we have chosen to evaluate those promoted under the European Road Safety Programs (1997-2001, 2003-2010) and the most significant legislation changes in Spain resulting from the enactment of the General Traffic Rules (1992), the introduction of vehicle renewal and inspection programs (1994, 1997), and the new Traffic law (2006), as single sets of measures instead of introducing dummy variables for each specific regulation. The definition of our dependent and independent variables are displayed in **Table 6**.

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8 Note it would be much better to use distance travelled or Average Daily Traffic data. Unfortunately, there is not available data on these variables at province level and for the whole period. As a result, the best proxy we can get is population per province.

<<Insert table 6 about here >>

5. Results

Our results are displayed in **Tables 7** (OLS fixed effects) and **8** (Negative Binomial)**.** The first columns (1) and (2) show our results when the dependent variable is the total fatality rate without and with the regulatory variables, respectively. Columns (3) and (4) repeats the exercise with the non-urban fatality rate. Finally, columns (5) and (6) consider the casualty rate. In all cases we find consistent results for those coefficients statistically significant in the restricted model for fatality rates. Some differences are found in the case of casualties, showing the distinct features of their production.

<< Insert table 7 about here >>

Interestingly, in relation to the first group of regressors capturing past road investment, the impact on total fatalities is statistically significant for past investment in road maintenance, the effect being consistent across models. As expected, its impact is higher for casualties than it is for fatalities. The sign of this coefficient indicates that investment in maintenance is effective in reducing both fatality and casualty rates. Note this result is still valid with the inclusion of regulatory variables, although the magnitude of the coefficient diminishes. This evidence seems to indicate that the omission of regulatory variables could overestimate the impact of maintenance spending. Indeed, the size of its coefficient is half of the one of the restricted models.

By contrast, past spending in construction does not seem to affect fatality rates or casualty rates. Only in the case of the full model for non-urban fatality rate do we find a positive and statistically significant change at 10% coefficient. This result is somewhat unexpected, but the magnitude of the effect is not particularly great. Note, however, that this result is consistent with Noland (2003), which refutes the effectiveness of road improvements in terms of lanes and width. While on the one hand it might be expected that new construction will result in better infrastructure, on the other, investing in new roads also increases road supply and, as a consequence, it induces higher demand.[9] Moreover, the Peltzman effect also suggests that having better infrastructure may result in higher speeds and risk-taking, given the confidence engendered by the quality of the infrastructure. Similarly, Mahalel and Szternfeld (1986) argued that improved standards influence perceptions, what can finally produce an underestimation of risks. According to

[9] The influential study by Winston and Langer (2006) shows that capacity enlargements are not a long-term solution to the congestion problem, since larger capacity results in higher demand.

our results, the impact of this demand-enhancing policy translates into greater numbers of casualties. Indeed, our evidence suggests that this second effect is greater than the former.

If we focus our attention on table 8, we find similar results for negative binomial regressions. On the one hand, past investments in maintenance are consistently effective in reducing fatalities and casualties. On the other, we find that past investments in construction only appear statistically significant and effective in reducing fatalities when we do not control for other regulatory variables. The omission of these variables would lead to the wrong conclusion that both maintenance and construction spending reduce fatalities. Note that as happens for the OLS fixed effects model the coefficient associated with maintenance spending drops from 0.0006 to 0.0025 with the inclusion of regulatory regressors. These coefficients are larger for casualties than for fatalities.

Less clear are the effects of the features of the infrastructure. In OLS fixed effects models, we find the share of motorways to reduce fatalities consistently across models. This result, however, is not confirmed by Negative Binomial estimates. Generally, infrastructure features as are considered in this study do not provide significant results.

Indeed, disaggregating the results between wider and narrower highways, we find that the impact of a greater proportion of narrow roads (5-7m) is an increase in the fatality rate in OLS fixed effects models and, contrarily, a decrease in the negative binomial models. We would have expected a negative sign for urban roads, as they are not likely to carry heavy traffic at high speed and hence have low crash risks. In non-urban areas, two lane roads are open roads which have higher speed and higher crash risks. The effect of wider roads is not significant in any case. We would have expected the widening of roads to improve road safety outcomes: motorways are – according to technical standards – wider and safer than the highways in the rest of the network, but large returns from adopting this strategy cannot be guaranteed according to our results. Indeed, the impact of wider roads can have their own limits. The difference between motorways and conventional roads is larger than the difference between 5-7m and >7m wide roads, which actually may not be of better quality in respect to narrow roads in some instances. In fact, roads less than 7m wide are likely to be two lane roads.

Among the second group of variables (traffic laws and regulations), we find evidence of the influence of the most recent changes in regulation in Spain. However, not all impacts are in the expected direction. First, we find effectiveness linked to the New Traffic Law in 2006 – presenting statistically significant coefficients for the rate of fatalities and the rate of casualties-, and to the European Road Safety Program 2003-2010. These two regulatory measures significantly reduced the number of fatalities and casualties, demonstrating the importance of the newly introduced road safety measures and of the penalty points system (together with the implementation of penal sanctions for traffic rule offenders) in enhancing road safety outcomes. Surprisingly, the European Program of Road Safety Promotion provides opposite results, perhaps because it coincided with years of important economic growth in Spain. However, it should be recalled that we used the aggregate road safety program as opposed to individual regulations so that some of the latter might have had a compensating effect on each other. As such, these multicollinearity concerns represent a limitation to our empirical strategy.

Contrary to expectations, the first national program promoting vehicle renewals and compulsory inspections was actually significant in increasing the number of fatalities, but only for negative binomial models on fatalities. It presents no significant effect on casualties.

Among the remaining variables we should stress the appropriateness of the controls employed. Most of them display highly statistical relationships with our dependent variables with the expected signs. However, note that some of these signs are dependent, on the one hand, on the method use. For instance, motorization shows positive signs for OLS fixed effects models on fatality and casualty rates, while the sign becomes negative for negative binomial method. On the other hand, the role of the elderly also changes after the introduction of regulatory measures in all models. In fact, the use of regulatory variables achieves that our elderly variable presents the expected negative sign. Finally, we should mention as well that the role played by the time trend, which captures not only technical improvements, but also higher public awareness concerning road safety over time. Its coefficient indicates that fatalities and casualties have declined over the last two decades.

6. Conclusions

This article has highlighted the importance of considering investment and infrastructure variables together with traffic regulatory variables when accounting for patterns and trends in road safety. While both groups of determinants are clearly relevant for the determination of road safety outcomes, we have found evidence of a certain amount of heterogeneity in the case of safety measures. In addition, we have seen the overestimation of impacts for infrastructure spending when regulatory measures were not included in the models. On the one hand, the omission of regulatory measures results in the overestimation of the impact of maintenance spending. On the other, it could lead to the wrong conclusion that spending in construction also improves road safety outcomes.

In the case of investment and infrastructure variables, our results indicate that investing in maintenance produces a safety benefit in terms of a reduction in the fatality rate. This main result is consistent across models and methods. The social desirability of this result would depend on cost-benefit ratios that are beyond the objective of this study. However, maintenance plays a much more relevant role in road safety than construction spending, according to our results. This evidence should encourage governments to undertake maintenance programs not only to guarantee efficient connections in terms of time, but also to enhance safety standards that can reduce the economic and social costs of accidents. Indeed, our results indicate that the focus on road fatalities must pay attention to maintenance instead of construction.

It is worth noting that the Spanish Government has recently asked the European Investment Bank to co-finance half of its 1000 million euro road conservation and improvement plan[10] aimed at alleviating the negative impact of cuts in public investment in maintaining this infrastructure. The importance of investing in road maintenance in Spain has been echoed by the Spanish Road Association (AEC), which warns that the actual state of maintenance of Spain's road network is the worst it has been since 1985 (AEC, 2012).

Our results on construction spending show that, while investing in capacity enlargements and new roads is necessary to develop an efficient transportation network, which in turn can enhance productivity and growth, such investment generates higher mobility – perhaps even more risky driving - and we must, therefore, be prepared to address the potential negative impact on road safety outcomes. This result suffers, however, from one of the limitations of this study, which is the lack of data on traffic volume that could account for the effects derived from inducing demand with construction. Despite finding evidence of effective impacts achieved by maintenance spending, this study does not offer a cost-benefit analysis, which should be considered before undertaking investment efforts.

Given our results, we believe that road safety should be modeled within a unified framework that gives joint consideration to infrastructure and investments, on the one hand, and to traffic regulations that impact the behavior of road users and in which aggregate road safety problems are addressed, on the other. In this respect, we find that the introduction of basic rules and well-designed changes in regulation and sanction policies

[10] Project promoting Road Safety & Rehabilitation - reported by European Investment Bank on September 17, 2012: http://www.eib.org/projects/pipeline/2012/20120223.htm

can be effective in reducing the number of fatalities and casualties as well. A unified framework of this nature should also provide more robust insights as to what each of these policies can contribute to the reduction in number of road accidents and road victims. Our results show both types of policy to be relevant, which means that omitting one of them may generate biased estimates.

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Table 1. Comparison of fatality rates per million inhabitants across European Countries (UE15) 1991-2010.

Country	**Fatality Rate 1991**	**Country**	**Fatality Rate 2010**		Country	Change Ranking	Change Fatality Rate
Portugal	323	Greece	111		**Spain**	**-6**	**-76,21%**
Spain	**227**	Portugal	79		Luxembourg	-3	-70,37%
Luxembourg	216	Belgium	75		Germany	-3	-68,30%
Greece	207	Italy	68		Sweden	-2	-67,81%
Austria	201	Austria	66		Portugal	-1	-75,54%
Belgium	188	Luxembourg	64		Austria	0	-67,16%
France	184	France	62		France	0	-66,30%
Average	**163,73**	**Average**	**57,27**		Ireland	0	-62,69%
Italy	143	**Spain**	**54**		United Kingdom	1	-62,65%
Germany	142	Finland	51		Netherlands	1	-62,35%
Ireland	126	Ireland	47		Denmark	1	-61,01%
Finland	126	Denmark	46		Finland	1	-59,52%
Denmark	118	Germany	45		Belgium	3	-60,10%
Sweden	87	Netherlands	32		Greece	3	-46,37%
Netherlands	85	United Kingdom	31		Italy	4	-52,44%
United Kingdom	83	Sweden	28				

Source: CARE Database.

Table 2. Road safety trends in the Spanish Provinces (1996-2010)

Provinces*	Change in Injury Crashes 1996-2010	Change in Total Victims 1996-2010	Provinces*	Change in Injury Crashes 1996-2010	Change in Total Victims 1996-2010
Álava	-62%	-59%	La Rioja	-1%	-11%
Albacete	-37%	-47%	Lugo	-58%	-62%
Alicante	-19%	-23%	Madrid	39%	34%
Almería	-10%	-9%	Málaga	-1%	-9%
Ávila	34%	8%	Murcia	-61%	-58%
Badajoz	7%	-6%	Navarra	-10%	-23%
Illes Balears	-23%	-26%	Ourense	-63%	-66%
Barcelona	13%	16%	Asturias	-10%	-10%
Burgos	-30%	-40%	Palencia	-29%	-31%
Cáceres	59%	31%	Palmas, las	-56%	-54%
Cádiz	61%	71%	Pontevedra	-5%	-6%
Castellón	-30%	-39%	Salamanca	-3%	-9%
Ciudad Real	-18%	-23%	S.C. Tenerife	-7%	-15%
Córdoba	-29%	-29%	Cantabria	-20%	-20%
A Coruña	-46%	-51%	Segovia	-31%	-37%
Cuenca	-20%	-35%	Sevilla	18%	12%
Girona	42%	24%	Soria	-12%	-14%
Granada	-7%	-8%	Tarragona	25%	13%
Guadalajara	-10%	-25%	Teruel	3%	1%
Guipúzcoa	-1%	-11%	Toledo	5%	-13%
Huelva	-13%	-17%	Valencia	-8%	-13%
Huesca	-9%	-12%	Valladolid	-59%	-61%
Jaén	-14%	-23%	Vizcaya	27%	103%
León	-32%	-37%	Zamora	-53%	-58%
Lleida	41%	19%	Zaragoza	0%	-7%

Source: Based on data provided by the Spanish Traffic General Directorate
* The Autonomous Cities of Ceuta and Melilla are excluded.

Table 3. Spanish road network and road type shares over total network (1990-2010).

Year	Total Network (Km)	Motorways[1] (% over total network)	Other roads[2] (% over total network)	Other roads[2] with less than 7m width (% over total network)	Other roads[2] with more than 7m width (% over total network)
1990	156,172	3.28	96.72	77.77	18.95
1991	156,974	3.70	96.30	74.85	21.46
1992	158,324	4.41	95.59	72.18	23.40
1993	159,630	4.64	95.36	70.36	25.01
1994	162,196	4.78	95.22	70.13	25.09
1995	162,617	5.00	95.00	68.43	26.57
1996	162,100	5.24	94.76	67.31	27.44
1997	162,795	5.57	94.43	65.66	28.77
1998	163,273	5.91	94.09	64.93	29.16
1999	163,769	6.29	93.71	63.29	30.42
2000	163,557	6.38	93.62	62.42	31.19
2001	163,799	6.81	93.19	63.02	30.17
2002	164,139	6.95	93.05	62.55	30.50
2003	164,584	7.30	92.70	61.68	31.02
2004	165,152	7.53	92.47	60.50	31.96
2005	165,646	7.94	92.06	59.25	32.81
2006	166,339	8.34	91.66	58.54	33.12
2007	166,011	8.85	91.15	56.97	34.18
2008	165,011	9.16	90.84	64.34	35.66
2009	165,463	9.44	90.56	63.65	36.35
2010	165,787	9.63	90.37	61.57	38.43

Source: Based on data provided by the Spanish Ministry of Transportation.
1. Motorways include tolled motorways, free motorways and dual carriageways.
2. All other roads excluding motorways and dual carriageways.

Table 4. Distribution of investments by type in the Spanish road network (1990-2010).

Year	Total Investments[1] (million euro)	Construction[1] (million euro)	Construction[1] (% over total investments)	Maintenance[1] (million euro)	Maintenance[1] (% over total investments)	Motorway Company Investments (million euro)
1990	3.515	2.847	81	668	19	-
1992	3.935	3.224	82	711	18	-
1994	4.519	3.651	81	868	19	-
1996	3.831	2.954	77	877	23	-
1998	4.734	3.335	70	1.039	30	-
2000	2.278	1.773	78	505	22	262
2002	5.523	4.104	74	1.419	26	1.232
2004	5.649	4.052	72	1.597	28	1.520
2006	3.375	2.528	75	846	25	1.304
2007	7.257	5.096	70	2.160	30	524
2008	7.564	5.020	66	2.544	34	474
2009	7.477	5.089	68	2.388	32	894
2010	6.318	3.873	61	2.446	39	484

Source: Based on data provided by the Spanish Ministry of Transportation.
1. Only investments made by the public administration. Data on the distribution of investments by Motorway companies are not always available.

Table 5. Chronology of regulatory measures, programs and laws.

Measure	Year	Description
ITV (first enforcement)	1985	First regulation of technical vehicle inspection
Traffic Law / General Traffic Rules	1990/1992	First law regulating traffic and road safety
ITV (second enforcement)	1994	Second regulation of technical vehicle inspection
RENOVE program	1994	Grants promoting fleet renewal
European program of road safety promotion 1997-2001	1997	Joint program to recommend measures and policies to reduce road fatalities
PREVER program	1997	Grants promoting fleet renewal
BAC (reduction)	1999	Blood alcohol content limit reduction to 0.5mg/ml
European Road safety Action Plan 2003-2010	2003	Joint program to recommend measures and policies to reduce road fatalities
Motorbike License	2004	Experienced car drivers allowed to drive motorbikes
Seat-Belt	2006	Mandatory seat-belt law in all seats and vehicles
New Traffic Law	2006	Reform of the former traffic law (Points License)
Penal Sanctions	2007	Penal sanctions for road safety regulation offenders
VIVE program	2008	Grants promoting fleet renewal

Table 6. Definition and descriptive statistics of variables employed.

Variables	Definition
Dependent Variables	
Total Rate of Fatalities	Number of fatalities per 100,000 inhabitants (deaths until 30 days after the crash)
Total Rate of Casualties	Number of casualties per 100,000 inhabitants
Fatalities	Number of deaths in road accidents (deaths until 30 days after the crash)
Casualties	Number of injured in road accidents
Spending variables	
Past Inv. Construction	Million euro invested per 100,000 inhabitants in the construction of new road network during the previous two years
Past Inv. Maintenance	Million euro invested per 100,000 inhabitants in the maintenance of the existing road network during the previous two years
Infrastructure variables	
% Motorways	Percentage of Motorways over the total road network in the province
% 5-7 meters	Percentage of roads wider than 5 meters and narrower than 7 meters over the total network in the province
% >7 meters	Percentage of roads wider than 7 meters over the total network in the province
Regulatory variables	
General Traffic Rules	Binary variable taking value 1 after the enactment of the General Traffic Rules in 1992 and 0 in the years prior to that.
Inspection and Renewal	Categorical variable taking value 1 when vehicle inspection is compulsory (1994), 2 if in addition there exists a program of subsidies promoting old vehicle renewal (1997), and 0 otherwise.
European Program 97	Binary variable taking value 1 when the First European Program of Road Safety Promotion (1997) is enacted, and 0 otherwise.
European Program 03	Binary variable taking value 1 when the European Road safety Action Plan 2003-2010 is in place (2003), 0 for previous years.
New Traffic Law 06	Binary variable taking value 1 when penalty points system and penal sanctions for traffic rule offenders are enacted (2006) and 0 otherwise.
Other Control variables	
Motorization	Number of vehicles per 1000 inhabitants
Unemployment rate	Share of population unemployed in the province
Elderly	Share of population at the province older than 65 years old
Doctors	Number of physicians per capita in the province

Table 7. Least-squares semi-log estimates for fatality and casualty rates.

Regressors	OLS Fixed Effects AR(1) log Fatality Rate (1)	OLS Fixed Effects AR(1) log Fatality Rate (2)	OLS Fixed Effects AR(1) log Non-Urban Fatality Rate (3)	OLS Fixed Effects AR(1) Log Non-Urban Fatality Rate (4)	OLS Fixed Effects AR(1) log Non-Urban Casualty Rate (5)	OLS Fixed Effects AR(1) log Non-Urban Casualty Rate (6)
Investment variables						
Past Inv. Maintenance	-0.0009 (-4.44)***	-0.00038 (-2.11)**	-0.00099 (-4.46)***	-0.00042 (-2.26)**	-0.0007 (-4.49)***	-0.00056 (-3.50)***
Past Inv. Construction	2.49e-06 (0.05)	0.00005 (1.40)	0.00002 (0.54)	0.00007 (1.91)*	-0.00004 (-1.10)	-0.00002 (-0.64)
Infrastructure variables						
% Motorways	-0.0490 (-6.54)***	-0.03523 (-5.45)***	-0.04484 (-5.84)***	-0.0338 (-5.04)***	0.0003 (0.07)	0.00303 (0.57)
% 5-7 meters	0.0021 (1.99)**	0.0011 (1.12)	0.0018 (1.71)*	0.0009 (0.96)	0.00002 (0.03)	-0.0002 (-0.31)
% >7 meters	-0.0010 (-0.79)	-0.0006 (-0.52)	-0.00108 (-0.89)	-0.0006 (-0.57)	-5.69e-06 (-0.01)	0.00002 (0.03)
Regulation variables						
General Traffic Rules	-	-0.26595 (-0.96)	-	-0.2790 (-1.11)	-	-0.03760 (-0.48)
Inspection and Renewal	-	-0.0399 (-1.39)	-	-0.0311 (-1.05)	-	-0.0018 (-0.09)
European Program 97	-	0.07481 (2.71)***	-	0.0701 (2.51)**	-	0.0392 (2.18)**
European Program 03	-	-0.1033 (-3.30)***	-	-0.0915 (-2.88)***	-	-0.0170 (-0.81)
New Traffic Law 06	-	-0.2944 (-9.99)***	-	-0.3098 (-10.25)***	**-**	-0.08891 (-4.14)***
Control variables						
Motorization	-0.0009 (-3.53)***	-0.00011 (-0.48)	-0.0011 (-4.50)***	-0.00035 (-1.47)	0.00017 (0.93)	0.00030 (1.65)
Unemployment rate	-0.0134 (-5.36)***	-0.0191 (-8.89)***	-0.0171 (-6.71)***	-0.0223 (-10.08)***	-0.01319 (-7.71)***	-0.01445 (-8.43)***
Elderly	0.0339 (2.43)**	0.0060 (0.51)	0.0310 (2.16)**	0.00215 (0.18)	0.02602 (2.51)**	0.0210 (2.05)**
Doctors	-0.0031 (-5.04)***	-0.0022 (-4.40)***	-0.0033(-5.09)***	-0.00228 (-4.35)***	-0.0015 (-3.20)***	-0.0013 (-2.91)***
Wald chi2	-					
F-test of joint significance	47.60***	79.49***	49.06***	79.20***	15.71***	12.80***
R2	0.40	0.54	0.45	0.54	0.19	0.22

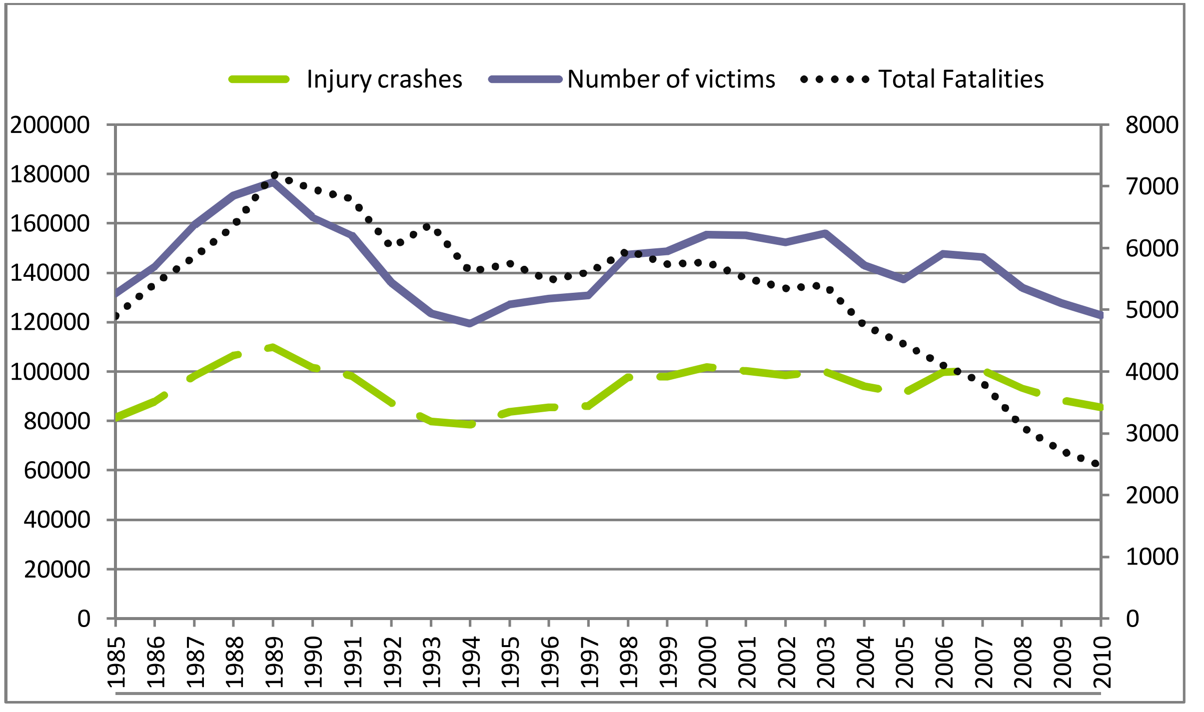
In parenthesis we provide robust Student's-t values. Each regression includes province fixed effects and a constant term. * Statistically significant at 10%, ** at 5%, *** at 1%.

Table 8. Negative Binomial estimates for fatality and casualty counts.

Regressors	NB Fixed Effects Fatalities (7)	NB Fixed Effects Fatalities (8)	NB Fixed Effects Fatalities (8)	NB Fixed Effects Non-Urban Fatalities (9)	NB Fixed Effects Non-Urban Fatalities (10)	NB Fixed Effects Non-Urban Casualties (11)	NB Fixed Effects Non-Urban Casualties (12)
Investment variables							
Past Inv. Maintenance	-0.0006 (-4.44)***	-0.00025 (-1.96)**	-0.00051 (-3.80)***	-0.0007 (-4.95)***	-0.0003 (-2.42)**	-0.0008 (-6.23)***	-0.0006 (-4.85)***
Past Inv. Construction	-0.00007 (-2.68)***	-0.00003 (-1.27)	-0.00001 (-0.54)	-0.00007 (-2.37)**	-0.00002 (-0.92)	7.56e-06 (0.27)	0.00003 (1.03)
Infrastructure variables							
% Motorways	-0.0032 (-0.68)	-0.001065 (-0.26)	-0.0076 (-1.77)*	-0.0013 (-0.27)	0.00103 (0.24)	0.0076 (1.62)	0.00757 (1.63)
% 5-7 meters	-0.00145 (-1.71)*	-0.0016 (-2.14)**	-0.00082 (-1.03)	-0.0016 (-1.81)*	-0.0020 (-2.41)**	-0.0003(-0.43)	-0.0005 (-0.75)
% >7 meters	-0.0005 (-0.52)	-0.0002 (-0.26)	-0.00003 (-0.04)	-0.00107 (-1.01)			0.00077 (0.86)
Regulation variables							
General Traffic Rules	-	0.00161 (0.03)	-0.0325 (-0.57)	-	0.0355 (0.62)	-	
Inspection and Renewal	-	0.15935 (7.64)***	0.0256 (1.46)	-	0.1664 (7.62)***	-	0.0061(0.26)
European Program 97	-	-0.0360 (-1.79)*	0.0251 (1.24)	-	-0.0414 (-1.97)**	-	0.04829(2.05)**
European Program 03	-	0.0438 (1.73)	-0.0686 (-2.84)***	-	0.05378 (2.03)**	-	0.0237 (0.83)
New Traffic Law 06	-	-0.1822 (-7.46)***	-0.3107 (-13.48)***	-	-0.1968(-7.67)***	-	-0.1086 (-4.30)***
Control variables							
Motorization	0.0008 (4.26)***	0.0009 (4.93)***	-0.00002 (-0.12)	0.00072 (3.30)***	0.0007 (3.81)***	-0.0003 (-1.65)*	-0.0004 (-2.37)**
Unemployment rate	-0.0116 (-8.06)***	-0.01550 (-11.21)***	-0.0161 (-11.16)***	-0.0139 (-9.32)***	-0.01813 (-12.46)***	-0.0179 (-12.54)***	-0.0190 (-12.76)***
Elderly	0.0304 (4.34)***	-0.03094 (-4.08)***	-0.0384 (-4.81)***	0.0284 (3.90)***	-0.0341 (-4.32)***	-0.0065 (-1.08)	-0.0218 (-3.30)***
Doctors	-0.00187 (-5.28)***	-0.00121 (-3.66)***	-0.0017 (-5.07)***	-0.0018 (-4.94)***	-0.00118 (-3.41)***	-0.0012 (-3.91)***	-0.0012 (-3.80)***
Offset variable (Num. Vehicles)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	-0.0454 (-12.42)***	-0.0543 (-10.55)***	No	-0.0433 (-11.26)	-0.0530 (-9.78)***	0.0034 (0.96)	0.0114 (2.10)**
Log Likelihood	-3850	-3743	-3795	-3732	-3621	-6363	-6342

In parenthesis we provide robust Student's-t values. Each regression includes province fixed effects. * Statistically significant at 10%, ** at 5%, *** at 1%.

Figure 1. Trends in Road Safety Outcomes in Spain (1985-2010)



Appendix A. Selected literature on road infrastructure and traffic conditions since 2000.

Study	Result	Regulatory variables (RV) and Infrastructure variables (IV)

Abdel-Aty and Essam-Radwan (2000)	Heavy traffic, speeding, narrow lane width, larger number of lanes, urban roadway sections, narrow shoulder width and reduced median width, all increase the likelihood of accidents.	IV: Section length, horizontal curve, shoulder width, median width, lane width, urban section
Noland (2003)	Results refute claims that infrastructure improvements have been effective at reducing total fatalities and injuries. Number of interstate lanes is positively associated with more deaths and injuries. Seat belt laws were effective.	RV: Seat belt laws IV: Lane miles, number of different road types, number of lanes, lane widths
Flahaut (2004)	Infrastructure plays a substantial role in the co-occurrence of road accidents. All infrastructure variables are found to be statistically significant.	IV: Distance to major junction, proportion of built-up area, type of road , distance to a change in the speed limit, adherence, type of surface, distance to different type of road
Noland and Oh (2004)	An increase in lane numbers and widths is associated with growth in number of accidents, while outside shoulder width is associated with reduced number of accidents.	IV: Lane miles, mean lanes, lane width, shoulder width, horizontal and vertical curves per mile, mean deflection angle,
Noland and Quddus (2004)	Urbanized areas are associated with fewer casualties while areas of higher employment density are associated with more casualties. More deprived areas tend to have higher levels of casualties. The effect of road characteristics is less significant but there is some positive association with the density of A and B types.	IV: Motorway length, different type of road length, number of roundabouts, number of junctions
Haynes et al. (2008)	Traffic flow is the main determinant. There was no evidence that curves affect number of fatal crashes, but urban roads were significantly and negatively related to two measures of road curvature: ratio of road length to straight distance and the cumulative angle	IV: Junctions per km, road altitude, bend density, detour ratio, cumulative angle, median angle, road length.
Anastasopoulos, Tarko and Mannering (2008)	Several factors related to pavement condition and quality were found to significantly influence vehicle accident rates including the effects of friction. In terms of geometric factors and their effect on accident rates, median types and width, shoulder widths, number of ramps and bridges and curves were all found to be statistically significant.	IV: Friction indicator, pavement, rutting indicators, width, shoulders width, barriers, ramps, horizontal curves, vertical curves, bridges, rumble strips
Meuleners et al. (2008)	The programs have been effective overall, reducing overall crash rate by 15%.	Iv: Intersection treatments, road section treatment, roundabouts, signals, islands, median, curb extensions (nibs), ban right turns, priority signs.
Wanvik (2009)	This study estimates the safety effect of road lighting on accidents at night. The results show that the positive effect of road lighting is greater in relation to fatal accidents than it is on injuries and that the effect of road lighting is significantly smaller during adverse weather and road surface conditions than during fine conditions.	Iv: Road lighting, road surface conditions
Albalate and Bel (2012)	Extending the motorway network is associated with a reduction in fatality rates, while all other road types do not have the same positive effects. This result is only statistically significant for free motorways; tolled motorways do not provide any significant impact.	RV: BAC level, Speed limit on motorways IV: Proportion in % of motorways, free and tolled motorways; proportion in % of primary and secondary roads over the total road network.
Park et al. (2012)	Wider edge line markings on rural, two-lane highways have positive safety effects on vehicle safety.	IV: Width of edge lines, shoulder width
Vieira Gomes and Cardoso (2012)	The application of several low cost engineering measures, aimed at road infrastructure correction and road safety improvement on a multilane road, reduced the annual number of injuries and the annual number of head-on collisions. The annual frequency of accidents with fatalities and serious injuries was also reduced.	IV: The application of corrective measures: curbed median and speed activated traffic signals

Appendix B. Selected literature on laws, regulatory and enforcement measures since 2000.

Study	**Result**	**Regulatory variables (RV) and Infrastructure variables (IV) variables**
Loeb (2001)	The law was effective but its impact varies depending on the type of injury rates examined.	RV: Seat belt laws

Dee (2001)	BAC laws effective in reducing traffic fatalities, particularly among younger adults	RV: BAC laws, Administrative license revocation, 'dram shop' statute or case law, mandatory jail time for first DUI offense, Zero tolerance law, seat belt laws, Speed limits
Dee and Sela (2003)	Increase in speed limits did not lead to higher fatality rates in overall population, but pushed up fatality rates of women and elderly	RV: Speed limits, Seat belt laws, Enforcement, License Revocation, BAC level
Cohen and Einav (2003)	Mandatory seat-belt laws unambiguously reduce traffic fatalities	RV: Seat belt laws, speed limits, BAC limits, minimum legal drinking age (MLDA)
Dee, Grabowsky and Morrisey (2005)	Graduate driver license (GDL) regulations reduced traffic fatalities among 15-17 year olds by at least 5.6%	RV: GDL laws, Speed limits, seat belt laws, BAC levels, Administrative license revocation, Zero tolerance laws
McCarthy (2005)	Road accidents among elderly drivers is very elastic with miles driven. Administrative license restrictions reduced non-fatal injury crashes but had no impact on driver safety. Speed limit increases pushed up number of fatal crashes	RV: Alcohol license density, traffic citations, administrative license restriction, BAC laws, Speed limit
Christensen and Elvik (2007)	Inspections were found to reduce the number of technical defects in cars markedly, but had no effects on accident rates.	RV: Inspection system
Kaplan and Prato (2007)	BAC laws are more effective in reducing number of casualties than in cutting number of accidents	RV: BAC laws, Administrative license revocation
Carpenter and Stehr (2008)	Mandatory seatbelt laws were highly effective reducing fatalities and crash-related serious injuries among youths	RV: Seat-belt laws, BAC levels, GDL, zero tolerance laws, speed limits
Albalate (2008)	Lower BAC laws effective for young road users, especially males in urban environments	RV: BAC levels, MLDA, Points license, Random checks IV: % highway miles and % national roads over total road network.
Yannis et al. (2008)	Police enforcement of two infringements - speeding and drinking-and-driving - shows significant effect on accidents and fatalities.	RV: Enforcement of infringements: speeding and drinking-and-driving.
Ward Vanlaar et al. (2009)	Strong evidence in support of GDL was found. Its positive effects in reducing collisions, fatalities and injuries among novice drivers depend on several components of GDL. This study identifies the most effective components of GDL programs.	RV: Components of GDL program
Castillo-Manzano, Castro-Nuño & Pedregal (2010)	The introduction of a penalty points system in Spain brought about an average reduction of 12.6% in the number of deaths in highway accidents. It would take 2 years for this effect to disappear. For other safety variables the effect would disappear after 1 year.	RV: Points license, seat belt laws.
Tay (2010)	The number of speed cameras and the number of apprehended drivers has significant effects in reducing the number of injuries.	RV: Speed cameras and their location, apprehension of offenders.
Nikolaev at al. (2010)	After banning hand-held cell phone use while driving the number of fatal automobile accidents decreases.	RV: A ban on hand-held cell phone use while driving
Izquierdo et al. (2011)	Penalty points system in Spain reduced the number of fatalities. This change in driver behavior is due to a combination of three factors: penalty points system, stepping up of surveillance measures and sanctions, and the publicity given to road safety issues.	RV: Points license, Reform of the Penal Code (December 2007)
Fell (2011)	The implementation of GDLs can reduce by 8 to 14 percent the number of 16- and 17-year-old drivers involved in fatal crashes (relative to 21- to 25-year-old drivers), depending on other existing laws.	RV: GDL law
Castillo-Manzano and Castro-Nuño (2012)	Analyzing the effects of implementation of driving licenses based on points systems on road traffic accidents and the duration of these effects, the findings suggest that the strong initial positive impact (15 to 20% reductions in accidents, fatalities and injuries) seems to wear off in under eighteen months due to the absence of complementary enforcement to back up these measures.	RV: Penalty Point System
Tay (2009)	Manned enforcement has a significant impact on both total and serious crashes, automated enforcement only has an effect on total crashes. Manned enforcement provides specific deterrence targeted at the high-risk drivers, automated enforcement provides a general deterrence effect on a broad spectrum of the driving population.	RV: Speeding and speed enforcement.
Deerig at al. (2002)	The population safety belt usage rate is associated with little or no effect on reducing fatality rates. Hither safety belt usage rates arising from states with primary enforcement laws tend to suggest reductions in fatality rates.	RV: safety belt primary enforcement.
Tay (2005)	The anti-drink driving enforcement and publicity campaigns have a significant independent effect in reducing crashes, their interactive effect is anti-complementary. The anti-speeding enforcement and publicity campaigns had no independent effect, their interactive effect is significant.	RV: Random breath tests (RBT), Number of traffic infringement notices issued per month (Speed limits).
Delaney et al. (2006)	Exissting dink-driving enforcement efforts have successfully contributed to reductions in casualty crashes at all severity levels. International evidence suggests that Ramdom Breath Testing (RBT) preograms are cost beneficial. There is a remainging group of drivers in the drink-driving enforcement who have not been influenced by current enforcement methods.	RV: Random breath test (RBT)