The impact of traffic violations on the cost of traffic accidents with victims

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Abstract

We analyse accidents with victims and calculate the influence of traffic violations on the probability of having a serious or fatal accident, compared to a slight accident. Traffic violations related to speed limitations, administrative infringements or faults related to the driver are considered. Data were obtained from all available reports on accidents with victims that occurred in Spain from 2003 to 2005. A multinomial logistic regression model is specified to find the probability that an accident with victims is slight, serious or fatal, given the presence/absence of thirty different types of traffic violations. The average cost per victim and the average number of victims per accident are then used to find the estimated cost of an accident with victims, given the information on the traffic violations incurred. This demonstrates which combinations of traffic violations lead to higher estimated average costs, compared to cases in which no traffic violation occurred. We conclude with some recommendations on the severity of penalties, and suggest that regulators penalize the occurrences of some specific combinations of traffic violations more rigorously.

Keywords: Traffic violations, traffic accidents with victims, accident severity, economic cost of traffic accidents

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1. Introduction

Our aim is to demonstrate the link between different types of traffic violations and the severity of traffic accidents. We find that some traffic violations cause a significant increase in the probability of suffering a severe accident, compared to situations in which there is no traffic violation. We also study combinations of several traffic violations. We use an extensive data base of accidents with victims that occurred in Spain. We assign an economic cost to the severity level of each accident, and we are able to identify the impact of each traffic violation on the final average cost of the accident. Our results can be useful to transform the occurrence of a traffic violation into economic terms. In our approach, we do not impose proportionality. Thus, the occurrence of two traffic violations does not necessarily imply that the expected cost of the accident would be the same as the sum of the expected cost of the accident if each traffic violation had occurred alone.

The economic cost of traffic accidents has been extensively studied in aggregate terms. It is common to express the cost in terms of economic magnitudes such as Gross Domestic Product or per capita income (e.g., Connelly and Supangan, 2006; Kopits and Cropper, 2005; López et al., 2004; Elvik, 2000). Other authors have focused on the concepts to be used when measuring the cost of traffic accidents (Andersson, 2005; Schwab and Soguel, 1995; Alfaro et al., 1994). The association between traffic violations and the occurrence of traffic accidents is also well documented. For example, Macdonald and colleagues (2004) show that drivers who are receiving treatment for an addiction or alcohol abuse incur a larger number of traffic violations than those who are not. But they also find evidence that receiving treatment for drug addiction or alcohol abuse considerably reduces the probability of causing an accident. Vingilis and Wilk (2008) show that driving under the influence of alcohol increases the probability of collisions among younger drivers, while Neynes and Boyle (2007) analyze the effect of distractions leading to traffic accidents among young drivers.

Renner and Anderle (2000) find a relationship between certain characteristics of personality (like extraversion or impulsiveness) and incurring traffic violations in a sample of young drivers. The types of traffic violations they include are related to excess speed when driving, not respecting priority or passing a red light sign. Their study concludes that traffic violations among young drivers are due to normal behaviours rather than behavioural disorders. In the same spirit, Castellà and Pérez (2004) analyze the relationship between certain behavioural patterns and attitudes about incurring traffic violations. They use

personality tests (along the lines of Ortet et al., 2002) and tests on reactions to punishment or reward as a result of actions (as suggested by Torrubia et al., 2001). Individuals that perceive less peril when violating traffic rules tend to incur more traffic violations than individuals that are more risk averse. This effect is also considerably larger for men than for women. As a general result of this literature on traffic violations and accidents, many countries like Spain, France and Italy, among others, have implemented point-record mechanisms in their driving license systems (see Nallet et al., 2008; Bourgeon and Picard, 2007).

To our knowledge, there is no empirical analysis of the impact of traffic violations on the severity of an accident. Severity is a concept that is not easily measured. We will nevertheless establish a comprehensive categorization based on the bodily injury that results from the accidents we analyse. We therefore only consider accidents with victims. We estimate multivariate logistic regression models to examine the effect of traffic violations on the probability of increased accident severity, where the exogeneous information is the presence or absence of each type of traffic violation considered here. We then report expected average costs of an accident based on its severity (i.e., the category the accident has been assigned to as a result of type of bodily injury that it has caused).

There were 130,144 accidents with victims in Spain from 2003 to 2005. In cases of accidents with victims, it is compulsory for police officers to write a report on the accident, which gives us an exhaustive source of individual information on these events. Our analysis of these reports suggest that 89.5% of accidents with victims refer to traffic violations which caused the accident. These traffic violations are related to administrative norms (for instance, not having the adequate driving license), violations of the traffic code with respect to priority, driving carelessly or driving too fast.

Unfortunately, we only have information on the average cost of an accident per severity level. We do not have information on the real final cost of every accident in the data source because this cost is usually known much later, when compensations are paid, for instance. Thus, it may take some time to calculate real final costs.

Our approach allows us to establish a causal link between occurrences of traffic violations (possibly more than one at a time) and accidents. Therefore, we can assess the impact of every type of traffic violation on the final accident cost. Our results compare accidents where no traffic violation has been reported to other accidents which do have some association with a traffic violation. These results also have interesting policy implications regarding such issues as the magnitude of fines, and raise several important questions. Given our results, it is fair to ask if the size of the fine associated with every traffic violation is

proportional to the expected cost of the accident that it may cause. Our results may also raise questions about whether the penalty attached to traffic violations in terms of points, in point record mechanisms, is proportional to the expected cost of an accident for which every traffic violation is responsible.

2. Methods

2.1. Population under study and design of our research

In this study, we analyse traffic violations reported in accidents with victims. The number of accidents with victims that occurred in Spain from 2003 to 2005 is 130,144. This information is exhaustive because police officers are required to write a report in cases of injury or fatality. We have selected accidents involving a maximum of three vehicles, which excludes chain crashes and other peculiar accidents. We argue that the causality of a traffic violation becomes less clear when more than three vehicles are involved. One traffic violation may cause another traffic violation, the latter being the real cause of the accident, but the first being the one causing the occurrence of the second. Accidents involving three vehicles at most are 97.5% of the sample, so we have only excluded a small percentage. All types of vehicles are considered here (truck, car, cycle, etc.).

Among the accidents we analysed, 46.0% had only one vehicle involved (and therefore only one driver), 48.8% involved two vehicles and 5.2% involved three vehicles. Data were provided by the Dirección General de Tráfico in Spain, which is the national authority. They were obtained using the original forms that are completed by a police officer right after accidents occur. It is highly recommended that this official report exists for the victim's interest. Police officers are obliged to report information concerning all accidents they assist that have injured individuals or fatalities to the national authority. The form they use is called *Cuestionario Estadístico de Accidentes de Circulación con Víctima*s. A new protocol has been recently implemented that allows officers to report the form on-line and gives a one month revision period to correct any inaccuracies about the victims resulting from the accident if necessary. Most medical staff who help the victims are also familiar with the procedure, so all efforts are made to guarantee that the vast majority of accidents with victims are indeed included in the national database. Only one form is filled out for every accident, and information is given on all vehicles, victims and damages in that accident. As a result, our unit of analysis is the accident with victims.

Our research is aimed at finding the weight of every traffic violation on the severity of the traffic accident. Since severity is a qualitative magnitude in our setting, we will define it in three categories following the legally recognized definitions of the Spanish national authority. They use a three-level measure of severity to construct yearly statistics on traffic injuries and fatalities. Severity is based on the condition of victims as a consequence of the accidents. Victims include drivers, as well as occupants of the vehicles involved in the accident and pedestrians. An accident with victims is defined as *slight* if all victims who have suffered personal injuries either had minor injuries which did not require hospitalization at all or which required hospitalization for not more than 24 hours. An accident with victims is defined as *serious* if at least one of the victims had to be hospitalized for at least 24 hours but didn't die within those 24 hours. An accident with victims is considered *fatal* if at least one person died within 24 hours as a consequence of the accident.

Accident severity can be regarded as a qualitative dependent variable. We estimate multinomial logistic regression models using exogeneous information on the occurrence of traffic violations causing the accident.[†] The exogeneous variables included in the model specifications are binary indicators of the occurrence of each type of traffic violation considered in the questionnaire, no matter which driver involved in the accident incurred the violation. Each exogeneous variable is called $x_{ik,}$ where i refers to the i-th accident and k to the k-th type of traffic violation. We code this variable as 1 if at least one of the drivers incurred the k-th type of traffic violation and 0 otherwise.

Using a multivariate model specification allows us to analyse not only the individual effect of every traffic violation on its own, but also the joint effect. This particular feature is interesting because some accidents involve more than one traffic violation simultaneously. When a traffic accident with victims occurs, the possibilities for combinations of possible traffic violations are abundant. Since we considered 30 different types, given the observed number of simultaneous violations, one can calculate all possible combinations. We observed at most five simultaneous traffic violations in our dataset. When analysing the results, we examined all possible combinations of traffic violations involving up to five different types. For every given number of simultaneous traffic violations, we calculated the combination with the larger probability of leading to a fatal or serious accident. We compared that probability with a baseline that we have established as the probability of having a fatal or a serious accident when no traffic violation occurs. We noted that some combinations of traffic

[†] We initially estimated ordered logistic models, but the parallel lines test rejected the ordered logistic regression model at the 95% confidence level.

violations are associated with a lower probability of having a fatal or a serious accident when compared to situations in which there are no traffic violations. In fact, these situations increase the odds of *slight* accidents to occur and therefore diminish the odds of more severe accidents. These types of traffic violations are usually associated with situations that lead to lighter crashes than average.

The estimated probabilities that result from our models are then used to quantify the expected cost of an accident with victims, given the traffic violations that have occurred. Indeed, let us call c_K the cost of an accident given that K traffic violations occurred, and let us assume that the type of those traffic violations is known. We denote the corresponding binary variables by the vector x_K. Then using the multinomial logistic model, we calculate the expected cost of this accident with victims as:

$$E(c_K) = \hat{c}_0 P(y_0 = 1 \mid x_K) + \hat{c}_1 P(y_1 = 1 \mid x_K) + \hat{c}_2 P(y_2 = 1 \mid x_K)$$

where $\hat{c}_0$, $\hat{c}_1$ and $\hat{c}_2$ are estimated average costs by severity level (slight, serious and fatal) and y_l, l=0,1,2 are binary random variables indicating slight, serious and fatal accidents. $P(y_l = 1 \mid x_K)$ can be estimated from the multinomial model conditional on the exogenous variables, i.e. the traffic violations.

In order to estimate the average cost of an accident with victims, we include the cost of emergency services and police assistance, the cost of medical aid and hospital resources, the estimated cost of bodily injuries from which the victim does not recover, the cost of lost human capital, and finally, the cost of damages. This information was obtained from a report on the cost of accidents in Spain (Fundación RACC, 2007).

2.2. Traffic violations

Traffic violations included in this study can be classified into three large groups: a) violations related to speed limits, b) administrative violations and c) violations related to the driver. Below we present more information on the specific violations that are considered in the dataset. We have to stress here that we have not considered violations related to alcohol or drug abuse, because some of those faults are not available when the accident occurs. We also argue that they are the cause of other traffic violations, such as driving too fast or driving in the opposite direction.

2.2.1. Violations related to speed limits

There are three different traffic violations in this group:

1) Driving with inappropriate speed for the present conditions (*Speed1*).
2) Driving faster than established by speed limit (*Speed2*).
3) Driving too slowly, bothering the traffic (*Speed3*).

2.2.2. Administrative violations

There are five types of traffic violations in this group:

1) Not having a driving license (*Licence1*).
2) Driving license is expired (*Licence2*).
3) The number of occupants or the weight exceeds the limit (*Weight*).
4) The car does not have the certificate of inspection (*Itv*).
5) When applicable, the tachograph has not been revised properly (*Tacograph*).

2.2.3 Violations related to the driver

The accident report form considers twenty-two different traffic violations in this group:

1) Careless or distracted driving (*Driving1*).
2) Incorrect use of vehicle lights (*lights*).
3) Driving in the opposite direction (*Forbidden*).
4) Driving partially using the opposite lane (*Lane*).
5) Forbidden turn (*Bad turn*).
6) Incorrect pass (*Bad pass*).
7) Driving in zig-zag (*Zig-zag driving*).
8) Driving too close to the vehicle in front (*Security distance*).
9) Braking with no apparent reason (*Braking*).
10) Not respecting priority (*Right of way*).
11) Not respecting traffic light signs (*Traffic-lights*).
12) Violating stop sign (*Stop*).
13) Not respecting give way or yield sign (*Way*).
14) Not respecting pedestrian crossing (*Pedestrian crossing*).
15) Not respecting any other traffic sign (*Traffic signs*).
16) Incorrect indications of manoeuvring (*Manoeuvring*).

17) Entering lane without due care (*Without care*).
18) Dangerous or forbidden parking (*Dangerous parking*).
19) Driving with cyclists or motorcyclists in parallel (*Cyclers1*).
20) Cyclist or motorcyclist running or driving outside due lane limits (*Cyclers2*).
21) Vehicle doors opened carelessly (*Doors*).
22) Other road code violations not indicated above (*Others*).

The last type of traffic violation, which we have called *Others*, includes all kinds of contraventions, such as not respecting police officers indications or not respecting indication in roads when there are works.

3. Results

3.1. Descriptive analysis

A basic description of the variables in the database is presented in Table 1, which shows the percentage of accidents by severity, as well as the percentage of accidents by type of traffic violation. A total number of 130,144 accidents with victims were considered after excluding those with more than three vehicles involved. We found 94,375 slight accidents, which corresponds to 72.5% of the total number of accidents with victims. Furthermore, there were 29,611 serious accidents (22.8%) and 6,158 fatal accidents (4.7%).

Table 1 shows that the most frequent types of traffic violations related to serious accidents are speed limit infringements (*Speed1* and *Speed2*). We also note that distraction or careless driving of one of the drivers is very frequently related to serious and fatal accidents (*Driving1*). Other violations with a remarkable frequency in serious or fatal accidents are: not having a driving license (*Licence1*), driving partially using the opposite lane (*Lane*) and violating stop sign (*Stop*). About 10% of all traffic accidents with victims do not have any associated traffic violation, in all levels of severity. (This means that the officer filling out the accident report form did not find any traffic violation.) Of course, some accidents may be caused by hazardous elements such as bad weather or defective conditions on the road.

Table 1
Percentage of accidents with victims in which a traffic violation was reported, by severity level

	Slight, n = 94,375	Serious, n = 29,611	Fatal, n = 6,158
No traffic violation	10.4%	10.6%	10.9%
Violations related to speed			
Speed1	22.9%	28.8%	32.1%
Speed2	4.0%	6.9%	13.9%
Speed3	0.3%	0.2%	0.4%
Administrative violations			
Licence1	5.2%	7.6%	8.8%
Licence2	0.4%	0.5%	0.6%
Weight	0.1%	0.2%	0.3%
Itv	2.5%	2.6%	3.6%
Tacograph	0.3%	0.4%	0.4%
Violations related to the driver			
Driving1	30.7%	31.5%	32.1%
Lights	0.1%	0.2%	0.2%
Forbidden	0.6%	0.8%	1.0%
Lane	3.6%	6.5%	11.0%
Bad turn	4.6%	4.6%	2.5%
Bad pass	3.0%	3.6%	3.8%
Zig-zag driving	0.1%	0.1%	0.1%
Security distance	5.6%	1.9%	0.7%
Braking	0.2%	0.1%	0.1%
Right of way	3.9%	3.3%	1.7%
Traffic-lights	2.9%	1.7%	0.6%
Stop	6.1%	6.1%	4.4%
Way	4.2%	1.9%	0.6%
Pedestrian crossing	1.8%	2.1%	0.9%
Traffic signs	0.4%	0.4%	0.6%
Manoeuvring	0.4%	0.2%	0.1%
Without care	1.1%	0.9%	0.4%
Dangerous parking	0.2%	0.2%	0.2%
Cyclers1	0.1%	0.1%	0.0%
Cyclers2	0.1%	0.1%	0.1%
Doors	0.5%	0.2%	0.1%
Others	17.5%	19.8%	23.8%

The total number of accidents with victims is 130,144. An accident is *slight* if victims suffered minor injuries not leading to hospitalization for more than 24 hours. An accident is *serious* if bodily injury for at least one victim led to hospitalization for more than 24 hours, and an accident is *fatal* if at least one victim died within 24 hours of accident occurrence.

An analysis of the simultaneous occurrence of traffic violations is presented in Table 2. As previously shown in Table 1, approximately 89.5% of accidents with victims involved *at least* one traffic violation. Table 2 shows that only one traffic violation occurred in 57.1% of traffic accidents with victims. In contrast, 27.8% of all accidents with victims involved two simultaneous traffic violations, 4.3% of accidents involved three traffic violations, and only 0.2% of accidents involved four or five traffic violations. From the description in Table 2 it follows that the severity of accidents with victims increases when the number of traffic

violations increases from one to five. The percentage of slight accidents diminishes with respect to the percentage of serious or fatal accidents as the number of traffic violations increases. For instance, when only one traffic violation has been reported, then 20.6% of accidents are serious and 3.5% are fatal. If we look at accidents where three violations have been reported, then the percentage of serious accidents increases to 29.4% and the percentage of fatal accidents increases to 8.8%. In the extreme case when five traffic violations have been reported, then 47.6% of such accidents are serious and 14.3% are fatal.

Table 2
Number of traffic violations reported in one accident (columns) by accident severity level (rows)

	Number of traffic violations reported in one accident						
	0	1	2	3	4	5	Total[a]
Slight accidents	9,854	56,387	24,476	3,465	185	8	94,375
% accidents	10.4	59.8	25.9	3.7	0.2	0.0	(72.5)
% traffic violations	72.1	75.9	67.6	61.8	58.7	38.1	
Serious accidents	3,137	15,321	9,399	1,647	97	10	29,611
% accidents	10.6	51.7	31.7	5.6	0.3	0.0	(22.8)
% traffic violations	23.0	20.6	25.9	29.4	30.8	47.6	
Fatal accidents	668	2,612	2,350	492	33	3	6,158
% accidents	10.8	42.4	38.2	8.0	0.5	0.1	(4.7)
% traffic violations	4.9	3.5	6.5	8.8	10.5	14.3	
Total[b]	13,659	74,320	36,225	5,604	315	21	130,144
	(10.5)	(57.1)	(27.8)	(4.3)	(0.2)	(0.0)	(100.0)

[a] Total number of accidents with victims by severity level. In parentheses below, percent of total number of accidents with victims.
[b] Total number of accidents by number of simultaneous traffic violations. In parentheses below, percent of total number of accidents with victims.

The results shown in Table 2 have encouraged us to use a causal model that can explain the effect of traffic violations on accident severity. Surprisingly, the distribution of the severity levels calculated for accidents with traffic violations is very similar to the distribution of accident severity levels when no traffic violations were reported. When there is at least one traffic violation the percent of slight accidents with victims is 72.6%, the percent of serious accidents is 22.7% and the percent of fatal accidents is 4.7%. This is statistically not different from the percents observed when there is no traffic violation, respectively 72.1%, 23.0% and 4.9%.

3.2. Estimation of a multinomial logistic regression model

Estimated coefficients for a multinomial logistic regression model of accident severity, where the reference category is "slight accident," are presented in Table 3. The first set of

parameters corresponds to the numerator of the probability that an accident with victims will be serious. The second set of parameters contains the numerator of the probability that an accident with victims will be fatal. P-values are also shown next to the parameter estimates.

Table 3
Multinomial logistic regression model for the severity of accidents with victims. Reference category is slight accident

Predictor	Serious accident, $y_{i1}=1$	Fatal accident, $y_{i2}=1$
	Parameter estimates	Parameter estimates
Intercept	-1.21***	-2.83***
Violations related to speed		
Speed1	0.30***	0.42***
Speed2	0.63***	1.39***
Speed3	0.04	0.54**
Administrative violations		
Licence1	0.36***	0.46***
Licence2	0.24**	0.36**
Weight	0.66***	1.32***
Itv	0.01	0.32***
Tacograph	0.04	0.19
Violations related to the driver		
Driving1	-0.03	-0.07*
Lights	0.48**	0.63*
Forbidden	0.16**	0.36***
Lane	0.46***	0.89***
Bad turn	0.00	-0.64***
Bad pass	0.15***	0.17**
Zig-zag driving	-0.04	-0.69
Security distance	-1.14***	-2.15***
Braking	-0.72***	-0.60
Right of way	-0.20***	-0.93***
Traffic-lights	-0.53***	-1.63***
Stop	-0.02	-0.38***
Way	-0.81***	-2.00***
Pedestrian crossing	0.14***	-0.76***
Traffic signs	-0.32***	-0.22
Manoeuvring	-0.95***	-1.69***
Without care	-0.21***	-1.05***
Dangerous parking	0.03	0.03
Cyclers1	-0.08	-0.37
Cyclers2	0.42*	0.78**
Doors	-0.77***	-1.99***
Others	-0.10***	-0.08**

*** p-value<0.01; ** p-value<0.05; * p-value<0.10

Parameter estimates should be interpreted as follows: a positive significant parameter indicates that the presence of the traffic violation increases the probability of an accident to be serious (or fatal) with respect to being slight. This means that the presence of the corresponding traffic violation increases the expected severity of the accident outcome.

Conversely, a negative significant sign diminishes the odds of a serious (or fatal) accident and increases the odds of a slight accident, therefore diminishing the severity level.

The Chi-squared statistical test rejects the null hypothesis of global parameter significance (p-value<0.01). The opposite of two times the log-likelihood increases to 9,572.20 from 4,339.87 with 60 degrees of freedom, when the absence of exogenous variables is imposed.

The significance of parameter estimates varies according to severity level. For instance, for serious accidents, most parameter estimates are significant at the 1%, 5% or 10% level. Nine coefficients are not statistically significant. When looking at the estimated parameters for the probability of a fatal accident, only six of them are not significantly different from zero.

Traffic violations related to excess speed significantly increase the odds of serious or fatal accidents versus a slight accident. Driving too slowly increases the odds of a fatal accident. However, the effect of driving too slowly on the odds of serious versus slight accidents is statistically indistinguishable.

Concerning administrative violations, we observe that not having the adequate driving licence or not having a valid driving license increases the probability of suffering a serious or fatal accident. The same interpretation holds for an excessive number of occupants or carrying too much weight. The absence of due inspection documents for the vehicle significantly increases the probability of a fatal accident as well. However, we do not find evidence that a non- revised tachograph (this only applies for certain large vehicles) increases probability of more severity.

Other violations such as incorrect use of vehicle lights, driving in the opposite direction, driving partially using the opposite late, and an incorrect vehicle pass are positively related to more severe accidents (that is, the associated parameter signs are positive and significant). Conversely, we find evidence of some opposite effects as well. For instance, all violations that are related to priority (with or without signs) or security distance seem to be associated with slighter accidents. Only a pedestrian crossing priority infringement increases the probability of a serious accident. We note that these types of traffic violations tend to occur in urban zones, and it is well documented that accident severity is lower in urban areas (DGT, 2005).

The presence of cyclists riding bicycles outside the lane marks notably increases the probability of a serious or fatal accident, whereas opening doors has the opposite effect. Other results from the analysis suggest that careless or distracted driving is more related to slight or

serious accidents than it is to fatal accidents, which has a significant negative parameter. No evidence was found of a relationship between accident severity level and forbidden parking or zig-zag driving.

The previous results allow us to predict the probability of each severity level (slight, serious or fatal) for an accident with victims given the traffic violations that occurred. More than one traffic violation can be considered in the prediction.

3.2. The economic cost of traffic violations

Table 4 shows the average number of victims resulting from accidents, calculated by both severity of accident and severity of bodily injury. The definitions of the severity of bodily injury are the same as those used for accidents, but are applicable to each individual in this case. A *slightly injured* individual suffered bodily injury requiring medical aid that did not exceed 24 hour of hospitalization. A *seriously injured* person had to stay in the hospital at least 24 hours as a result of the accident. A *fatality* is a person who died within 24 hours as a consequence of the accident. The third column of Table 4 shows the average cost per victim, estimated for each injury type. This information was obtained from specialized reports that analyzed Spanish data (Fundación RACC, 2007). Finally, the last column of Table 4 reports the expected average cost of an accident with victims by accident severity level, using the information on cost per victim and average number of victims as displayed in the previous two columns.

Table 4
Average number of victims, average cost per victim and estimated average cost of an accident, by severity level

Severity of accident	Average number of victims	Average cost per victim *		Estimated average cost of accident
Slight	1.47 slightly injured	Slightly injured:	34,160 Eur	50,215.2 Eur
Serious	1.20 seriously injured	Seriously injured:	121,925 Eur	164,073.5 Eur
	0.52 slightly injured	Slightly injured:	34,160 Eur	
Fatal	1.14 died	Dead:	558,990 Eur	714,949.6 Eur
	0.50 seriously injured	Seriously injured:	121,925 Eur	
	0.49 slightly injured	Slightly injured:	34,160 Eur	

* Data are taken from Fundación RACC (2007). The estimated final cost per victim takes into account direct and indirect costs as a consequence of the accident (emergency, rescue services, police assistance, medical aid, hospitalization, further consequences to the victim, lost human capital and damages derived from the accident).

The expected cost of traffic accidents with victims given the occurrence of some combination of traffic violations is presented in Table 5. The results are obtained in two steps.

In the first step, the multinomial logistic regression model is used to predict the probability that severity is slight, given that the accident has victims and one combination of traffic violations. Then, the probability that the accident is serious and the probability that it is fatal are calculated for the same combination of traffic violations. Given the large amount of possible combinations, we only present the results corresponding to the same combination of traffic violations. As a reference, we present the expected estimated cost of an accident with victims for the combination of traffic violations that leads to the maximum expected estimated cost. The last column presents the ratio between the maximum expected estimated cost for a given number of traffic violations and the expected estimated cost of an accident when there is no traffic violation.

The expected estimated cost of an accident with victims when no traffic violation is reported is above 100,000 Eur. This cost is the first figure shown in the sixth column of Table 5. This is used as a baseline to measure the impact of traffic violations on accident severity. Note that since some traffic violations are associated with small crashes, this baseline figure does not correspond to the minimum expected cost. The presence of traffic violations that reduce accident severity would decrease the expected estimated cost, which could have been used as a reference as well. For brevity, we have only shown the results for the baseline mentioned above, but similar conclusions can be drawn from the latter.

Table 5
Estimation of expected cost for an accident with victims depending on the number of traffic violations incurred. Maximum expected estimated cost

Number of reported traffic violations (1)	Type of traffic violations leading to maximum expected cost* (2)	Estimated probability of a slight accident given traffic violation in column (2) (3)	Estimated probability of a serious accident given traffic violation in column (2) (4)	Estimated probability of a fatal accident given traffic violation in column (2) (5)	Estimated expected cost given traffic violation in column (2) (6)	Ratio of estimated expected cost with respect to no traffic violations
0	-	0.74	0.22	0.04	104,307.3 Eur	1
1	*sv2*	0.56	0.31	0.13	173,912.0 Eur	1.67
2	*sv2-av3*	0.34	0.36	0.30	290,869.5 Eur	2.78
3	*sv2-av3-dv4*	0.21	0.35	0.44	385,125.1 Eur	3.69
4	*sv2-av3-dv4-dv20*	0.12	0.31	0.57	462,787.3 Eur	4.44
5	*sv2-sv3-av3-dv4-dv20*	0.08	0.23	0.69	532,309.7 Eur	5.10

* *sv2*: s*peed2*; *av3*: *weight*; *dv4*: l*ane*; *dv20*: *cyclers2*; *sv3*: *speed3*

Discussion

The cost of accidents depends quite substantially on the number of bodily injuries. In this work, we have focused only on collisions involving bodily injuries because the information on them is exhaustive. We classify accidents by three severity levels according to the condition of the resulting victims. We also estimate the cost per victim using external data.

We find evidence that some traffic violations are associated with a higher probability of serious or fatal accidents. In fact, for every possible combination of traffic violations, we can predict the probability that the accident is slight, serious or fatal. The most costly traffic violation by itself is exceeding the speed limit, which increases the expected cost of an accident by two-thirds, compared to accidents that do not involve any traffic violations.

The most serious combination of two traffic violations is excess speed and exceeding the number of occupants or the authorised maximum weight. The ratio of expected costs for this combination of traffic violations to the expected costs when there is no traffic violation is 2.78. This means that the cost of the accident in this case is almost three times the cost when no traffic violations are involved.

The most costly combination of three traffic violations is the previous two plus driving partially into the opposite lane. Having these three traffic violations together raises the expected cost of the accident dramatically to more than three times the expected cost when there is no traffic violation. Similar arguments follow for combinations of four or five traffic violations, but such cases are very infrequent.

The methodology proposed in this article can be applied to more severity levels and can accommodate different cost estimates. Our estimates of the cost per victim were very extensive because human capital loss was also considered.

One limitation of this study is that we did not consider accidents without victims because of the lack of public information on the cost of such accidents. Thus, we were unable to include accidents involving physical damage to objects, vehicles or buildings only in the analysis. However, in aggregate terms, the cost of these accidents is on average much less than the accidents that result in bodily injury. Moreover, we could also say that since no bodily injury results from accidents without victims, then the cost of those accidents on human victims is zero. Another limitation in the models that were used here is that we did not include interaction terms. We wanted to keep the specification as clear as possible. We also deliberately did not include information on the accident other than the presence or absence of

the types of traffic violations considered here. We did not want to take into account age of drivers or number of occupants, which would probably increase the prediction power. In fact, we wanted to avoid those in order to derive the net direct effect of the traffic violations. This effect should not be blurred by correlations between the type of drivers that incur certain traffic violations (e.g., young drivers who drive too fast), inducing multicollinearity in the regression model.

Our results can be used to establish a link between the cost of accidents with victims and the penalty associated with traffic violations. In the Spanish system, drivers can be penalized by a reduction in the number of points. If all points are lost, the driving license is discontinued. Exceeding the number of occupants is not among the traffic violations that are most highly penalized with points in the Spanish system. The maximum penalty for any violation is six points, whereas this traffic violation is penalized with four points. Yet the empirical results show that if combined with too much speed, an excessive number of occupants or too much weight causes much higher expected costs in accidents with victims. Therefore, it would be recommended to increase the penalty for excessive occupants, at least when occurring together with speed limit infringements. In addition, our results show that exceeding the number of occupants (or weight) alone is the second most dangerous traffic violation, next to driving too fast. This also suggests that regulators should consider raising the penalty for such violations. Finally, we would like to stress that penalizations of traffic violations do not necessarily address the economic cost of accidents. Because they have a deterrence effect on drivers, penalties are used for preventive purposes. In that context, it seems unreasonable that the occurrence of more than one traffic violation would lead to a penalty that is more than the sum of the penalties for every traffic violation. Our model results suggest that in terms of the expected cost of accidents with victims, there is a joint effect of more than one traffic violation that can be measured and can help regulators to refine penalty systems and prevention campaigns.

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