Journal of Infrastructure, Policy and Development (2020) Volume 4 Issue 2.
DOI: 10.24294/jipd.v4i2.1163

ORIGINAL ARTICLE

For whom the bell tolls: Road safety effects of tolls on uncongested SCUT highways in Portugal[†]

Alfredo Marvão Pereira[1*], Rui Marvão Pereira[1] and João Pereira dos Santos[2]

[1] *Department of Economics, William & Mary, Williamsburg, Virginia, USA*

[2] *Nova School of Business and Economics, Faculdade de Economia, Nova University Lisbon, Lisbon, Portugal*

ABSTRACT

We present a difference-in-differences analysis of the road safety effects of introducing tolls on SCUT highways in Portugal, a policy motivated purely by financial considerations, as congestion was never an issue. Using negative binomial count models and a comprehensive dataset on all mainland municipalities covering 2008 to 2014, we find that introducing tolls led to an increase in the total numbers of accidents and road injuries in municipalities where SCUT highways are located. Additionally, we register a change in the composition thereof, with fewer occurrences on highways (including on SCUT highways) and an increase on national and other roads. Finally, we find that most effects pertained to light injuries. No statistically significant effects were identified for fatal or serious injuries. Furthermore, as a result of introducing tolls on SCUT highways, we estimate that around 20% of the toll revenue collected is lost on the costs linked to road accidents. This questions the rationale of introducing such tolls, even from a revenue-raising standpoint.

***Keywords**: road safety; accident; injury; toll; difference-in-differences; SCUT; Portugal*

1. Introduction

Modern road networks are designed for better transportation, to reduce congestion and travel times, to improve road safety, and, more generally, to promote economic and social development (for a comprehensive review of the nature and magnitude of externalities linked to the use of automobiles, see Parry *et al.* (2007)).

This article focuses on Portugal and aims to identify how introducing tolls on SCUT highways affected road safety at the municipal level. This change in pricing the use of roads was motivated not by congestion but rather by the need to raise revenue.

The Portuguese SCUT highway network was conceived in the mid-1990s as a system designed, built, operated, and later maintained by public-private partnerships. Concessions would be granted revenues from "shadow tolls", i.e., transfers from the public budget, based on

ARTICLE INFO
Received: March 9, 2020
Accepted: November 25, 2020
Available online: December 31, 2020

*CORRESPONDING AUTHOR
Alfredo Marvão Pereira, Department of Economics, William & Mary, Williamsburg, Virginia, USA; ampere@wm.edu

CITATION
Pereira AM, Pereira RM and dos Santos JP (2020). For whom the bell tolls: Road safety effects of tolls on uncongested SCUT highways in Portugal. *Journal of Infrastructure, Policy and Development*, 4(2): 287–305. doi: 10.24294/jipd.v4i2.1163

[†] The authors would like to thank Luís Catela Nunes, José Tavares, Pedro Portugal, Ernesto Freitas, and participants of the Young Economist's Meeting and the Annual Meeting of the Portuguese Economic Journal for very helpful comments and suggestions, as well as Pedro Rodrigues for very effective editorial support. The usual disclaimers apply.

the volume of road traffic. This led to the acronym SCUT (Sem Custo para o Utilizador, which translates as "Without Cost for the User"). At a total cost equivalent to 2.65% of GDP in 1999, the year in which construction work started (Pereira and Andraz, 2006), the resulting SCUT system—consisting of seven individual highways—accounts for about 987 km, representing 36% of the overall highway network extension in Portugal at the time it was concluded in 2008 (Instituto Nacional de Estatística (INE), 2008).

One of the arguments presented for developing this new highway network was to shift traffic away from older and rather deteriorated alternative roads, thereby contributing to significantly improve road safety. New roads would embody new building techniques and more up-to-date engineering technologies, which would make travel not only faster but, more importantly from our standpoint, safer. Despite the expected increase in traffic induced by the availability of new highways and the higher speeds practiced thereon, the significant amount of traffic diverted from alternative riskier routes would lead to increased overall road safety.

Indeed, for the four of the seven SCUT highways which were the object of formal cost-benefit analyses—Beira Interior, Interior Norte, Beiras Litoral and Alta, and Grande Porto (Pereira, Pereira and Andraz, 2010)—the benefits of improved road safety accounted respectively for 19.7%, 37.6%, 16.9%, and 33.2% of the total benefits. Accordingly, the benefits from road safety improvements had more than a marginal role in the drive to create these highways.

While the SCUT highways were initially toll-free, this has since changed. In the aftermath of the financial and sovereign debt crises, beginning in 2010, the Portuguese government was forced to significantly step up and accelerate the country's efforts to consolidate its public finances. It therefore comes as no surprise that, with the intent to raise public revenues, it became politically expedient to convert the system of shadow tolls on the SCUT highways to a system of real tolls,[1] with tolls introduced in two different waves, first in late 2010 and then in late 2011. By 2011, all seven SCUT highways had become "former SCUT highways". It is worth stressing that the only purpose of this change in policy was to raise public revenues. Congestion was never an issue. The implications of introducing tolls on the use of the SCUT highways and on the possible diversion of traffic to alternative riskier roads were effectively absent from the public debate.

After 2008, and until 2014, the period that is relevant for this paper, there have been major changes in traffic patterns in Portugal. First, there was a significant decline in road traffic, induced in good part by the macroeconomic slowdown, a decline that becomes more pronounced with the introduction of tolls on the SCUT highways (Unidade Técnica de Acompanhamento de Projectos (UTAP), 2015). More significantly, there has been a major decline in the use of SCUT highways with the respective traffic diverted to alternative roads. By 2014, traffic levels on SCUTs were down to just 56% of their 2010 counterparts, while traffic intensity on alternative older toll-free roads increased by 2% (Dias, 2015).

This begs the question of how much of this return to the intensive use of old alternative roads has translated into more road accidents and fatalities. This article sketches an answer, using a difference-in-differences approach (for a similar econometric approach, see, for example, Currie and Walker

---

[1] See Pereira and Andraz (2010) for a discussion on the economic and budgetary effects of the SCUT freeways and an early argument against the introduction of such tolls.

(2011) and Green *et al.* (2014, 2016)). We consider different types of road safety data for the period of 2008 through 2014 for the 278 municipalities in Portugal, of which 59 host SCUT highways.

By 2008, all SCUT highways were in full operation without tolls. At the end of 2011, tolls had been introduced on all SCUT highways. Introducing these tolls provides a natural experiment, allowing us to determine to what extent road safety evolved differently in the municipalities with and without the SCUT highways after the introduction of such tolls.

This approach is based on a conceptual framework in which commuters have preferences defined over alternate routes. Each route has a set of characteristics, which include the time from the origin to destination, road safety, as well as other user costs, including fuel costs and vehicle maintenance costs. These, in turn, depend on the quality of the road, such as the type and quality of pavement, the terrain, traffic levels, and the speed at which vehicles are traveling. The commuters' choice is affected by the condition of the roadway alternatives, including the road safety characteristics of each road.

The introduction of tolls on the roadways constitutes a direct cost for users and, as such, affects the choice between alternative roads. In turn, shifts in the commuter's choice are reflected in a change in the accident rate and their severity. On highly congested roadways, the introduction of tolls can internalize the negative externalities associated with high levels of traffic volume, alleviating the adverse effects of each driver on commute time and reducing accident rates (see, for example, Li *et al.* (2012)). On the other hand, the presence of tolls on non-congested highways may divert traffic to alternate roadways, overburdening the existing network and increasing traffic and accidents (see, for example, Albalate (2011) and Albalate and Bel (2012)). Our analysis in this article focuses on the introduction of tolls on uncongested roadways.

The remainder of this paper is organized as follows: Section 2 presents the basic data and their sources. Section 3 presents the methodology used and Section 4 discusses our central results. Section 5 summarizes and concludes.

2. Empirical approach, data on road safety, and control data

2.1. Empirical approach

We estimated a difference-in-differences model for the effects of tolls on road safety. The great appeal of a difference-in-differences estimation comes from its potential to circumvent many of the endogeneity problems that typically arise when making comparisons between heterogeneous individuals.

Our identification strategy rested on the fact that the decision to introduce tolls on the former SCUT highways was political in nature and was decided at the national level, i.e., without direct involvement of the municipalities that were affected. Thus, introducing tolls on these specific roadways was orthogonal to both the number and the severity of road accidents and further allowed us to identify the effect of tolls on road safety. This addresses a common criticism of traffic safety studies, particularly in cases where interventions that affect safety are implemented because there is a safety problem in the first place. Estimates examining these sorts of interventions most likely suffer from endogeneity biases. In our analysis, however, the introduction of tolls on these roads was motivated by purely political and financial reasons at an aggregate level, thus dismissing these possible issues.

Our unit of analysis was the municipality. This allowed us to observe the net effect of traffic diverted from highways to secondary roads within the municipality, and the subsequent effects on overall road safety, while controlling for differences in speed, enforcement of drunk driving, seatbelt, and mobile phone restrictions, as well as road conditions in the neighboring area.

There are 278 municipalities in continental Portugal, with an average size of 127 square miles per municipality. For each SCUT, **Table 1** identifies all of the municipalities it crosses, and **Figure 1** displays the geographical distribution of municipalities where the SCUT highways are located.

The treatment group consisted of the 59 municipalities which have a segment of the SCUT highway network. Between 2008 and 2010, none of the SCUT highways had direct user costs. Between 2010 and 2011, tolls—the treatment—were introduced on each of the seven SCUT highways. The post-treatment period was defined accordingly. For the municipalities where the introduction of tolls occurred on October 15th, 2010, the post-treatment dummy equals 1 from 2011 onwards. Similarly, for the routes where the introduction of tolls happened on December 8th, 2011, the post-treatment dummy equals 1 in 2011, 2013, and 2014.

Our control group consisted of the remaining 219 municipalities in Portugal. The highways in these municipalities are in large part tolled highways. The secondary network of national and municipal roads is not tolled. The change in the number and severity of accidents after the

Table 1. Municipalities affected by the introduction of tolls on SCUT highways

Highway	Affected Municipalities
Tolls introduced on October 15th, 2010	
SCUT Grande Porto – 79 km	
A4: AE Transmontana	Matosinhos, Maia
A41: CREP - Circular Regional Exterior do Porto	Matosinhos, Valongo, Santa Maria da Feira, Espinho
A42: AE Douro Litoral	Valongo, Paços de Ferreira, Paredes, Lousada
SCUT Litoral Norte – 113 km A28	Matosinhos, Vila do Conde, Póvoa de Varzim, Esposende, Viana do Castelo, Caminha
SCUT Costa da Prata – 110 km A29	Estarreja, Ovar, Espinho, Vila Nova de Gaia
Tolls introduced on December 8th, 2011	
SCUT Algarve – 133 km A22	Lagos, Monchique, Portimão, Lagoa, Silves, Albufeira, Loulé, Faro, Olhão, Tavira, Castro Marim, Vila Real de Sto. António
SCUT Beira Interior – 217 km A23	Torres Novas, Entroncamento, Constância, Abrantes, Mação, Gavião, Vila Velha de Rodão, Vila Nova da Barquinha, Castelo Branco, Fundão, Belmonte, Covilhã, Guarda
SCUT Interior Norte – 162 km A24	Viseu, Castro Daire, Lamego, Peso da Régua, Vila Real, Vila Pouca de Aguiar, Chaves
SCUT Beiras Litoral e Alta – 173 km A25	Ílhavo, Aveiro, Albergaria-a-Velha, Sever do Vouga, Oliveira de Frades, Vouzela, Viseu, Mangualde, Fornos de Algodres, Celorico da Beira, Guarda, Pinhel, Almeida

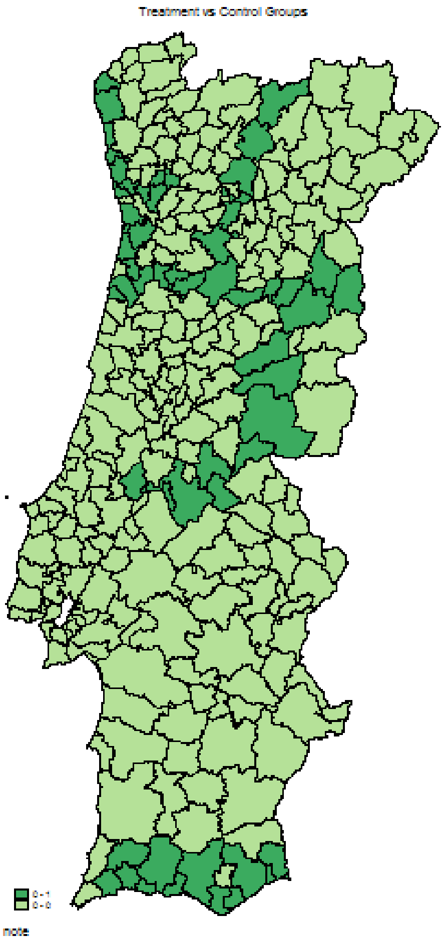


Figure 1. Municipalities affected by SCUT highways.

introduction of tolls is thus the result of traffic diverted from the SCUT highways.

2.2. Road safety data

Data covers all of the 278 municipalities of continental Portugal for a period of seven years, from 2008 to 2014, for a total of 1946 observations. Data for the number of accidents[2] and the number of victims are from the Instituto Nacional de Estatística and Autoridade Nacional da Segurança Rodoviária. This data set includes the total number of accidents, as well as the number of victims, and allocates these figures among accidents or victims by type of roads: on highways, on national roads, and on all other roads. It also includes the decomposition of the number of victims among minor injuries, serious injuries, and deaths.[3] The summary statistics for the whole sample period are presented in **Table 2**.

Between 2008 and 2014, however, the macroeconomic situation in Portugal deteriorated sharply as a result of the sovereign debt crisis the country experienced. The high levels of unemployment

---

[2] A road accident is characterized as a random, sudden, and abnormal event on a public road as a consequence of motor vehicle circulation, resulting in victims or material damage, regardless of whether the vehicle is moving or not (including when entering or exiting the vehicle and/or when the vehicle is being repaired).

[3] A serious injury is defined as injuries requiring a period of hospitalization longer than 24 hours and that the victim survives within 30 days after the accident.

and the lower income levels reduced traffic volumes across the country. The number of accidents fell from 33,613 to 30,566 between 2008 and 2014.

Similarly, the number of victims fell from 44,709 to 39,653. To ascertain that our results are not

Table 2. Municipalities affected by the introduction of tolls on SCUT highways

Variable (No.)	**Obs.**	**Mean**	**Std. Dev.**	**Min.**	**Max.**
Total Accidents	1946	117.1	194.8	0	2457
Accidents on Highways	1946	8.2	20.2	0	213
Accidents on National Roads	1946	27.4	29.5	0	193
Accidents on Other Roads	1946	81.4	169.1	0	2382
Total Victims	1946	154.1	243.6	0	3042
Victims on Highways	1946	12.4	28.8	0	305
Victims on National Roads	1946	39.1	42.1	0	279
Victims on Other Roads	1946	102.6	206.8	0	2939
Total Victims	1946	154.1	243.6	0	3042
Minor Injuries	1946	143.2	232.8	0	2918
Serious Injuries	1946	8.2	10.3	0	132
Fatalities	1946	2.7	3.3	0	29

Table 3. Definition of control variables

Variable	**Operational Description**	**Data source**
Population	Total number of citizens inhabiting a given municipality.	INE
Unemployment rate	Percentage of registered unemployed in working-age municipal population.	IEFP
Population Above 65	Percentage of individuals above 65 years old in municipal population.	INE
Sales Index	Index that takes into account both population and wealth in each municipality, as well as indicators such as fiscal burden, electricity consumption, number of cars sold, number of bank agencies, and number of retail commercial establishments.	Marktest
Total Urban Area	Percentage of municipal area allocated for urban usage according to the official Municipal Spatial and Land Use Plan.	DGOTDU
Highways Dummy	Binary variable that takes the value one if there is a highway crossing the municipality.	ANSR

Sources: INE (Statistics Portugal); IEFP (Instituto de Emprego e Formação Profissional - National Employment Agency); Marktest, a private company that builds indicators for Portuguese municipalities; DGOTDU (Direção Geral Do Ordenamento do Território), department for geographical planning; and ANSR (Autoridade Nacional de Segurança Rodoviária), government agency for road security driven by these explanations, we introduce a vector of time-variant controls to mitigate endogeneity concerns.

2.3. Data for control variables

For robustness, the analysis relied on a number of control variables. The vector of controls included measures of municipal population size, demographic structure, land use, and municipal economic activity. Indeed, models for traffic safety have identified economic factors, legislation, social stress, the age of drivers, and fuel prices as important determinants of traffic injuries and fatalities (see, for example, Van den Bossche and Wets (2003)). **Table 3** provides details on each of the control variables, including their definition and source.

To capture possible nonlinearities between road casualties and population, we included the number of inhabitants in the municipality and the value squared. We also added the unemployment rate in the region. Using U.S. data covering the period 1976–2010, Ruhm (2015) found a pro-cyclical relationship between the unemployment rate and transport accidents. In addition, we controlled for the demographic structure of the population comprising the share of the population above 65 years old.

In the absence of relevant data at the municipal level, as a proxy of municipal income and purchasing power, we used the Sales Index computed by Marktest, as proposed by several papers studying local political business cycles in Portugal (see, for example, Martins and Veiga (2014)).

In addition, Ossenbruggen *et al.* (2001), Noland and Quddus (2004), and Kmet and MacArthur (2006) suggested that land use and intensity of urbanization can have an effect on traffic-related injuries. We accounted for these effects by including the percentage of the municipal area for urban usage.

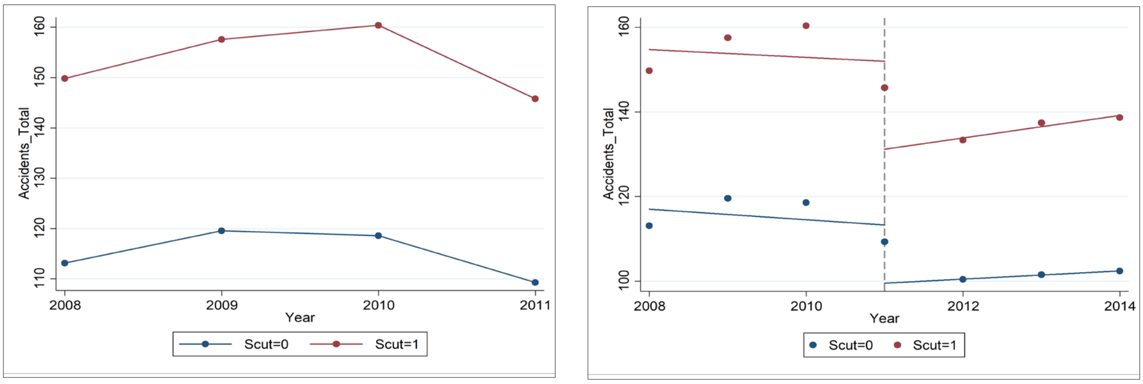
Finally, we included a dummy variable to take into consideration the existence of at least one highway (SCUT or otherwise) in a given municipality. This was done to make sure that we were comparing municipalities with better access in a consistent manner.

3. Preliminary results and empirical model

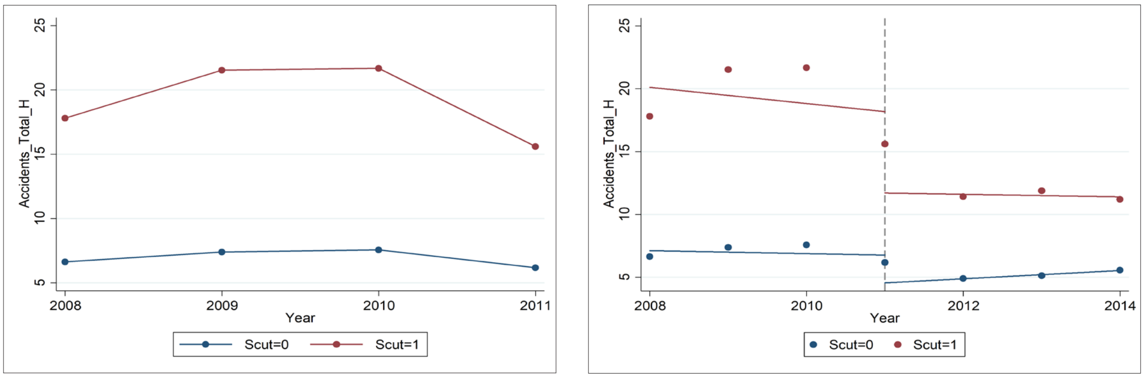
3.1. Preliminary results: Parallel trends

The internal validity of a difference-in-differences framework relies on the parallel-trend assumption. In short, the trend in each of the dependent variables considered must be the same for all municipalities in the absence of treatment. This assumption can be tested using different techniques. For the purpose at hand, one common approach is to compare the evolution of the different outcome variables in the treated and control municipalities during the pre-treatment period, i.e., 2008 to 2011 (Angrist and Pischke, 2008), as shown in **Figure 2** to **Figure 4**.

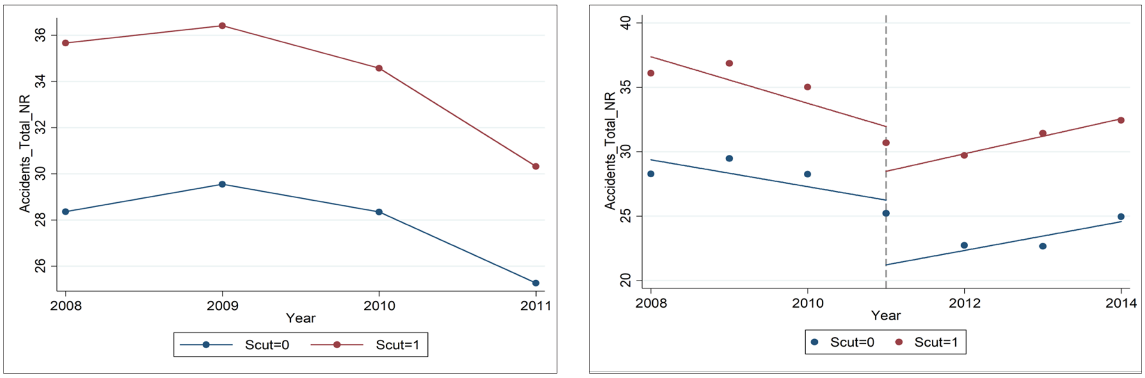
With the exception of the initial distinct trends in the number of deaths, the graphs do not provide substantive evidence of differential trends between the treatment and control local authorities that is capable of compromising our empirical approach. For all the remaining variables, difference-in-differences estimates were assumed to detect the causal effect of treatment.



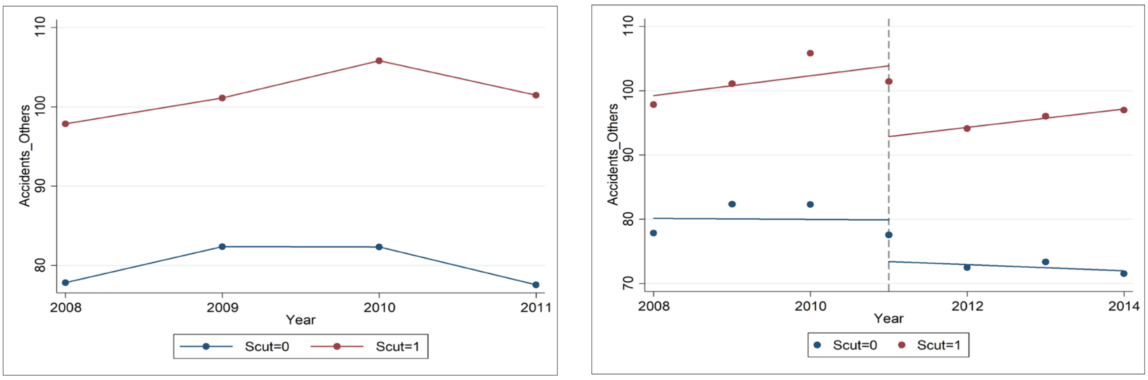
Total no. of accidents



Accidents on highways

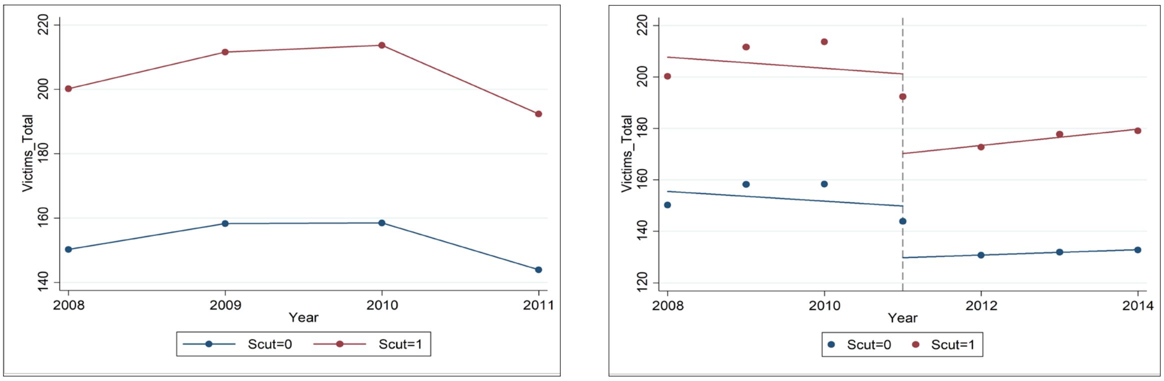


Accidents on national roads

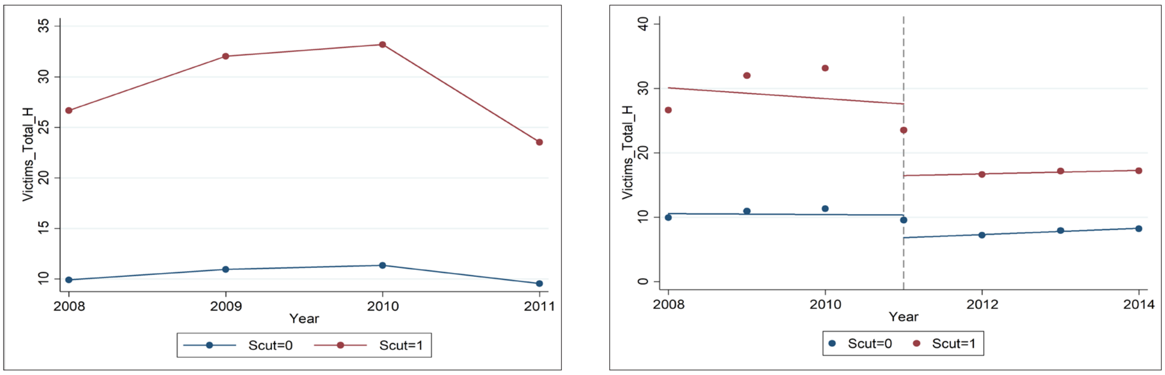


Accidents on other roads

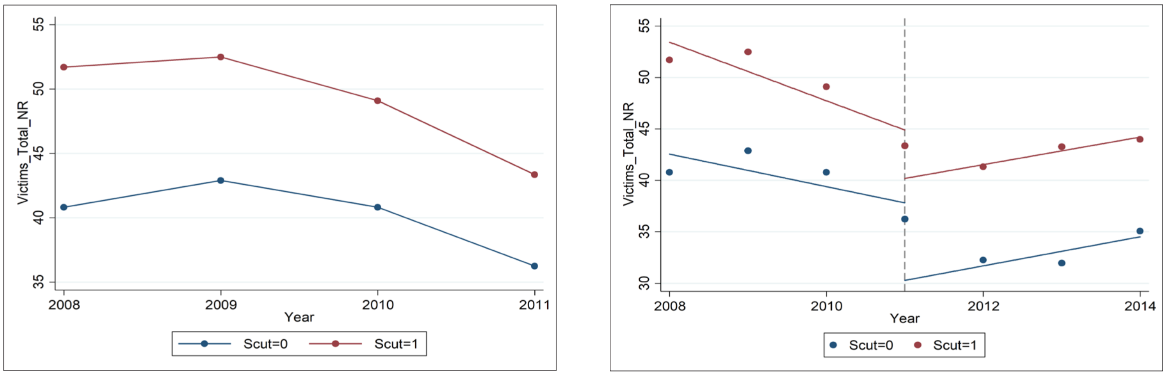
Figure 2. Accidents per type of road.



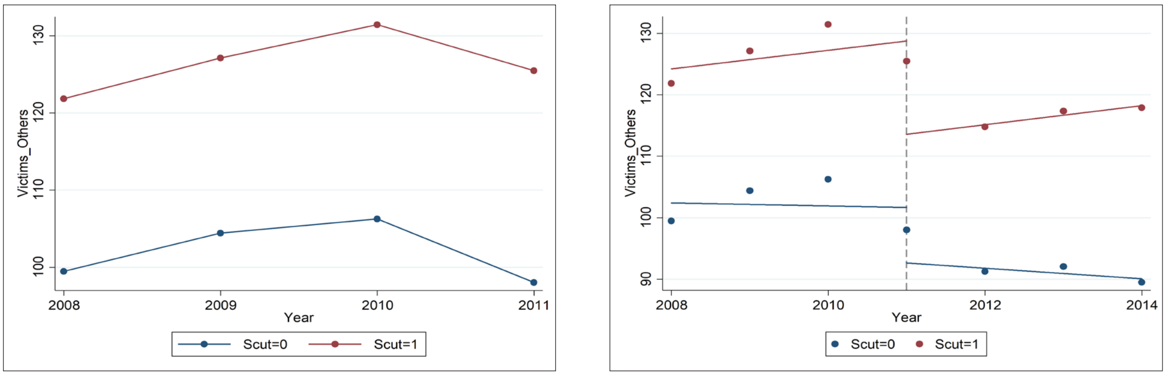
Total no. of victims



Victims on highways

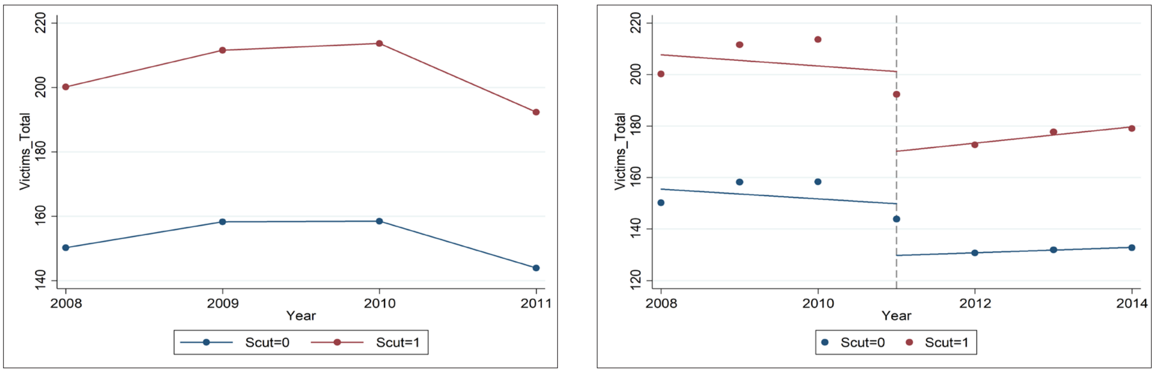


Victims on national roads

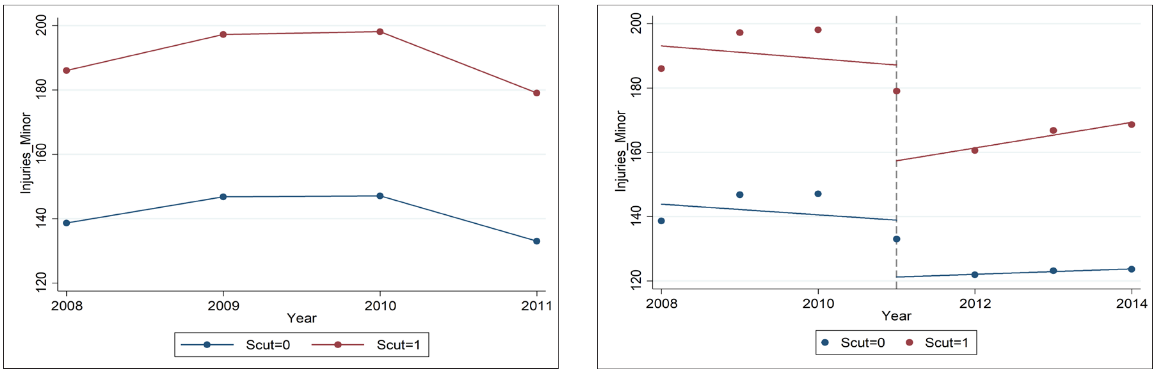


Victims on other roads

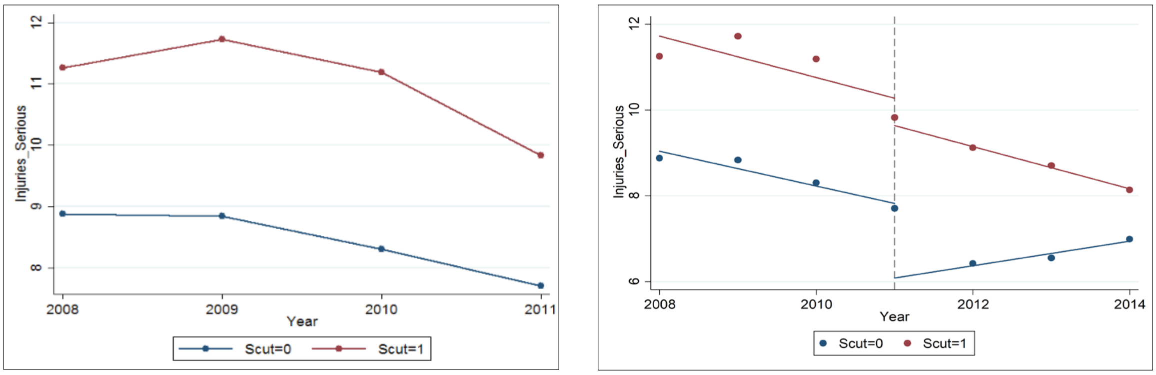
Figure 3. Victims per type of road.



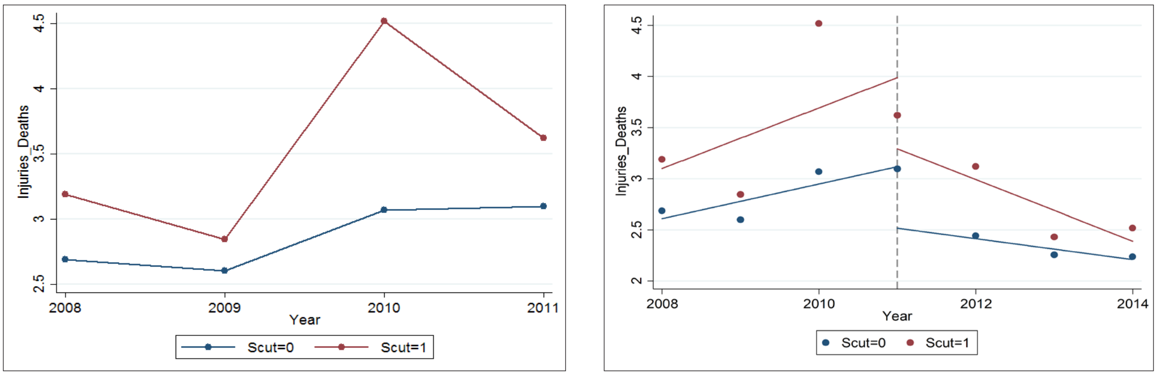
Total no. of victims



Minor injuries



Serious injuries



Fatalities

Figure 4. Victims per type of injury.

3.2. Econometric model

We estimate difference-in-differences models as follows:

$$y_{it} = \beta_0 + \gamma_t + \delta_1 Scut \cdot dT_i + \alpha_i + \beta_1 X_{it} + e_{it} \quad (1)$$

The dependent variables for municipality i in year t are 1) the number of accidents (on highways, national roads and all other roads), 2) the total number of victims (on highways, national roads and all other roads), and 3) the total number of victims (minor and major injuries, and deaths).

 is a binary variable that is 1 for the treatment group, is a binary variable that takes the value 1 for the post-treatment period, and is the variable of interest. are year fixed effects, and are municipal fixed effects (Guimarães, 2008).

The difference-in-differences is appropriate when interventions are random, conditional on time and group fixed effects. Therefore, much of the debate around the validity of a difference-in-differences estimate typically revolves around the possible endogeneity of the interventions themselves. We dealt with this possible concern by checking the common trends assumption as in the previous section and by conditioning our results on the vector of municipal controls,.

Count regression methods, such as Poisson or negative binomial models, are routinely used to estimate cross-sectional and panel data on accidents (see, for example, Lord *et al.* (2005)). The Poisson distribution assumes that the mean and variance are the same. In cases of overdispersion, as is our case, the negative binomial is more flexible given that its distribution has one more parameter than the Poisson regression, which adjusts the variance independently from the mean (see, for example, Noland and Quddus (2004), Haynes *et al.* (2007), and Wang *et al.* (2009), and Green *et al.* (2016)).

In this section, we present the negative binomial results for the total number of accidents and victims. In both cases, we consider the total number as well as the decomposition per type of road: on highways (of which the SCUTs are a part), on national roads, and on all remaining roads (including municipal roads). All regressions included the computation of the incidence rate ratio at the end for a more direct interpretation of the results. This ratio indicates how changes in the variable of interest affect the rate at which the dependent variable occurs. For instance, an incidence rate ratio of 0.7 means that those who were treated will have 0.7 times the incident events as those that were not. Robust standard errors were clustered per municipality, as proposed by Bertrand *et al.* (2004).

For each dependent variable, we present two regression outputs. The first included municipal and year fixed effects to the difference-in-differences interaction, while the second added the vector of controls previously described.

The results remain robust after the introduction of the vector of regional control variables. In the large majority of the following specifications, the share of individuals above 65 years old and the percentage of urban area appear to have a consistently significantly positive effect on the counts. Regarding the other controls, they are, in general, insignificant.

4. Empirical results

4.1. Effects of tolls on the number of accidents and number of victims

Table 4 shows that the introduction of tolls on the SCUTs has increased the number of accidents. When comparing with control municipalities, the number of total accidents in the treatment group is 4% higher after the introduction of tolls. Moreover, this is the case for all types of roads, except highways. In fact, we observe that accidents on highways in the municipalities with SCUT highways decreased by between 21.1% and 16.4% after the introduction of tolls, while accidents on both national roads increase by between 9.0% and 7.2%, and accidents on other roads increase by between 7.6% and 7.7%.

The same is true for the number of victims. **Table 5** suggests that SCUT municipalities in the treatment period had a 3% to 3.4% increase in the number of total victims vis-à-vis its control counterparts after the introduction of the tolls. Here again, this reflects a decline between 27.2% and 22.4% in highways and an increase of 10.6% to 9.2% for national roads and 7.5% and 7.3% for other roads.

In both cases, therefore, there is evidence pointing towards the fact that the introduction of tolls in the SCUTs changed the composition of the number of accidents and the number of victims away from highways to other types of roads. One should notice that while not all highways are SCUTs, all SCUT roads are highways, and all alternative routes are national roads. This reinforces the interpretation of the effects as being caused by the introduction of tolls.

4.2. Effects of tolls on the number of victims by type of injury

We look now more carefully at the total number of victims, considering minor and serious injuries, and deaths. The results are presented in **Table 6**. The effect of introducing tolls on SCUTs is only statistically significant for minor injuries, a result that remains robust with controls. Specifically, we estimate an increase of between 3.9% and 3.5% in minor injuries in the treatment municipalities after the introduction of tolls. This is consistent with accidents in alternative roads being caused by increased congestion or other lower-speed hazards. Finally, the number of serious injuries and deaths do not seem to be affected by the introduction of tolls.

4.3. Robustness checks

One usual way to run placebo tests for difference-in-differences consisting of re-estimating the model relying on a placebo treatment set in a fake treatment year. In our case, the sample was restricted to the pre-treatment period, i.e., 2008–2010, and the regression model was re-estimated with placebo treatment setting in 2009 for the first SCUT municipalities and in 2010 for all of them. As **Table 7** shows for our key dependent variables, estimates are close to zero and always insignificant, thereby dismissing concerns of possible selection bias.

5. Summary and concluding remarks

This paper analyzes the effects on road safety of the politically driven introduction of tolls on the uncongested Portuguese SCUT highways. The policy relevance of this issue is clear. If a significant effect on the deterioration of road safety of the introduction of tolls on the former SCUT highways

Table 4. - Accidents per road type

	Accidents– Total	**Accidents– Total**	**Accidents– Highways**	**Accidents– Highways**	**Accidents– National Roads**	**Accidents– National Roads**	**Accidents– Other Roads**	**Accidents– Other Roads**
Interaction	0.039**	0.039***	–0.225***	–0.179***	0.086**	0.070**	0.073***	0.074***
	(0.016)	(0.015)	(0.067)	(0.062)	(0.035)	(0.035)	(0.020)	(0.019)
Population		0.001		0.000		0.005**		0.001
		(0.001)		(0.001)		(0.002)		(0.000)
Population_ Squared		–0.000*		–0.000		–0.000**		–0.000
		(0.000)		(0.000)		(0.000)		(0.000)
Unemployment Rate		0.193		2.447		0.642		–0.021
		(0.599)		(1.800)		(1.044)		(0.827)
Population Above 65		5.404***		11.683***		9.309***		3.085**
		(0.997)		(3.843)		(2.128)		(1.257)
Sales Index		0.003		0.020		0.015		0.006
		(0.007)		(0.013)		(0.024)		(0.008)
Total Urban Area		0.004*		0.004		–0.023		0.008**
		(0.002)		(0.010)		(0.016)		(0.004)
Highways Dummy		0.079		16.613***		-0.035		0.047
		(0.053)		(0.418)		(0.075)		(0.064)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipal Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
/lnalpha	–5.880***	–6.368***	–3.750***	–4.170***	–4.185***	–4.413***	–5.395***	–5.563***
	(0.150)	(0.209)	(0.252)	(0.442)	(0.337)	(0.327)	(0.211)	(0.257)
Observations	1 946	1 946	1 946	1 946	1 946	1 946	1 946	1 946
Adjusted R^2	0.387	0.392	0.457	0.472	0.306	0.312	0.382	0.384
BIC	13 810	13 729	6 408	6 222	11 746	11 712	12 895	12 911
Incidence Rate Ratio								
Interaction	1.040**	1.040***	0.789***	0.836***	1.090**	1.072**	1.076***	1.077***

Note: Standard errors in brackets are clustered at the municipal level and robust to heteroscedasticity. Stars indicate significance levels of 10% (*), 5% (**), and 1% (***).

Table 5. Victims per road type

	Victims–Total	**Victims–Total**	**Victims–Highways**	**Victims–Highways**	**Victims–National Roads**	**Victims–National Roads**	**Victims–Other Roads**	**Victims–Other Roads**
Interaction	0.033*	0.030*	-0.317***	-0.254***	0.101***	0.088**	0.072***	0.070***
	(0.018)	(0.018)	(0.086)	(0.080)	(0.037)	(0.038)	(0.022)	(0.021)
Population		0.000		–0.001		0.005*		0.000
		(0.001)		(0.002)		(0.003)		(0.000)
Population_Squared		–0.000		0.000		–0.000**		–0.000
		(0.000)		(0.000)		(0.000)		(0.000)
Unemployment Rate		0.102		1.149		0.146		0.296
		(0.583)		(2.271)		(1.036)		(0.858)
Population Above 65		3.709***		15.200***		6.592***		1.443
		(1.048)		(4.659)		(2.340)		(1.320)
Sales Index		0.006		0.022		0.013		0.007
		(0.009)		(0.019)		(0.030)		(0.009)
Total Urban Area		0.007***		0.021		–0.001		0.007***
		(0.002)		(0.018)		(0.006)		(0.002)
Highways Dummy		0.036		18.169***		–0.046		–0.014
		(0.060)		(0.436)		(0.078)		(0.078)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipal Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
/lnalpha	–4.836***	–4.958***	–2.253***	-2.409***	–3.248***	–3.307***	–4.543***	–4.582***
	(0.112)	(0.128)	(0.150)	(0.151)	(0.155)	(0.150)	(0.135)	(0.145)
Observations	1 946	1 946	1 946	1 946	1 946	1 946	1 946	1 946
Adjusted R^2	0.340	0.342	0.388	0.405	0.263	0.265	0.346	0.347
BIC	15 543	15 550	7 629	7 665	13 485	13 499	14 239	14 277
Incidence Rate Ratio								
Interaction	1.034*	1.030*	0.728***	0.776***	1.106***	1.092**	1.075***	1.073***

Note: Standard errors in brackets are clustered at the municipal level and robust to heteroscedasticity. Stars indicate significance levels of 10% (*), 5% (**), and 1% (***).

Table 6. Victims per type of injury

	Victims–Total	**Victims–Total**	**Injuries–Minor**	**Injuries–Minor**	**Injuries–Serious**	**Injuries–Serious**	**Deaths**	**Deaths**
Interaction	0.033*	0.030*	0.037**	0.034*	0.003	–0.002	–0.088	–0.082
	(0.018)	(0.018)	(0.019)	(0.018)	(0.050)	(0.052)	(0.067)	(0.068)
Population		0.000		0.000		0.002*		–0.001
		(0.001)		(0.001)		(0.002)		(0.002)
Population_Squared		–0.000		–0.000		–0.000		–0.000
		(0.000)		(0.000)		(0.000)		(0.000)
Unemployment Rate		0.102		0.041		0.753		2.217
		(0.583)		(0.611)		(1.397)		(2.015)
Population Above 65		3.709***		4.399***		0.009		–1.298
		(1.048)		(1.042)		(3.227)		(4.045)
Sales Index		0.006		0.005		0.009		–0.022
		(0.009)		(0.009)		(0.014)		(0.021)
Total Urban Area		0.007***		0.008***		–0.002		–0.015*
		(0.002)		(0.002)		(0.005)		(0.009)
Highways Dummy		0.036		0.047		–0.055		–0.096
		(0.060)		(0.062)		(0.083)		(0.144)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipal Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
/lnalpha	–4.836***	–4.958***	–4.828***	–4.971***	–3.411***	–3.446***	–4.479***	–4.973***
	(0.112)	(0.128)	(0.108)	(0.123)	(0.174)	(0.181)	(0.808)	(1.484)
Observations	1 946	1 946	1 946	1 946	1 946	1 946	1 946	1 946
Adjusted R^2	0.340	0.342	0.343	0.345	0.274	0.275	0.259	0.260
BIC	15 543	15 550	15 276	15 272	8 976	9 024	6 358	6 404
Incidence Rate Ratio								
Interaction	1.034*	1.030*	1.039**	1.035*	0.998	0.998	0.915	0.921

Note: Standard errors in brackets are clustered at the municipal level and robust to heteroscedasticity. Stars indicate significance levels of 10% (*), 5% (**), and 1% (***).

Table 7. - Accidents and victims: Placebo results

	Accidents Total	**Accidents Total**	**Victims Total**	**Victims Total**
Interaction	0.016	0.017	0.010	0.004
	(0.016)	(0.016)	(0.020)	(0.020)
Population		0.002		0.000
		(0.001)		(0.002)
Population_Squared		–0.000		0.000
		(0.000)		(0.000)
Unemployment Rate		0.209		0.733
		(0.773)		(0.812)
Population Above 65		11.032***		9.723***
		(2.174)		(2.442)
Sales Index		–0.007		–0.017***
		(0.005)		(0.006)
Total Urban Area		0.007		0.009
		(0.005)		(0.008)
Highways Dummy		0.160***		0.185***
		(0.011)		(0.012)
Year Fixed Effects	Yes	Yes	Yes	Yes
Municipal Fixed Effects	Yes	Yes	Yes	Yes
/lnalpha	–8.424***	–7.368***	–6.237***	–6.671***
	(1.006)	(0.209)	(0.291)	(0.511)
Observations	834	834	834	834
Adjusted R^2	0.418	0.423	0.376	0.379
BIC	5 678.760	5 664.490	6 388.698	6 394.160

Note: Standard errors in brackets are clustered at the municipal level and robust to heteroscedasticity. Stars indicate significance levels of 10% (*), 5% (**), and 1% (***).

can be identified, the implied economic and social costs have to be considered together with other relevant costs, such as reduced traffic and higher commuting costs. Ultimately, this may help determine the wisdom of introducing tolls from a purely budgetary perspective.

Our identification strategy relies on a difference-in-differences approach that compares municipalities that were affected vis-à-vis the remaining municipalities. Our findings confirm an overall increase in the total number of both accidents and victims, mostly light injuries, in the municipalities crossed by these highways due to the introduction of tolls. This overall increase in the number of accidents and victims reflects simultaneously a decline of the incidence in highways in these municipalities and an increase in the incidence in national roads and other roads in the municipalities.

Given that we have identified adverse effects of the introduction of tolls on road safety, it is important to try to measure the economic and social costs induced by such effects. To assess the implications of introducing tolls on the former SCUT highways, it is important to weight the human costs of the tolls in terms of the resulting increase in the number of accidents and injuries, particularly the resulting increase in light injuries. Specifically, our estimates imply that the introduction of tolls increases the number of lightly injured victims by around 1,193 each year.

The economic value of road safety improvements in the context of cost-benefit analysis of road transportation infrastructure improvements is standardized in European Commission (2008) and outlined in the Bieckel *et al.* (2006) documentation for harmonized guidelines in road transportation projects. For Portugal, the average comprehensive economic and social cost per slightly injured victim[4] between 1996 and 2010 was approximately 23.100 in 2006 euros (Donário and dos Santos, 2012). Accordingly, the estimated increase in light injuries translates into an annual comprehensive loss of about 31.2 million euros.

To put things in a more general perspective, revenues in the former SCUT highways are reported by UTAP (2014, 2015). Total toll receipts for the former SCUT concessions, excluding value-added taxes, amounted to about 135.8, 146.9, and 161.6 million euros in 2012, 2013, and 2014, respectively. Accordingly, the economic and social cost of additional injuries corresponds to around 20% of the toll revenues for 2012–2014.

To be noted, our analysis includes exclusively the economic and social costs of added light injuries due to the new tolls. It does not include, for example, the added costs of commuting time and of wear and tear of the vehicles or even the environmental effects that result from the diversion of traffic from the SCUT highways to the alternative roads. Still, as they stand, the results presented in this article are another piece of the puzzle that seems to imply that introducing tolls for revenue purposes alone on non-congested highways is a rather questionable proposition.[5] The costs induced by the introduction of the tolls may not be negligible and should not be ignored when deciding whether or not to introduce such tolls.

---

4. The average economic and social cost of slightly injured victims includes the value of lost production, administrative costs of insurers, costs of road safety institutions, law enforcement and court costs, ambulance and hospital costs, property costs, and non-monetary social costs.

5. In this context, it should be noted that as of 2014, the last year of our sample, toll revenues for the former SCUT highways covered less than 30% of the gross public commitments relating to the SCUT network (UTAP, 2015). Clearly, the decision to introduce tolls did not consider the decline in traffic in the SCUT network this change would induce.

References

Albalate D (2011). "Shifting death to their alternatives: The case of toll motorways". *Journal of Transport Economics and Policy*, 45(3): 1–23.

Albalate D and Bel G (2012). "Motorways, tolls and road safety: Evidence from Europe". *SERIEs*, 3: 457–473. https://doi.org/10.1007/s13209-011-0071-6.

Angrist JD and Pischke J-S (2008). *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton, NJ, USA: Princeton University Press.

Bertrand M, Duflo E and Mullainathan S (2004). "How much should we trust differences-in-differences estimates?" *Quarterly Journal of Economics*, 119(1): 249–275. https://doi.org/10.1162/003355304772839588.

Bieckel P, Friedrich R, Burgess A, *et al.* (2006). "Proposal for harmonised guidelines". HEATCO—*Developing Harmonised European Approaches for Transport Costing and Project Assessment, Deliverable 5, Contract No. FP6-2002-SSP-1/502481*. Brussels, Belgium: European Commission.

Currie J and Walker R (2011). "Traffic congestion and infant health: Evidence from E-ZPass". A*merican Economic Journal: Applied Economics*, 3(1): 65–90. https://doi.org/10.1257/app.3.1.65.

Dias LL (2015). *Pagamentos de Portagens nas Ex-SCUT—Qual o Impacto na Sinistralidade Rodoviária?* [*Toll Payments at Ex-SCUT—What is the Impact on Road Accidents?*] Lisbon, Portugal: Faculdade de Ciências Socias e Humanas, Nova University Lisbon.

Donário AA and dos Santos RB (2011). *The Economic and Social Costs of Road Accidents: The Case of Portugal. Lisbon*, Portugal: EDIUAL—Autoridade Nacional de Segurança Rodoviária and Centro de Análise Económica de Regulação Social da Universidade Autónoma de Lisboa.

European Commission (2008). *Guide to Cost-Benefit Analysis of Investment Projects, Structural Funds, Cohesion Fund and Instrument for Pre-Accession—Final Report*. Brussels, Belgium: Directorate General Regional Policy.

Green CP, Heywood JS and Navarro M (2014). "Did liberalising bar hours decrease traffic accidents?" *Journal of Health Economics*, 35: 189–198. https://doi.org/10.1016/j.jhealeco.2014.03.007.

_____ (2016). "Traffic accidents and the London congestion charge". *Journal of Public Economics*, 133: 11–22. https://doi.org/10.1016/j.jpubeco.2015.10.005.

Guimarães P (2008). "The fixed effects negative binomial model revisited". *Economics Letters*, 99(1): 63–66. https://doi.org/10.1016/j.econlet.2007.05.030.

Haynes R, Jones A, Kennedy V, *et al.* (2007). "District variations in road curvature in England and Wales and their association with road-traffic crashes". *Environment and Planning A*, 39(5): 1222–1237. https://doi.org/10.1068/a38106.

Instituto Nacional de Estatística (INE) (2008). *Estatísticas de Transporte e Comunicação—2008* [T*ransport and Communication Statistics—2008*]. Lisbon, Portugal: INE.

Kmet L and Macarthur C (2006). "Urban-rural differences in motor vehicle crash fatality and hospitalization rates among children and youth". *Accident Analysis and Prevention*, 38(1): 122–127. https://doi.org/10.1016/j.aap.2005.07.007.

Li H, Graham DJ and Majumdar A (2011). "The effects of congestion charging on road traffic casualties: A causal analysis using difference-in-difference estimation". *Accident Analysis and Prevention*, 49: 366–377. https://doi.org/10.1016/j.aap.2012.02.013.

Lord D, Washington SP and Ivan JN (2005). "Poisson, Poisson-gamma and zero-inflated regression models of motor vehicle crashes: Balancing statistical fit and theory". *Accident Analysis and Prevention*, 37(1): 35–46. https://doi.org/10.1016/j.aap.2004.02.004.

Martins R and Veiga FJ (2014). "Does voter turnout affect the votes for the incumbent government?" *European Journal of Political Economy*, 36: 274–286. https://doi.org/10.1016/j.ejpoleco.2014.09.001.

Noland RB and Quddus MA (2004). "A spatially disaggregate analysis of road casualties in England". *Accident Analysis and Prevention*, 36(6): 973–984. https://doi.org/10.1016/j.aap.2003.11.001.

Parry IWH, Walls M and Harrington W (2007). "Automobile externalities and policies". J*ournal of Economic Literature*, 43(2): 373–399. https://doi.org/10.1257/jel.45.2.373.

Pereira AM and Andraz JM (2006). *The Economic and Fiscal Impact of Toll-free Highways in Portugal*. Lisbon, Portugal: Instituto para os Estudos sobre o Desenvolvimento.

_____ (2007). "On the economic and budgetary effects of the SCUTS—The Portuguese toll-free highways". *The Annals of Regional Science*, 48(1): 321–338. https://doi.org/10.1007/s00168-010-0404-6.

_____ (2010). *Análise Custo Benefício Ex-Ante e Ex-Post das SCUT—Beira Interior, Beira Litoral e Alta, Grande Porto, e Interior Norte* [*Ex-Ante and Ex-Post Cost-Benefit Analysis of SCUT—Beira Interior, Beira Litoral and Alta, Grande Porto, and Interior Norte*]. Lisbon, Portugal: Estradas de Portugal.

Ossenbruggen PJ, Pendharkar J and Ivan J (2001). "Roadway safety in rural and small urbanized areas". *Accident Analysis and Prevention*, 33(4): 485–498. https://doi.org/10.1016/S0001-4575(00)00062-2.

Ruhm CJ (2015). "Recessions, healthy no more?" *Journal of Health Economics*, 42: 17–28. https://doi.org/10.1016/j.jhealeco.2015.03.004.

Unidade Técnica de Acompanhamento de Projectos (UTAP) (2014). *Relatório Annual das PPP—2013* [*PPP Annual Report—2013*]. Lisbon, Portugal: UTAP.

_____ (2015). *Relatório Annual das PPP—2014* [*PPP Annual Report—2014*]. Lisbon, Portugal: UTAP.

Van den Bossche F and Wets G (2003). "Macro models in traffic safety and the DRAG family: Literature review". *Steunpunt Verkeersveiligheid bij Stijgende Mobiliteit RA-2003-08*. Diepenbeek, Belgium: Steunpunt Verkeersveiligheid bij Stijgende Mobiliteit.

Wang C, Quddus MA and Ison SG (2009). "Impact of traffic congestion on road accidents: A spatial analysis of the M25 motorway in England". *Accident Analysis and Prevention*, 41(4): 798–808. https://doi.org/10.1016/j.aap.2009.04.002.