Motorways, tolls and road safety. Evidence from European Panel Data

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Abstract:
The use of tolls is being widespread around the world. Its ability to fund infrastructure projects and to solve budget constraints have been the main rationale behind its renewed interest. However, less attention has been payed to the safety effects derived from this policy in a moment of increasing concern on road fatalities. Pricing best infrastructures shifts some drivers onto worse alternative roads usually not prepared to receive high traffic in comparable safety standards. In this paper we provide evidence of the existence of this perverse consequence by using an international European panel in a two way fixed effects estimation.

Keywords: Road Safety, Tolls, Motorways and Transportation.

JEL codes: H23; I18; R48.

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Summary

The use of tolls is being widespread around the world. Its ability to fund infrastructure projects and to solve budget constraints have been the main rationale behind its renewed interest. However, less attention has been payed to the safety effects derived from this policy in a moment of increasing concern on road fatalities. In the present paper we defend that setting tolls produce a perverse outcome in terms of road safety by shifting those vehicles not willing to pay for the best quality infrastructure onto lower quality adjacent roads. These infrastructures are usually not prepared to receive high levels of traffic in similar safety standards, increasing crash risks as a consequence. In order to test this hypothesis we use and international European database (CARE) and a two way fixed effects semi-log model of estimation. Results show that price regimes in motorways may make a difference on road safety outcomes even using aggregate country data. In fact, we provide econometric evidence on the positive impacts produced by free motorways on road safety outcomes while at the same time, we highlight that tolled motorways lose this virtue. These results lead to important public policy implications in the field of transportation and infrastructure management.

I. INTRODUCTION

The trend towards increased tolling of roads is clear (Estache and de Rus, 2000). This trend has been documented for less developed countries (Guasch, 2004), as well as for the most developed ones (Albalate, Bel and Fageda, 2007). In fact, the recent increase in private involvement in road infrastructures, and particularly in the case of motorways, makes of tolls an interesting tool to recover investments and to fund infrastructure programs. Fishbein and Babbar (1996) consistently argue that this renewed interest in toll roads is particularly strong because governments require alternative methods of financing transport needs given limited public resources. Thus, given that governments deal with competing expenditures and are pressured by budget constraints, the toll is seen as the tool able to avoid tax rises and expenditure cuts.

Unfortunately, tolls have been usually set only taking into account the financial breakeven of concessionaires and no weight has been put on other social efficiency criteria. Newbery (2000) explains that the usual question considered when setting tolls is whether the revenue is high enough to cover capital and operating costs guarantying some profit, rather than assuring net social benefits. This view is usually concerned with congestion costs as the main externality not internalized by tolls and many researchers have devoted their work to show the benefits from using tolls to regulate demands. Some recent studies, especially devoted to the use of congestion charges in urban environments and its benefits in practice are Parry (2002), Santos (2004), Olszewski and Xie (2005) and Hensher and Puckett (2007), among others.

From the seminal works by Pigou (1920) and Knight (1924), and the pioneer works by Walters (1961) and Vickrey (1969), transport economists claim for the internalization of externalities using road charges in order to seek efficient allocative outcomes. Nonetheless, this concern on pricing road transport was mainly thought to fight congestion costs though other externalities like road accidents, environmental pollution and noise have not received enough consideration until the last years.[1] This concept is known as Pigouvian taxation and has remained the leading principle in transport economics on road traffic externalities regulation (Button and Verhoef, 1998).

According to this pattern, less attention has been paid to the safety effects derived from establishing tolls. Indeed, road accidents is another road externality which enjoys increasing relevance in the current framework of public health awareness. In the present paper we defend that setting tolls produce a perverse outcome in terms of road safety by

[1] Nash (2007) argues that recently marginal cost pricing has been extended to include charging for the external costs of accidents and environmental impacts as well.

shifting those vehicles not willing to pay for the best quality infrastructure onto lower quality adjacent roads. These infrastructures are usually not prepared to receive high levels of traffic in similar safety standards, increasing crash risks as a consequence. This shift, which is usually called re-routing or rat-running effect in the transportation literature, produces worse road safety outcomes in the corridor than the situation in which a free motorway does not encourage re-routing.

This perverse outcome gains increasing relevance if we take into account that demand for safety is growing and becoming a major concern for policy makers. As a matter of fact, as **table 1** displays, road traffic injuries are positioned in the highest places in the world leading causes of death ranking provided by the World Health Organization (2004). In fact, they are the second cause of death for those between 5 and 29 years old, and the third for those between 30 and 44 years old. This position denotes its importance as a public health threat.

<< Insert table 1 about here >>

Apart from that, there are economic reasons that make of road safety an important goal for any economy as well. Several estimates point out that economic costs associated with road accidents are as high as 1% of GDP in low-income economies; 1,5% in middle-income economies; and as high as 2% in developed economies. For instance, Jacobs, Aeron-Thomas and Astrop (2000) estimated worldwide road accident costs in 518$ billion, with the costs in low-income countries exceeding the total annual amount received in development assistance. These costs are derived from vehicle and other damages, health expenditures and waste of production.

This being said, it is not surprising that concerns with all the above mentioned leads to several governments to devote increasing interest in active public policies to be implemented to achieve better safety outcomes and to avoid perverse practices which increase crash risks. Following this, our study tries to emphasize one of these perverse practices which is not considering the safety consequences of establishing tolls in motorways.

Our empirical study focuses on Europe where approximately 1/3 of its motorway network is directly charged and its length has grown dramatically in the last years. In **figure 1** we display the increase of the toll motorway network under ASECAP, which is the association of toll motorway concessionaires in Europe, for the decade 1996-2006. As is shown, the length of the toll motorway network in Europe has increased almost 50% in ten years.[2] All these elements make of Europe an interesting region to compare safety outcomes across price regimes. To do so, we use an international panel containing information from 15 countries (EU-15) during the period 1991-2003. The method of estimation is a two way fixed effects semi-log model which controls for several covariates and uses as dependent variable the rate of fatalities per million population.

<< Insert figure 1 about here >>

As results show, motorways are expected to have positive impacts on road fatalities since its quality and characteristics provide better outcomes.[3] However, this effect is only present when the motorway remains free and loses this positive impact when it is tolled. Since technical differences between both free and toll motorways are not relevant, we do not expect to find more accidents in tolled motorways than in free motorways due to infrastructure reasons.[4] In fact, toll motorways yield similar and even safer outcomes in comparison with free motorways in a country like Spain where both price regimes compose a mixed network in which tolled motorways are over the 20% of total motorway network. Hence, the interpretation of our results suggests that pricing motorways play a role in road safety outcomes by shifting to the worst road those drivers not willing to pay for the safest road. Consequently, this diversion produces more road fatalities in the corridor and, as we defend, even using aggregate country data this effect can be identified.

The present paper is organized as follows. In the next section we provide the related literature which may serve to introduce close concepts and similar concerns already treated by previous works. In the third section we describe the methodology carried out to test the main hypothesis and the data used, while in the fourth section we offer and explain our main results. Lastly, some concluding remarks can be found in the fifth section.

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[2] Finland, Ireland, Luxembourg and Sweden are not members of this association, but their small number of tolled motorways would not affect the ASECAP's toll network trend over time. Additionally, Germany is an associate member which only charges heavy vehicles and no general tolls are established in its network. For this reason ASECAP does not include Germany in its toll motorway network. The rest of EU15 countries are included in ASECAP statistical bulletin together with Norway, Croatia, Hungary, Serbia and Slovenia.

[3] However, some works do not find statistically significant the motorway length or even find negative effects. These results are usually justified by the presence of high speed and risky behaviour in this network. These effects are related to the so-called offsetting behaviour undercovered by Peltzman (1975).

[4] According to statistical data from the Spanish Ministry of Transport, toll motorways yield similar and even safer outcomes in comparison with free motorways in a country where both price regimes compose a mixed network in which tolled motorways are over the 20% of total motorway network. Even in some countries like Italy concessionaires of toll motorways receive incentives to reduce accidents in their network due to the construction of a price cap formula regulating their toll adjustment which includes a penalty for the number of road accidents. In this sense, private concessionaires have incentives to increase quality standards not only to attract more users to increase revenues but also to obtain productivity gains from price cap regulation.

II. RELATED LITERATURE

Several studies treated similar concerns related to the hypothesis of the current study or already noticed the existence of this shift produced by pricing roads. For instance, May and Milne (2000) assert that road charging may encourage widespread diversion onto minor routes. In fact, Rothengatter (2004) find that after setting tolls for heavy vehicles in Austria truck traffic was being diverted onto streets and roads, what is a clear example of the so-called "rat-running" effect. According to Verhoef, Nijkamp and Rietveld (1996), this shift is positively related to the elasticity of demand and negatively related to the quality of the adjacent road producing a shift of some vehicles onto worse roads. The rationale behind this is the following: the lower the quality of the adjacent road, the more inelastic the demand for the tolled motorway becomes. Moreover, Engel, Fischer and Galetovic (2004) find that the number of independently owned roads in a network makes road system more competitive, even if demand increases at the same rate. A direct consequence is that the number of alternatives prevents the toll motorway owner to set high toll levels without being hurt from this competition.

Other authors have already studied the price elasticity of demand in toll motorways. However, these estimations are usually based on short sections, tunnels, bridges and entrance to big cities making more difficult a reasonable comparison (Oum, Waters and Yong, 1992; Hirschman et al. 1995; Yoram, 2001; Loo, 2003; Olszewski and Xie, 2005; Courtney and Nishiyama, 2007). Fortunately, Matas and Raymond (1999) evaluate this elasticity for the Spanish toll motorways, finding a price elasticity of -0.3 in the short run. In the long run, this estimate increases by 50%.

Besides, they also pointed out that charging motorways generate perverse distortions in traffic allocation when taking into account not only the motorway, but also the network in which this belongs to. These distortions are supposed to be affected by price elasticities. For instance, Hirschman et al. (1995) state that elasticities in toll motorways are strongly related to the quality of its free alternative. Consistently, Matas and Raymond (1999) show that their estimated elasticity also depends on the quality of the alternative, from its composition and congestion. Finally, Wuestefield and Regan (1981) observed different elasticities depending on the type of journey made and its frequency.

The perverse effect analyzed in the current paper was considered by the DfT Feasibility Study of Road Pricing in the UK, where can be found that "the impact of re-routing, if it were to occur, could in certain places and at certain times result in an increase in accident levels. This is due to the increased number of vehicles using smaller roads, not built for a high level demand, which could lead to higher accident rates" (Department for Transport, 2004; p.143). Following the same rationale, Broughton and Gower (1998) estimated that a 10 per cent diversion of motorway traffic from the motorways in Kent (UK) would increase the number of injury accidents in its entire county by about 3.5 %. In a previous study by Gower, Shearn and Mitchell (1998), they predicted that a toll of 2.5p per mile (at 1994 prices) would produce that 10 per cent diversion level. In the same direction, Broughton and Gower (1998) estimated that this increase in the traffic flow would increase the number of injury accidents in the entire county by about 3.5 per cent taking into account traffic flows and road capacities.

In the present paper we use real international data to compare safety impacts from free and tolled motorways on the rest of road network. Somewhere else (Albalate, 2007) it is found that those routes adjacent to toll motorways in Spain suffer more accidents involving victims per km than those adjacent to free motorways after controlling by traffic density and composition. The present study contributes to the literature by testing for the first time whether price regimes in motorway networks affect road safety outcomes using an international data setin a two way fixed effects estimation. Since the literature on road externalities has been mainly focused in congestion costs claiming for the use of congestion charges as the unique first best pricing approach, our results provide new concerns on the use of tolls in interurban motorways.[5] Pricing best infrastructures seem to produce a safety damage which can be identified even using aggregate country data and it is not constrained to national characteristics thanks to the international approach of the current study.

III. ESTIMATION STRATEGY

In order to test whether this effect may arise even using international aggregate data, we take advantage of one international database containing road safety information for European countries. This database, which is named CARE (Community database on Accidents on the Roads in Europe), was created by the European Council in order to make it possible to identify and quantify road safety problems in the continent (Council Decision 93/704/EC). Thus, CARE contains country-level data from 1991 to 2005 for European Union countries, where data for 2005 are estimates. We only use data up to 2003, before EU enlargement, because all variables are not available for 2004. As a consequence, we have a sample based on 15 countries during 13 years for the total fatality rate per million

[5] In fact, congestion costs are more prone to appear in urban environments and consequently in access motorways to big cities. According to this, interurban tolls are usually not thought to fight congestion but to finance infrastructure projects.

population, which will serve as the endogenous variable related to road safety outcomes (195 observations).[6]

The estimation model chosen is a common two way fixed effects semi-log model that takes the following form:

$$\ln Y_{it} = X_{st}\,\beta + s_i + v_t + \varepsilon_{it} \qquad \textbf{(1)}$$

where $\mathbf{Y_{it}}$ is the fatality rate per million population in the country **i** at year **t**, $\mathbf{X_{it}}$ contains the vector of time-varying control covariates and $\mathbf{s_i}$ and $\mathbf{v_t}$ are country-specific and year-specific fixed effects. The rationale behind the use of both fixed effects is that country fixed effects control for time-invariant country-specific omitted variables and year dummies control for national trends. Besides, $\boldsymbol{\varepsilon_{it}}$ is a mean-zero random error. **Table 2** shows the time-varying covariates used and their descriptive statistics.

<< Insert table 2 about here >>

This two way fixed effects is also justified by Hausman test which provides that random effects estimates are not consistent in our framework.[7] The importance of using time fixed effects is also of relevance due to the decreasing trend of road fatalities enjoyed by EU countries during the period studied. **Figure 2** show that decreasing trend for the EU countries.

<<Insert figure 2 about here >>

Additionally, we replicate the estimation in order to control by heteroskedasticity in the first place, and to capture any pattern of correlation by using a cluster robust estimation in the second place. In the latter case the variance-covariance estimator used takes the following form:

$$V = (X'X)^{-1} \left(\sum_{i=1}^{N} u_i' u_i\right) (X'X)^{-1} \qquad \textbf{(2)}$$

$$u_i = \sum_{t=1}^{T} e_{it}\, x_{it} \qquad \textbf{(3)}$$

[6] According to Eisenberg (2003), the literature traditionally uses as output measures this fatality rate because of their accuracy and relevance for policy makers.

[7] Hausman (1978) test measures the correlation between regressors and error term using as a null hypothesis that there is no correlation. In our case this is rejected with a Prob>chi2 = 0.0013, and therefore the model chosen is fixed effects.

where **X** is the matrix of covariates, **N** the number of countries, $\mathbf{e}_{it}$ denotes the country-year specific residual and $\mathbf{x}_{it}$ the vector of regressors. [8, 9]

Concerning covariates again, we display in **table 3** the expected relationships between each of them and the rate of road fatalities per population. As the reader can observe, economic growth is expected to increase fatalities. Ruhm (1996) and García-Ferrer, De Juan and Poncela (2007) show that motor vehicle accidents exhibit a procyclical variation.

<< Insert table 3 about here >>

Two other variables included in the study which capture the use of roads are Vehicle-Km and Motorization. The first denotes the annual number passenger cars-Km, weighted by the national population. Therefore, this is capturing the degree of road use that an average driver enjoys in a given country. On the other hand, motorization denotes the number of passenger cars per capita. Although more cars per capita may mean more cars in the road and consequently higher risk, this variable is strongly correlated with economic development, which at the same time, is strongly and negatively related to road fatalities. In fact, the relationship between road fatalities and economic development is not lineal (Kopits and Cropper, 2005). Also Anbarci, Escaleras and Register (2006) explain in detail that fatality rates increase with economic development in low-income economies but become flat or even decreasing after reaching a certain threshold of development. Since our sample is based on first world economies, we consider that it is reasonable to expect negative relationships between economic development (through motorization) and road fatalities according to Kopits and Cropper (2005) results.

The core of our analysis is found in the infrastructure variables employed. First, we control for the presence of motorways as the best road infrastructures which provide the highest levels of road safety. Nonetheless, we are interested in distinguishing those kms which are tolled from those which are free of payment. Our hypothesis relies on the fact that more presence of motorways provides better results on road safety outputs, but these decrease when this type of infrastructure is priced. For this reason we expect to find a clear decreasing relationship between the shares of motorways in the road network and road fatalities, but we want to identify whether this happens for those motorways which are tolled as well. Primary roads and secondary roads are variables denoting different levels of

[8] This is known as the White-like formula to compute standard errors (White, 1984).

[9] Since this method is only valid asymptotically, we apply the finite sample adjustment used by STATA: N-1/(N-k) * M/(M-1), where N is the number of observations, k the number of regressors including the constant and M the number of clusters.

infrastructure quality, where primary roads are expected to provide better road safety outcomes than secondary roads.

Finally we also control by the level of alcohol consumption, the level of upper secondary graduates and the share of young males in the country. The first variable is expected to provide positive and significant impacts on road fatalities, as the medical and economics literature agree, and its discouragement is known to promote road safety (Ruhm, 1996; Moskowitz and Fiorentino, 2000; Eisenberg, 2003; Albalate, 2008). The second is a variable not usually employed to determine road safety outcomes. Nonetheless, it is usually suggested that the degree of education may play a role in the fulfillment of laws and rules and it is also responsible of driver attitudes and behavior. For this reason we additionally test whether this aggregate level of education enjoyed by a country may play a role in determining road safety outcomes.

The last covariate is the share of young males in the country. Again, many studies provide evidence on the vulnerability of young drivers, especially males, to road fatalities. For this reason we expect to find positive relationships between the share of this age-gender group and the rate of road fatalities. For instance, Noland (2003) already found strong effect on age cohort variables when using states as the unit of spatial analyses.

Data on all these variables are obtained from international databases, like Eurostat, WHO Europe, World Bank Development indicators, and the World Road Statistics.

IV. RESULTS

In **table 4** our results are displayed. Specification **(1)** uses the variable motorways as regressor to include both free and tolled motorways in order to show the expected relationship between the best infrastructure and road fatalities. As is shown, the coefficient associated to this covariate is negative and highly significant. Therefore, without any distinction between price regimes, motorways seem to favor road safety. The rest of variables provide the expected signs. Only the coefficients associated to Primary roads, Education and Young males are not apparently statistically significant.

<< Insert table 4 about here >>

Also, it is interesting what we find in infrastructure variables. As mentioned, motorways favor road safety, primary roads are not statistically significant and secondary roads are associated to more road fatalities. Therefore, we find some kind of decreasing relationship between infrastructure quality and fatalities if we take into account the size, sign and statistical significance of their coefficients. This result is consistent with Albalate (2008) in which only the variable motorways and primary roads are introduced and also with Flahaut (2004) where 2+2 lane configuration (2 lanes in each direction, both directions physically separated) is associated to the smallest probability of black zone. Moreover, he finds that 2 lane configuration without physical separation is by far the most unsafe road configuration and this is the usual road type of secondary roads.

In our results, motorways do provide the best results, while primary roads are not statistically significant and its coefficient is positive but very small in comparison with the rest of coefficients. Nonetheless, the one associated to secondary roads is positive, larger in comparison and statistically significant. Consequently, we find a decreasing relationship between infrastructure quality and road fatalities.

More related to the core of our analysis and our empirical contribution are results from specification **(2)**, where we distinguish between free and tolled motorways. As is shown, free motorways are strongly related to road safety and its coefficient is quite large. In fact it is larger than the coefficient associated to the motorways' variable of specification **(1)**. On the contrary, toll motorways do not seem to play any role on overall road fatalities. Its coefficient is not statistically significant in contrast with free motorways.

This result seems to suggest that only free motorways promote road safety. Since quality standards are similar in both price regimes as stated in the introduction, we do not expect to find more accidents in toll motorways than in free motorways. In fact, safety outcomes in toll motorways are as satisfying as the ones reported by free motorways. Thus, there are reasons to believe that different impacts on road safety from different pricing strategies may be produced not in the motorways network (free or tolled) but in the alternative road network that competes against them, giving support to the hypothesis tested in the current study which is that pricing motorways prevents the use of the best infrastructure by those not willing to pay for its use. These drivers must use lower quality roads and the accident risk suffered in the corridor is higher than that generated by free motorways which allow the use of the better road without price exclusion.

Again, in specifications **(3)** and **(4)** this result is consistent. In the first case we replicate the estimation but now controlling for heteroskedasticity while in the second we allow for any pattern of correlation by using a cluster robust estimation. In both cases we find that free motorways are strongly and positively related to road safety while toll motorways do not play an statistically significant role. Again, the coefficient associated to free motorways is significantly larger.

To sum up, in this section we have found that even using aggregate data, there are reasons to believe that establishing tolls prevents the achievement of better road safety outcomes. Since the presence of motorways is strongly correlated to lower road fatalities we should expect similar coefficients and strong relationships independently from the pricing regimes. Nonetheless, we find that in our two way fixed effects estimation only free motorways are associated to statistically significant impacts on overall safety across specifications. On the contrary, toll motorways do not play any statistically significant role and its coefficient is significantly smaller than the one associated to free motorways.

Our results lead to important public policy implications in the field of transportation and infrastructure management. Pricing motorways prevents to fully exploit the best infrastructure virtues from motorways, which are connecting two points in short time periods under the safest standards, since a group of drivers which are not willing to pay for using the motorway are shifted to alternative roads. Thus, more investment on maintenance and quality should accompany toll establishment when the policy maker still considers the importance of tolling the best road. Following the rationale defended in the present paper, this investment must be devoted to improve safety in the adjacent alternative routes which receive diverted traffic from the tolled motorway. Nevertheless, conflicts of interest can emerge from this proposal, since this may find the opposition of the toll motorway concessionaire affected by the quality level of its competing road (Engel, Fischer and Galetovic, 2004).

Another alternative for regulators and transport managers is the internalization of accident externalities by lowering tolls to improve safety outcomes in the corridor. This solution is close related to the literature on second-best pricing in road networks. In Verhoef, Nijkamp and Rietveld (1996) and Rowendal and Verhoef (2003) we find that first best pricing reduces congestion on the toll road through the fare, but does not take into account the level of congestion suffered in the alternative untolled road which receives the users diverted from the tolled one. Therefore, drivers shifted to congested untolled roads aggravate its congestion. As a result, first- best pricing ignores the spill-overs on the free roads and it is necessary to set second-best tolling which internalizes congestion across the whole network. This implies a downward adjustment of tolls below first best levels.[10]

V. CONCLUDING REMARKS

The use of tolls is becoming widespread around the world by their ability to solve budget constraints and avoid tax rises when governments need to face infrastructure enlargements or quality improvements. However, as is shown in the present paper, toll establishment

[10] Also see Viton (1995) and de Palma and Lindsey (2000) for analyses of private toll roads competing with untolled alternatives.

may be associated with road unsafety in a moment in which this is an increasing concern that worries transportation authorities and policy makers.

In this study we have used an international European panel and a two way fixed effects estimation to show that price regimes in motorways may make a difference on road safety outcomes even using aggregate country data. In fact, we provide econometric evidence on the positive impacts produced by free motorways on road safety outcomes while at the same time, we highlight that tolled motorways lose this virtue. The explanation behind this result is related to the so-called re-routing or rat-running effects, which relate toll establishment to traffic diversion onto lower quality roads.

This result leads to important public policy implications in the field of transportation and infrastructure management. More investment on maintenance and quality should accompany toll establishment when the policy maker still considers the importance of tolling the best road, and this investment must be devoted to improve safety in the adjacent alternative routes which receive diverted traffic from the tolled motorway. An alternative for regulators and transport managers is the internalization of accident externalities by lowering tolls to improve safety outcomes in the corridor. In our framework, priced-off drivers diverted onto lower quality roads are more prone to suffer accidents and therefore, tolling best infrastructures ignoring this effect may encourage road crash increases. Again, a downward adjustment of tolls may be necessary to internalize this perverse spill-over.

Finally, this study provides interesting results for both road safety and transportation literatures, opening a new concern which requires deeper understanding and consequently further research. Regarding road safety literature, we put new light on the importance of pricing infrastructures in terms of accidentality in alternatives, being this another risk factor not treated before. At the same time, we add an interesting concern which empirically complements the literature on transport externalities in a similar framework of those theoretical studies based on both financial tolls and congestion charging.

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Tables and Figures

Table 1 Road traffic injuries as a leading cause of death in the world, sorted by age groups (2002)

Age	Position in ranking of leading causes of death	Road Traffic Fatalities
0-4	13	49,736
5-14	2	130,835
15-29	2	302,208
30-44	3	285,457
45-59	8	221,776
All ages	11	1,183,492

Source: Adapted from The World Health Organization (2004)

Table 2. Definition of variables and descriptive statistics.

Variable	Definition	Mean	Std.Deviation
Growth	Rate of change (%) of the Real GDP, PPP$ per capita.	2.750	2.617
Vehicle-km	Annual number passenger cars-Km expressed in 1000 million km and weighted by the national population.	9.146	2.452
Motorization	Number of passenger cars per 1000 inhabitants	418.536	93.768
Motorways	Proportion in % of Motorways (km) over the total road network.	1.312	0.935
Free Motorways	Proportion in % of Free Motorways (km) over the total road network	1.036	0.0712
Toll Motorways	Proportion in % of Tolled Motorways (km) over the total road network	0.278	0.0324
Primary roads	Proportion in % of Primary roads (km) over the total road network	8.942	5.105
Secondary roads	Proportion in % of Secondary roads (km) over the total road network	1.838	0.393
Alcohol	Alcohol consumption in litres per capita	11.215	0.173
Education	% Population between 16-64 years old with upper secondary education.	55.911	18.270
Young males	% Males between 20 and 29 years old over total Population	7.578	0.056

Table 3. Definition of variables and descriptive statistics.

Covariates	Expected relationship
Growth	+
Vehicle-km	+
Motorization	-
Motorways	-
Free Motorways	-
Toll Motorways	+/-
Primary roads	+/-
Secondary roads	+/-
Alcohol	+
Education	+/-
Young males	+

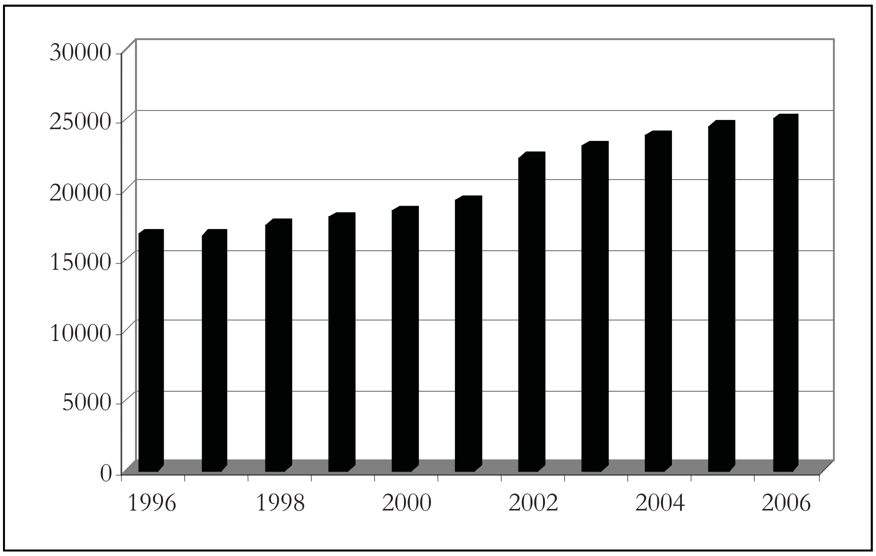
Table 4. Least-squares estimates for semi-log models. (N = 195)

Covariates	**FE (1)**	**FE (2)**	**FE (Heterosk.) (3)**	**FE (Clusters) (4)**
Growth	0.0080** (2.33)	0.0080** (2.33)	0.0080** (2.04)	0.0080 (1.41)
Vehicle-km	0.0504* (1.97)	0.0520* (1.97)	0.0520* (1.76)	0.0520 (1.05)
Motorization	-0.0017*** (-3.96)	-0.0018*** (-3.49)	-0.0018*** (-3.99)	-0.0018** (-2.59)
Motorways	-0.0528*** (-3.28)	-	-	-
Free Motorways	-	-0.0546*** (-3.31)	-0.0546*** (-4.08)	-0.0546** (-2.90)
Toll Motorways	-	-0.0373 -(0.66)	-0.0373 (-0.67)	-0.0373 (-0.54)
Primary roads	0.0028 (1.04)	0.0028 (1.04)	0.0028 (1.48)	0.0028 (1.20)
Secondary roads	0.0770* (1.69)	0.0743 (1.60)	0.0743 (1.34)	0.0743* (2.08)
Alcohol	0.0222** (2.49)	0.0218** (2.44)	0.0218** (2.31)	0.0218* (1.76)
Education	0.0037 (1.65)	0.0040 (1.64)	0.0040 (1.43)	0.0040 (1.08)
Young males	0.0021 (0.15)	0.0012 (0.08)	0.0012 (0.06)	0.0012 (0.04)
R^2	0.81	0.82	0.82	0.82

Notes: Two-way fixed effects estimation. Each model includes time and country dummy variables and a constant term. t-statistics are presented in parenthesis.
* Statistically significant at the 10% level; ** at the 5% level and *** at the 1% level.

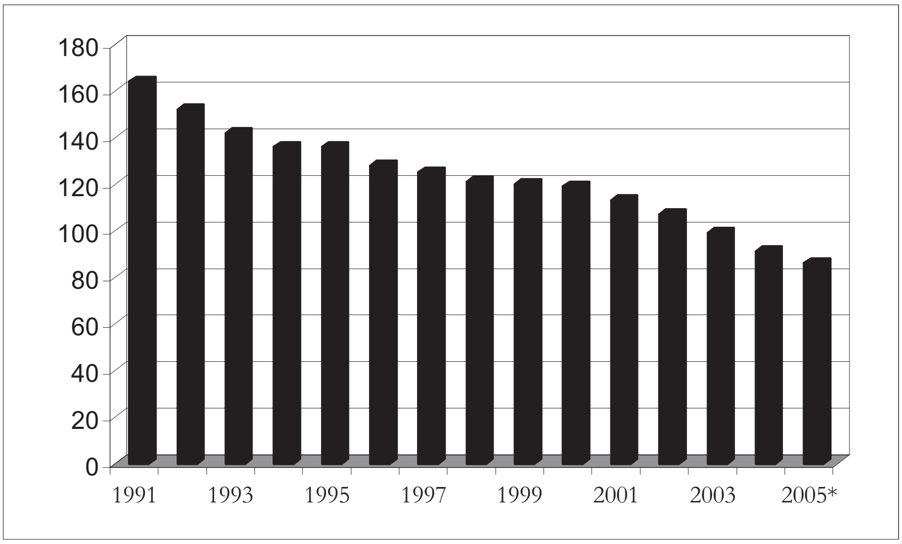
FIGURES

Figure 1 Length of toll motorway network of European ASECAP members (Km). (1996-2006).



Source: ASECAP (2007). Statistical Bulletin.

Figure 2. Rate of fatalities by million population. EU-15 countries. (1991-2005)



Source: CARE database.
*Data on 2005 are estimates.