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Abstract

We use a simple model of drivers' vigilance effort choice to show that drivers' propensity to follow traffic rules has two opposite effects on road safety. On the one hand, it lowers the frequency of dangerous situations. On the other hand, it also reduces drivers' vigilance effort as each driver anticipates that dangerous situations will be less frequent. These two opposite effects may lead to a non-monotonic relationship between compliance with road rules and the incidence of road traffic accidents. We present cross-country estimates that support the existence of a bell-shaped relationship between norms of compliance with rules and traffic fatalities.

Keywords: Road safety, compliance with rules, social capital.
JEL Classification: R41, Z10, D62.

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1 Introduction

Road traffic customs and coordination habits vary greatly from one country to the other, as best illustrated by the differences in behaviors adopted by drivers in various regions of the world (Lajunen et al. 2004, Parker et al. 2002, Nordfjærn et al. 2011). Among these attitudes, larger compliance with traffic rules by road users is frequently associated with enhanced traffic safety (Evans 1991, 2004) and is therefore often considered as an intermediary objective to be achieved in the search of road safety as shown by the World Road Association's Road Safety Manual that makes explicit recommendations on how to encourage drivers to comply with rules.

In this paper, we argue that compliance with traffic rules that serve as coordination devices has two effects on road safety. On the one hand, a higher propensity to follow rules lowers the frequency of dangerous situations, thereby decreasing the number of road traffic accidents. On the other hand, it also lowers drivers' vigilance effort, as each driver anticipates that dangerous situations will be less frequent, which increases the probability that an accident occurs conditional on a dangerous situation. These two opposite effects may lead to a non-monotonic relationship between compliance with road rules and road safety. A consequence of the adverse effects induced by lower vigilance is that an increase in drivers' compliance with traffic rules might actually be associated with lower road safety in societies with low compliance.

We first develop a simple theoretical framework that illustrates how average compliance with traffic rules can be introduced in a model of road behavior *à la* Blomquist (1986) and predicts that higher average compliance reduces drivers' vigilance effort. We then embed this mechanism in a straightforward accident probability function and show that the relationship between drivers' compliance with traffic rules and the aggregate accident probability is either monotonically decreasing or bell-shaped. In the second case, road traffic accidents are less frequent in societies where either no or all drivers comply with road rules than in societies with a mix of compliant and non-compliant drivers.

We then present empirical evidence that, in a cross-section of countries, there is indeed a bell-shaped relationship between road fatalities—a proxy for accidents—and compliance with rules—measured using attitudes toward both road- and non-road-related rules. The frequency of road fatalities first increases with the propensity to follow rules, up to a threshold where the effect of the latter variable on road safety becomes positive. A further increase in road rule compliance decreases road fatalities.

Since the seminal work by Putnam (2000), social capital and culture have received growing attention in the economic literature (see Fernández 2011 for a review). As argued by Guiso et al. (2011), social capital can be defined as "civic capital", i.e., "cultural norms and beliefs that [...] help members of a community to solve collective actions problems". To the best of our knowledge, Nagler (2013a,b) are the first papers to present empirical evidence regarding the effect of social capital, measured as trust, on road safety. In this paper, we look at norms of compliance with rules as a specific component of social capital.

Road rules and road environments have been developed and improved by governments to avoid road accidents. One of the channels through which road rules should lower the number of traffic accidents is by circumventing coordination issues. However, road legislation is not always enough to prevent risky behaviors and subsequent fatalities. Speeding, drunk driving, and running traffic lights are examples of individual attitudes often observed and that definitively increase the probability of being involved in road traffic accidents despite the existence of a rule (Åberg 1998). Stronger compliance with road rules is therefore expected to reduce road related injuries.

However, low compliance with rules may also be associated with a low number of traffic accidents as long as weak compliance with rules is common knowledge. Drivers indeed adapt their behavior to that of others (Peltzman 1975, Björklund and Åberg 2005). They might thus be more careful if they expect others not to comply with traffic rules. For example, in Brazil it is common not to stop at red lights after sunset to avoid being car-jacked and drivers are advised to adapt their behavior accordingly.[1,2] Not to comply with rules becomes the shared social norm (Wittgenstein 1953) and to be vigilant helps to overcome the associated costs. This example highlights the two behavioral dimensions at play: compliance with road rules *per se* and the level of safety effort that each road user chooses to undertake. It also illustrates how individuals are able to efficiently adapt their behavior if a norm of behavior is shared. In contrast, heterogeneous norms (e.g. a society made of a mix of compliant and non-compliant drivers) makes elicitations of others' behavior more difficult and triggers coordination failures (Schelling 1960, Lewis 1969).

Numerous scholars who have investigated the determinants of road-related injuries have been interested in exploring the link between income and road traffic fatalities across countries (see for example Wintemute 1985, Jacobs and Cutting 1986, van Beeck et al. 2000 and Kopits and Cropper 2005, 2008). Most of these studies conclude that road traffic fatalities increase with income (along with the increase in motorization) up to a certain threshold, after which countries seem to be able to invest in safety measures (including safer cars and road infrastructures) that reduce traffic fatalities. Jacobs and Cutting (1986), Söderlund and Zwi (1995), Anbarci et al. (2006), Bishai et al. (2006), Kopits and Cropper (2008) and Grimm and Treibich (2013) look at the impact of additional explanatory variables and reveal that income can be considered as a proxy for a set of relevant factors such as urbanization, vehicle mix, road quality, corruption, alcohol abuse and health services. In addition to these determinants, cultural heterogeneity and differences in cooperation attitudes are likely to be important determinants of differences in road safety across societies (Nagler 2013a,b). This paper contributes to this literature by presenting preliminary evidence that compliance with rules is an important determinant of road safety and that its effect is non-monotonic.

The idea of a non-monotonic relationship between rule compliance and road safety can be traced back to the very core of safety choices made by rational agents. The conceptual framework originates from models such as those developed by Blomquist (1986), Boyer and Dionne (1987) and Bishai et al. (2006). These models, assume that drivers weigh the costs of safety or vigilance effort—e.g., disutility or time losses—against benefits—e.g., to escape potential fines or material and physical consequences of an accident—to maximize their expected utility. In such a framework, drivers will decrease their own safety effort in response to better external safety conditions. As pointed out by Bjørnskau and Elvik (1992), Pedersen (2003) and Hollander and Prashker (2006), among others, this compensation mechanism also arises in response to changes in the behavior of other

[1] This feature of Brazilian traffic is reported by different media who share tips about driving in Brazil. See *saopaulo.angloinfo.com* and *traveltips.usatoday.com*, *Wikivoyage* and *InternationalDriversAssociation* among others. A 1999 Los Angeles Times article reported that "drivers approaching intersections [...] worry not just about carjackers but also about getting rear-ended or broadsided by other drivers who are worried about carjackers" when Rio de Janeiro authorities first announced that "citations will not be issued to drivers who run red lights late at night at low speed" in response to "a spate of carjackings at red lights".

[2] See García-Villegas (2011, 2019) about the culture of non-compliance with rules in Latin America.

drivers. In that spirit, an increase in drivers' average compliance with traffic rules reduces the risk of accidents as more drivers respect rules. For example, they stop when they are expected to do so, leaving the way free for another driver. This direct effect on road safety competes with a second indirect effect. From the point of view of an individual driver, a rise in average compliance with road rules is equivalent to an improvement in external safety. Others' compliance with road rules is therefore "appropriable [...] as a resource" in one's choice (Portes 1998). Consequently, a driver has incentives to lower her safety effort as the probability to face a risky situation decreases. This individual-level trade-off translates into lower safety effort by all individuals and triggers a negative externality for road safety as lower vigilance leads to more accidents in risky situations. Overall, the resulting effect on road safety of an increase in compliance with road rules is partly undetermined depending on the relative importance of the two effects. The stylized theoretical framework presented in this paper rules out the possibility that the total effect is monotonically positive—i.e., that larger compliance with rules will always result in more accidents—, and uncovers that it may be either monotonically negative or bell-shaped—i.e., increasing compliance with road rules first deteriorates road safety up to a point where the former starts to be beneficial for the latter. This bell-shaped relationship echoes the aforementioned idea that coordination is easier and helps to reach better outcomes when only one norm of behavior exists (either compliance with rules by all or by nobody) rather than when two norms coexist.

Exploratory empirical results presented hereinafter support the prediction that the above relationship is actually bell-shaped. We use road fatalities per $100,000$ inhabitants as a proxy for road traffic accidents and use questions from the World Values Survey and the European Values Study to capture a society's average norms of compliance with rules. These data allow us to run pooled cross-country estimations that demonstrate the existence of a bell-shaped relationship between road death toll and compliance with rules, while accounting for other determinants of road safety.

The remainder of this paper is organized as follows. Section 2 rationalizes the relationship between road rule compliance and traffic accidents. The data used, the estimation strategy and the empirical results are presented in section 3. Finally, section 4 briefly concludes and stresses the limitations of the paper.

2 Theoretical framework

This section rationalizes the relationship between traffic safety, modelled as accident probability and norms of compliance with traffic rules. We first show how compliance with traffic rules can enter a stylized model of road behavior *à la* Blomquist (1986) and how it reduces an individual's vigilance effort. We then construct the aggregate accident probability and study how it varies with compliance with rules.

Note that the theoretical framework we present considers norms of compliance as exogenous and abstract from the fact that norms can be influenced by outcomes. Also, we use a partial equilibrium approach and refrain from modelling the strategic decision-making of a complete population of drivers.

2.1 Individual choice of vigilance effort

We model an individual's vigilance effort when interacting with other drivers. Let us assume that interactions occur in situations where a norm of behavior toward a rule exists and is common knowledge. Such situations match the case of intersection lights where drivers facing a red light are supposed to stop while those facing a green light are supposed to continue driving.

When approaching an intersection, the driver may face a red or a green light, both with equal probability. Drivers may choose not to stop when facing a red light. We assume that each driver has an exogenous and identical probability $c \in [0, 1]$ to follow the rule, i.e. to stop when the light is red. Parameter c reflects the average compliance with rules in the society and can also be interpreted as the share of drivers who comply with rules.[3]

When the light is red and the driver stops, which occurs with probability c, no interaction occurs and no accident can take place. In contrast, when the light is red and the driver crosses the road against the rule, she will meet another driver for sure if we assume that traffic flows are such that all roads are always used and that drivers facing a green light always cross. Symmetrically, a driver facing a green light will meet another driver with probability $1-c$, i.e., when the other driver breaks the rule. That is, all drivers face a situation that might lead to an accident with probability $1 - c$.

However, the likelihood that such a situation actually leads to an accident depends on e, a driver's vigilance effort which influences $p(e)$, the probability that an accident occurs when meeting another driver. For simplicity, we assume that a driver's vigilance effort does not interact with efforts made by other drivers. Therefore, the probability of an accident conditional on facing a dangerous situation depends only on the driver's vigilance effort. Following Blomquist (1986), let us assume that this probability decreases with the vigilance effort, that is $p_e < 0$, and that $p_{ee} > 0$. Furthermore, we assume that the driver suffers a loss $L > 0$ if an accident occurs. Finally, the driver suffers disutility $D(e)$, with $D_e > 0$, and $D_{ee} > 0$ when exerting vigilance effort e.

Assuming that the driver is risk neutral and that she only wants to maximize her expected utility, she will choose e to maximize the following expression:

$$\mathbb{E}(U) = (1 - c)[-D(e) - p(e)L] - cD(e),$$

where the last term represents the forgone effort made in cases where the light is green and the other driver stops at red light.

The associated first-order condition can be written as:

$$(c - 1) p_e L = D_e, \tag{1}$$

while the second order condition is:

$$(c - 1) p_{ee} L - D_{ee} < 0. \tag{2}$$

Expression (1) implicitly defines the optimal vigilance effort as a function of c. Let us write the differential of (1) to investigate how e varies with c:

$$\frac{de}{dc} = \frac{-p_e L}{(c - 1) p_{ee} L - D_{ee}}.$$

[3]This assumption about the exogeneity of individuals' propensity to behave according to the rules echoes standard assumptions made in the social capital literature about the exogenous distributions of types in the society (see Aghion et al. 2010 and Algan et al. 2016 among others).

Using (2) and because $p_e < 0$ and $L > 0$, we get:

$$\frac{de}{dc} < 0.$$

These results are not surprising in a framework *à la* Blomquist (1986), as an increase in c represents an increase in external—i.e., beyond the driver's direct control—safety conditions. As a reaction, the driver diminishes her own vigilance effort.

2.2 Aggregate accident probability and comparative statics

For a representative driver travelling in an area where drivers have a probability c to follow rules, the aggregate probability of an accident can simply be written as:

$$\mathbb{P}\left(\text{Accident}\right) = (1-c)\, p\left[e\left(c\right)\right],$$

where $e\left(c\right)$ is the function implicitly defined by equation (1) above. Let us write the differential of the aggregate accident probability as:

$$\frac{d\mathbb{P}\left(\text{Accident}\right)}{dc} = (1-c)\, p_e \frac{de}{dc} - p\left[e\left(c\right)\right].$$

This expression is positive if:

$$\frac{p_e \frac{de}{dc}}{p\left[e\left(c\right)\right]} > \frac{1}{1-c}. \tag{3}$$

The left-hand term of expression (3) represents the relative effect of an increase in c on the probability that an accident occurs through the reduction of vigilance effort. The right-hand term of the expression represents the relative effect of an increase in c on the probability that an accident occurs through the direct decrease in the proportion of drivers who do not follow rules. In other words, the above expression means that the probability of having an accident increases with the average propensity to follow rules if the effect of the decrease in vigilance effort exceeds the effect of the reduction in the accident probability induced by an increase in the average compliance to rules.

Condition (3) can be rewritten as:

$$c < 1 - \frac{p\left[e\left(c\right)\right]}{p_e \frac{de}{dc}} \equiv \bar{c}. \tag{4}$$

Expression (4) implicitly defines the threshold $\bar{c}$ below which the accident probability increases with the propensity to follow rules. Above this threshold, the accident probability decreases as the propensity to comply with rules increases. Since $\bar{c}$ cannot be larger than 1, the relationship cannot be increasing for all values of $c \in [0, 1]$.[4] In contrast, the relationship can be decreasing for all values of c since $\bar{c} \leq 0$ can occur.[5] As a consequence, this framework predicts that the relationship between accident probability and the propensity to follow traffic rules is either monotonically decreasing, or bell-shaped.

[4] $\bar{c} \geq 1$ is equivalent to $\frac{p[e(c)]}{p_e \frac{de}{dc}} \leq 0$, which is not possible.

[5] $\bar{c} \leq 0$ is equivalent to $\frac{p[e(c)]}{p_e \frac{de}{dc}} \geq 1$, which may be possible under specific functional forms.

3 Empirical evidence

This section presents empirical evidence regarding the cross-country relationship between road mortality and norms of compliance with rules. We first present the data and the identification strategy. We then present results that support the prediction of the theoretical framework presented in section 2.

3.1 Data and methodology

Because of data availability, there is virtually no way to compute a direct indicator of accident probability at the country level. We thus use the number of road fatalities per $100,000$ inhabitants as a proxy of accident probability. We computed this variable from data made available by the International Transport Forum.

We capture norms of compliance with rules at the country level using two sets of questions from the World Values Survey (WVS) and the European Values Study (EVS). We first select three questions that are directly or indirectly related to road rules. The second set of questions is related to other rules and will help us to deal with potential reverse causality issues, as well as to present results that build on a larger number of observations.

In the WVS and the EVS, questions related to compliance with rules are formulated as follows: "Please tell me for each of the following statements whether you think it can always be justified, never be justified, or something in between, using this card". Proposed answers range from 1 for "never justifiable" to 10 for "always justifiable". Questions that speak to road-related rules use the following statements: "driving under the influence of alcohol"—which we will refer to as *alcohol* in tables and figures—, "taking and driving away a car belonging to someone else"—labelled *joyriding*—and "speeding over the limit in built-up areas"—labelled *overspeed*. We also selected three questions about non-road-related rules. These questions are formulated as presented above and use the following statements: "claiming government benefits to which you are not entitled"—which we will refer to as *benefits*—, "avoiding a fare on public transport"—labelled *transport*—and "someone accepting a bribe in the course of their duties"—labelled *bribe*. For each of the norms of compliance, we construct the share of individuals who report that this behavior is "never justifiable" at the country-year level. This variable represents the share of population that comply with the rule, that is the probability that a random individual comply with the rule.[6]

We use the latest available data from the International Transport Forum, WVS and EVS and construct an unbalanced panel of 40 countries with data from 1981 to 2018.[7,8] We use this sample to test for the existence of a non-linear relationship between road fatalities and norms of compliance with rules.

The theoretical framework developed in the previous section highlighted the possibility of a bell-shaped relationship between compliance with rules and road safety. This non-

[6]While WVS and EVS norms-related questions used a 10-item scale, most of the variation across countries originates from individuals who answer "never justifiable" as opposed to any of the other available answers.

[7]See Appendix Table A1 for the list of countries included in the sample and the years in which they are observed.

[8]The unbalanced panel structure of the sample mostly originates from the fact that not all the questions we use have been systematically included in all WVS and EVS waves, or in all country questionnaires.

monotonicity arises because increasing compliance with rules has two opposite effects on road safety. On the one hand, it reduces the frequency of risky situations. On the other hand, it leads to a decrease in drivers' vigilance efforts. This latter effect occurs through individual choices that are not observable across countries. Accordingly, we rely on a specification where both the direct and indirect effects of compliance with road rules are captured by a quadratic form.

As shown by the variance decomposition statistics displayed in Appendix Table A2, surveys that can be used to capture norms of compliance with rules do not offer sufficient within-country time variation to implement identification strategies that would use country fixed effects. Our empirical identification strategy thus relies on pooled cross-country estimations that exploit differences between countries. We use ordinary least squares to estimate the following expression:

$$\text{Road fatalities}_{it} = \alpha + \beta_1 \text{Norm}_{it} + \beta_2 \text{Norm}_{it}^2 + \mathbb{X}_{it} + \mathbb{T}_t + \varepsilon_{it}, \tag{5}$$

where *Road fatalities* is yearly road fatalities per $100,000$ inhabitants in country i in year t, *Norm* denotes one of the above presented norms of compliance with rules, $\mathbb{X}$ and $\mathbb{T}$ are vectors of covariates and time fixed effects, respectively, and ε is the error term. We account for the repeated observation of some countries by clustering standard errors at the country level. Vector $\mathbb{X}$ includes other determinants of road safety that were documented in the literature (see Loeb 1987, Keeler 1994, Ruhm 1996, Kopits and Cropper 2008, Grimm and Treibich 2013 among others): real GDP per capita in quadratic form, life expectancy, the number of motor vehicles per $1,000$ inhabitants, education, the population age structure, population density and unemployment rate. Sources and definitions of all variables are tabulated in Appendix Table A3. Summary statistics of all variables are presented in Appendix Table A4. Correlations between the different norms of compliance are tabulated in Appendix Table A5. Appendix Table A6 displays correlations between rules compliance variables and covariates. The distributions of norms of compliance across countries are displayed in Appendix Figures A1(a)–(f).

3.2 Results

Table 1 reports the estimated coefficients of expression (5) using road-related norms of compliance. In all cases, a likelihood-ratio test supports the use of the quadratic specification against a linear specification. Point estimates of β_1 and β_2 are positive and negative, respectively, which supports the existence of a bell-shaped relationship between road fatalities and norms of compliance. The associated turning points, computed as $\frac{-\beta_1}{2\beta_2}$, lie within the data range. Formal statistical tests *à la* Lind and Mehlum (2010) can help to deny or confirm the existence of the bell-shaped relationship. The results of these tests are reported at the bottom of Table 1 and unambiguously reject the hypothesis of a monotonic relationship while supporting the existence of an inverted-U relationship between road fatalities and compliance with road-related rules.

An important concern about the above presented results is that there may exist some reverse causality between road fatalities and the spread of road-related norms of compliance with rules. For instance, let us imagine that more frequent traffic accidents lead individuals to be less tolerant regarding dangerous behaviors on the road. This would explain why road fatalities and intolerance toward speeding or drunk driving first co-move. Imagine further that there exists a threshold above which individuals consider the death toll to be so high that the society engages in some opinion-modifying campaign against these risky behaviors while also raising fines for non-compliance with norms, thereby limiting dangerous behavior and lowering the number of road fatalities. This would explain why road fatalities and intolerance toward speeding or drunk driving move in opposite directions once the peak has been reached. An imperfect way to overcome this concern is to use the non-road-related norms of compliance instead of road-related variables. The former are less likely than the latter to be influenced by road safety outcomes. They also offer the advantage of being available for a larger number of country-year pairs. Also, given the observed positive correlation between road-related and non-road-related norms of compliance documented by Appendix Table A5, this approach mimics a reduced form instrumental variable approach.

Table 2 reports the estimated coefficients of expression (5) using non-road-related norms of compliance with rules. These regressions and the associated formal tests convey the same message as the preceding ones: the data support the existence of a bell-shaped relationship between road fatalities and norms of compliance.[9]

Marginal effects of the estimated relationships are reported in Appendix Figures A2(a)–(f). They help to visualize the data range over which an increase in compliance with rules deteriorates road safety outcomes by increasing road fatalities. Similarly, Figures 1(a)–(f) plot the predicted value of road fatalities at different levels of norms of compliance with rules. The displayed bell-shaped relationships help to grasp the order of magnitude of the reported estimates by showing that countries with intermediate levels of compliance with rules have substantially more road fatalities than countries with low or high levels of compliance.

4 Conclusion

In this paper, we studied the relationship between norms of compliance with rules and road safety using a simple theoretical framework that shows that an increase in compliance with road rules has two opposite effects on road safety. On the one hand, more compliance with road rules directly reduces the frequency of dangerous situations. On the other hand, it diminishes individuals' vigilance efforts in reaction to a change in external safety conditions. If the latter effect dominates the former, the initial increase in norms of compliance with rules can induce a deterioration of road safety. This framework helps us to uncover the possible existence of a bell-shaped relationship between norms of compliance with rules and road fatalities. We provide evidence of such a bell-shaped relationship in a cross-section of countries.

The paper faces several limitations. On the theoretical side, a full characterization of the relationship between road safety and compliance with traffic rules would require modelling an n-player model in which norms would be influenced by road outcomes. Such extensive modelling is beyond the scope of this exploratory paper. On the empirical side, the approach used in the paper could be threatened by omitted variables that may influence road deaths and attitudes toward compliance with rules. A first step toward a firmer conclusion could be reached using within-country variations, e.g., variations over time at the country level. Such an approach is unfortunately difficult to implement

[9]Appendix Tables A7 and A8 display estimates we obtain when supplementing (5) with region fixed effects that further account for unobserved correlations across neighboring countries. Estimates of interest and associated tests are comparable to those displayed in Tables 1 and 2.

because of limited data availability or variability. Another way to overcome this concern would require an instrumental variable strategy such as the one used by Nagler (2013a,b) who instrument norms across US states by snow depth during winter months. Gathering international harmonized road traffic data by month, however, is difficult.

Overall, this study rationalizes and documents the existence of a non-linear relationship between road safety and norms of compliance with rules that calls for further investigation. Preliminary lessons can still be drawn from this paper's findings. The theoretical framework we use indeed contains two local optima in terms of accidents: (i) zero-compliance with rules and high individual vigilance efforts and (ii) universal compliance and low vigilance efforts. If we assume that the utility derived by individuals from " breaking the rule" does not enter the social welfare function, then the situation where all drivers comply with road rules becomes the unique optimum. The accident probability is then at its lowest level and no costs are supported for vigilance. As a consequence, any policy that would improve compliance with road rules must be recommended. However, such a policy might first be accompanied by an increase in accidents as shown by the increasing part of the bell-shape documented in this paper. This deterioration of road safety could be interpreted as a signal of an inefficient (and actually detrimental) policy that should be interrupted. However, these paper's results indicate that such an interpretation would be wrong as the initial deterioration of road safety would rather indicates than the decreasing part of the curve has not yet been reached. Policy enhancing compliance with road rules should therefore be continued up to the point where its total effect on road safety is positive.

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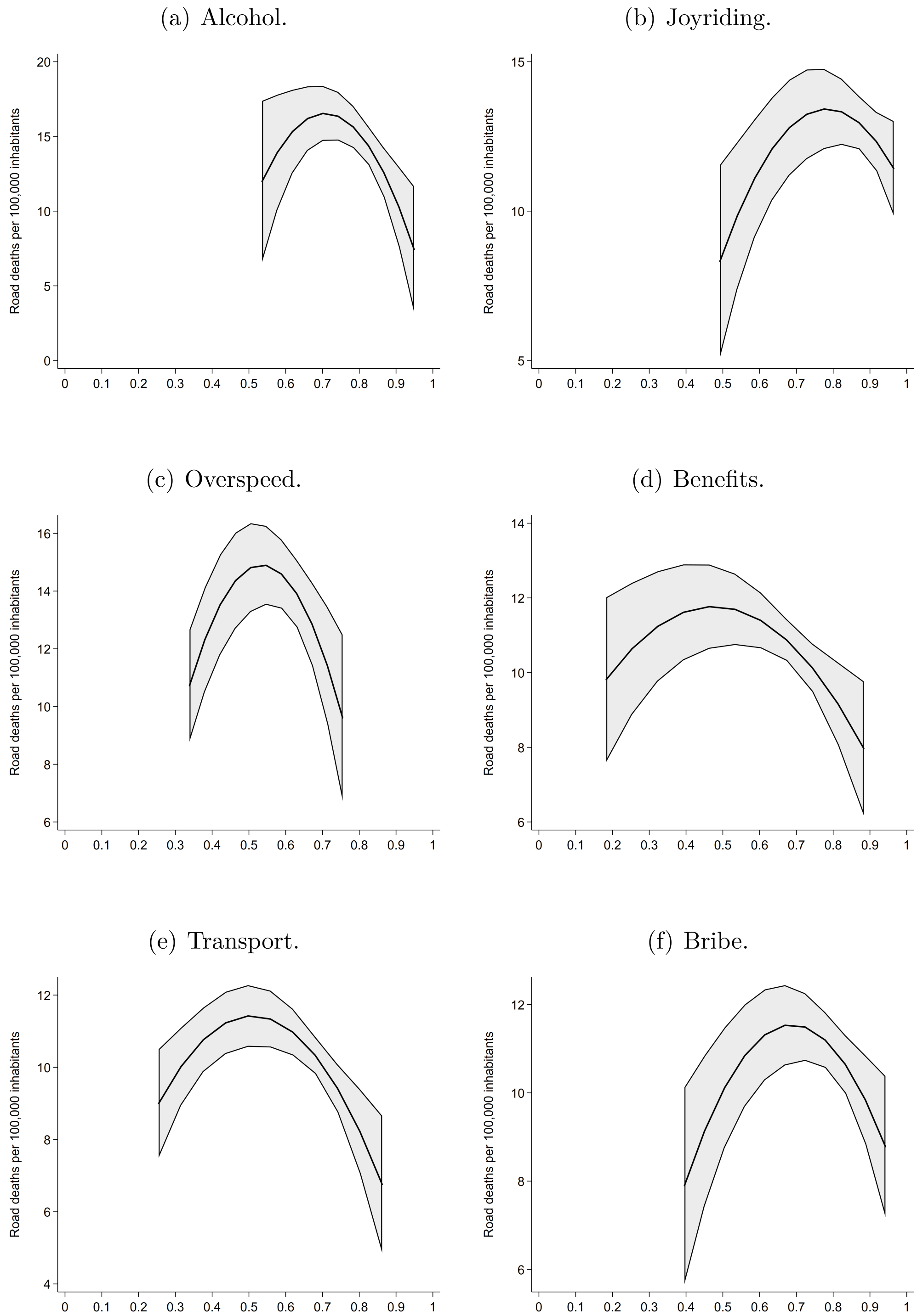
Figure 1: Estimated relationship between norms of compliance with rules and road fatalities.



Predicted values from expression (5). The shaded area represents 90% confidence intervals. See Tables 1 and 2 for raw coefficients and Figure A2 for marginal effects. Predicted values calculated between the 1st and 99th percentiles of each norm of compliance, but for overspeed where the range is restricted by the 5th and 95th percentile of the distribution. Shaded areas represent 90% confidence intervals. See Appendix Table A3 for the sources and definitions of variables.

Table 1: Estimated relationship between road fatalities and road-related norms of compliance.

Dependent variable: Road fatalities per 100,000 inhabitants			
	(1)	(2)	(3)
Alcohol	219.842**		
	(98.119)		
$Alcohol^2$	-155.464**		
	(65.303)		
Joyriding		94.460**	
		(40.469)	
$Joyriding^2$		-60.327**	
		(26.873)	
Overspeed			116.508***
			(25.330)
$Overspeed^2$			-109.019***
			(26.192)
Per capita GDP	-0.172	-0.088	-0.082
	(0.218)	(0.127)	(0.195)
Per capita GDP^2	0.002	0.000	0.000
	(0.002)	(0.001)	(0.002)
Life expectancy	-1.310**	-1.110***	-1.343
	(0.609)	(0.395)	(0.944)
Motor vehicles	0.015*	0.011**	0.025*
	(0.008)	(0.005)	(0.012)
Population aged 15-64	0.745**	0.600**	-0.329
	(0.339)	(0.227)	(0.470)
Population above 65	-0.102	-0.073	-0.567
	(0.363)	(0.244)	(0.368)
Population density	-0.004	-0.008***	-0.002
	(0.004)	(0.003)	(0.004)
Unemployment rate	0.051	0.082	0.301
	(0.164)	(0.172)	(0.211)
Education	-0.025	-0.016	-0.086
	(0.044)	(0.033)	(0.053)
Observations	61	106	28
Adjusted R-squared	0.550	0.595	0.573
P-value of LR test	0.008	0.016	0.001
Turning point	0.707	0.783	0.534
P-value for non-monotonicity	0.038	0.042	0.001

*** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered by country in parentheses. Estimates of expression (5). The *p-value of likelihood-ratio test* tests the estimated model against the one without the squared norm of compliance of interest. The *turning point* corresponds to the value of the norm of compliance such that the derivative of the dependent variable with respect to the latter equals zero. The *p-value for non-monotonicity* is obtained following Lind and Mehlum (2010). See Appendix Table A3 for the sources and definitions of variables.

Table 2: Estimated relationship between road fatalities and nonroad-related norms of compliance.

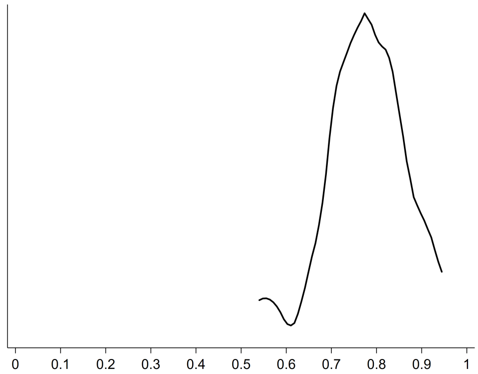
Dependent variable: Road fatalities per 100,000 inhabitants			
	(1)	(2)	(3)
Benefits	21.748**		
	(9.332)		
Benefits^2	-22.864**		
	(8.893)		
Transport		38.161***	
		(13.314)	
Transport^2		-37.466***	
		(12.530)	
Bribe			58.782***
			(19.689)
Bribe^2			-42.729***
			(14.530)
Per capita GDP	-0.038	-0.105	-0.081
	(0.091)	(0.078)	(0.084)
Per capita GDP^2	0.000	0.001	0.000
	(0.001)	(0.001)	(0.001)
Life expectancy	-0.902***	-0.838***	-0.814***
	(0.266)	(0.270)	(0.274)
Motor vehicles	0.010***	0.011***	0.011***
	(0.003)	(0.003)	(0.003)
Population aged 15-64	0.592***	0.722***	0.716***
	(0.178)	(0.195)	(0.191)
Population above 65	0.031	0.004	-0.085
	(0.135)	(0.138)	(0.143)
Population density	-0.004*	-0.003	-0.005*
	(0.002)	(0.003)	(0.002)
Unemployment rate	0.110	0.070	0.102
	(0.112)	(0.111)	(0.118)
Education	-0.000	-0.005	0.005
	(0.027)	(0.027)	(0.028)
Observations	219	205	222
Adjusted R-squared	0.671	0.661	0.650
P-value of LR test	0.001	0.000	0.002
Turning point	0.476	0.509	0.688
P-value for non-monotonicity	0.013	0.004	0.006

*** $p<0.01$, ** $p<0.05$, * $p<0.1$. Standard errors clustered by country in parentheses. Estimates of expression (5). The *p-value of likelihood-ratio test* tests the estimated model against the one without the squared norm of compliance of interest. The *turning point* corresponds to the value of the norm of compliance such that the derivative of the dependent variable with respect to the latter equals zero. The *p-value for non-monotonicity* is obtained following Lind and Mehlum (2010). See Appendix Table A3 for the sources and definitions of variables.

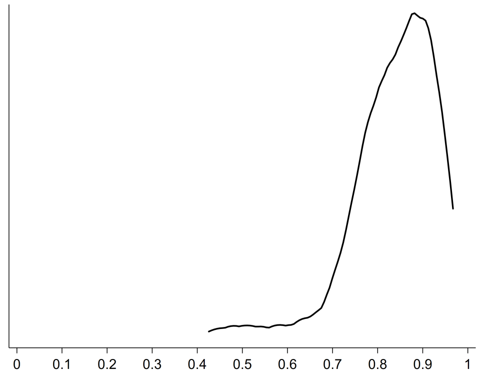
Appendix

Figure A1: Distributions of norms of compliance.

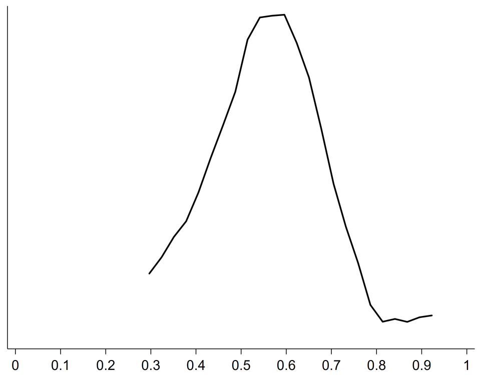
(a) Alcohol.



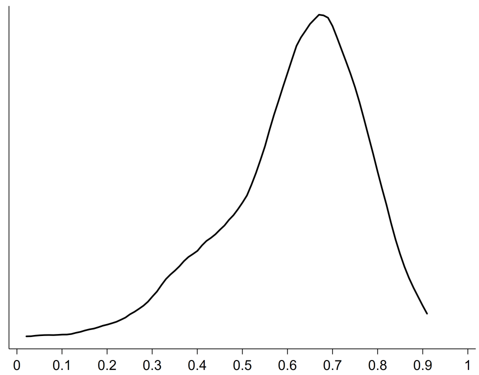
(b) Joyriding.



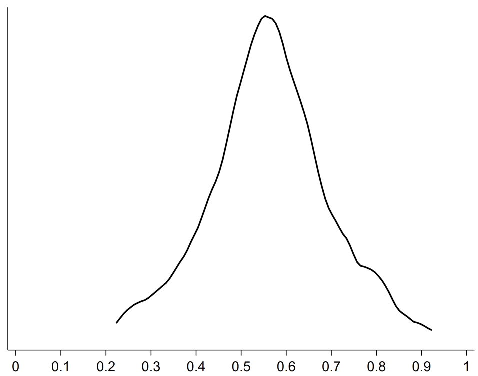
(c) Overspeed.



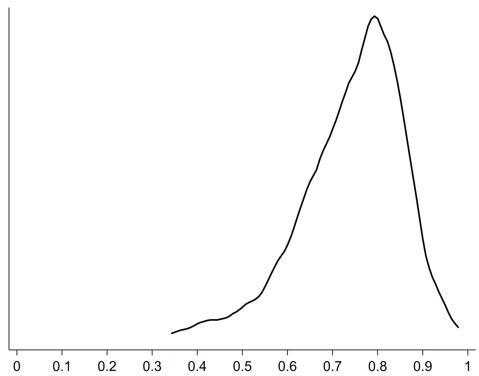
(d) Benefits.



(e) Transport.



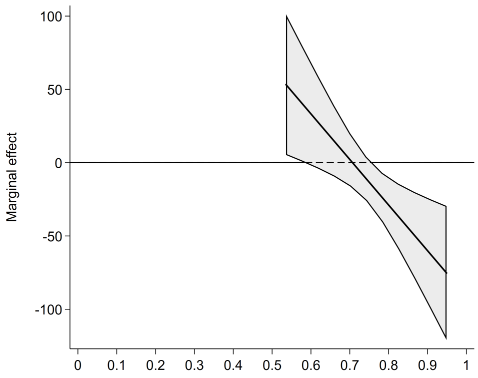
(f) Bribe.



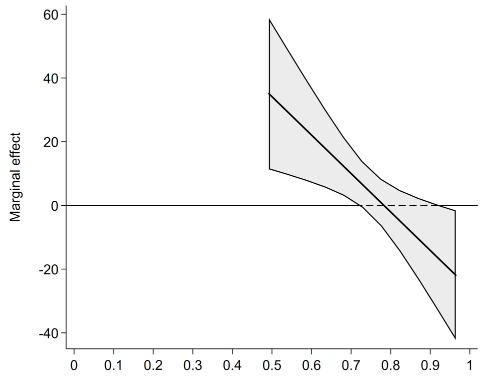
Distributions obtained using a kernel-density estimation on 100 points over the full range of data. See Appendix Table A3 for the sources and definitions of variables.

Figure A2: Marginal effects of norms of compliance on road fatalities.

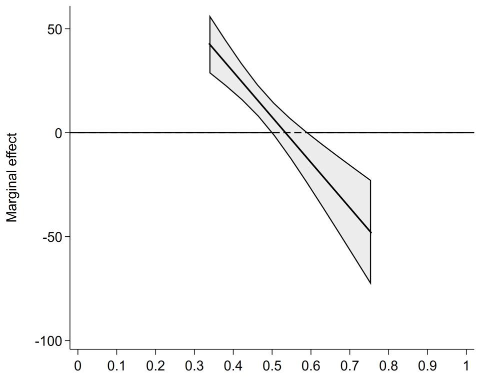
(a) Alcohol.



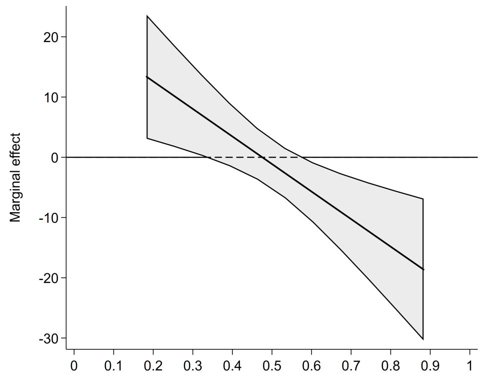
(b) Joyriding.



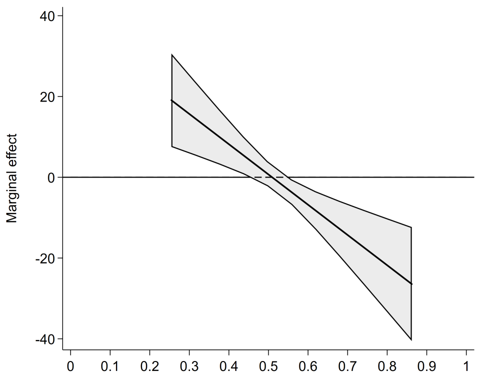
(c) Overspeed.



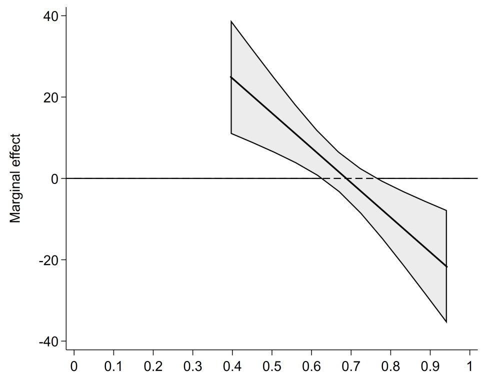
(d) Benefits.



(e) Transport.



(f) Bribe.



Marginal effects from expression (5). The shaded area represents 90% confidence intervals. See Tables 1 and 2 for raw coefficients. Marginal effects calculated between the 1st and 99th percentiles of each norm of compliance, but for overspeed where the range is restricted by the 5th and 95th percentile of the distribution. See Appendix Table A3 for the sources and definitions of variables.

Table A1: List of countries included in the sample (with observation years).

Australia (1981, 1995, 2005, 2012, 2018)	Lithuania (1990, 1997, 1999, 2008, 2018)
Austria (1990, 1999, 2008, 2018)	Luxembourg (1999, 2008)
Belgium (1981, 1990, 1999, 2009)	Malta (1983, 1991, 1999, 2008)
Bulgaria (1991, 1997, 1999, 2006, 2008, 2017)	Mexico (1981, 1990, 1996, 2000, 2005, 2012, 2018)
Canada (1982, 1990, 2000, 2006)	Netherlands (1981, 1990, 1999, 2006, 2008, 2012, 2017)
Croatia (1996, 1999, 2008, 2017)	New Zealand (1998, 2004, 2011, 2020)
Czech Republic (1991, 1998, 1999, 2008, 2017)	Norway (1982, 1990, 1996, 2007, 2008, 2018)
Denmark (1981, 1990, 1999, 2008, 2017)	Poland (1989, 1990, 1997, 1999, 2005, 2008, 2012, 2017)
Estonia (1990, 1996, 1999, 2008, 2011, 2018)	Portugal (1990, 1999, 2008)
Finland (1981, 1990, 1996, 2000, 2005, 2009, 2017)	Romania (1993, 1998, 1999, 2005, 2008, 2012, 2018)
France (1981, 1990, 1999, 2006, 2008, 2018)	Serbia (1996, 2001, 2006, 2008, 2017, 2018)
Germany (1981, 1990, 1997, 1999, 2006, 2008, 2013, 2017, 2018)	Slovakia (1990, 1991, 1998, 1999, 2008, 2017)
Greece (1999, 2008, 2017)	Slovenia (1992, 1995, 1999, 2005, 2008, 2011, 2017)
Hungary (1982, 1991, 1998, 1999, 2008, 2009, 2018)	South Korea (1982, 1990, 1996, 2001, 2005, 2010, 2018)
Iceland (1984, 1990, 1999, 2009, 2017)	Spain (1981, 1990, 1995, 1999, 2000, 2007, 2008, 2011, 2017)
Ireland (1981, 1990, 1999, 2008)	Sweden (1982, 1990, 1996, 1999, 2006, 2009, 2011, 2017)
Israel (2001)	Switzerland (1989, 1996, 2007, 2008, 2017)
Italy (1981, 1990, 1999, 2005, 2009, 2018)	Turkey (1990, 2007, 2009, 2011, 2018)
Japan (1981, 1990, 1995, 2000, 2005, 2010, 2019)	United Kingdom (1981, 1990, 1999, 2005, 2008, 2009, 2018)
Latvia (1990, 1996, 1999, 2008)	United States (1982, 1990, 1995, 1999, 2006, 2011, 2017)

Table A2: Variance decomposition of norms of compliance.

	Alcohol					Benefits				
	Partial SS	df	MS	F	P-value	Partial SS	df	MS	F	P-value
Model	0.42	40	0.01	6.31	0.000	3.48	67	0.05	5.01	0.000
Country	0.41	34	0.01	7.23	0.000	2.94	38	0.08	7.47	0.000
Time	0.01	6	0.00	0.55	0.768	0.23	29	0.01	0.76	0.808
Residual	0.03	20	0.00			1.57	151	0.01		
Total	0.46	60	0.01			5.05	218	0.02		
N	61					219				
R-squared	0.927					0.690				
	Joyriding					Transport				
	Partial SS	df	MS	F	P-value	Partial SS	df	MS	F	P-value
Model	0.87	48	0.02	7.70	0.000	2.65	67	0.04	6.18	0.000
Country	0.78	36	0.02	9.23	0.000	1.75	38	0.05	7.20	0.000
Time	0.04	12	0.00	1.46	0.150	0.51	29	0.02	2.74	0.000
Residual	0.13	57	0.00			0.88	137	0.01		
Total	1.00	105	0.01			3.52	204	0.02		
N	106					205				
R-squared	0.866					0.751				
	Overspeed					Bribe				
	Partial SS	df	MS	F	P-value	Partial SS	df	MS	F	P-value
Model	0.48	27	0.02	n/a	n/a	1.96	68	0.03	5.18	0.000
Country	0.48	27	0.02	n/a	n/a	1.50	39	0.04	6.88	0.000
Time	n/a	0	n/a	n/a	n/a	0.22	29	0.01	1.38	0.102
Residual	0.00	0	n/a			0.85	153	0.01		
Total	0.48	27	0.02			2.81	221	0.01		
N	28					222				
R-squared	1.000					0.697				

The table displays statistics of the decomposition of the variance of norms of compliance across countries and time. Abbreviation "n/a" stands for "not applicable". The question related to overspeed is available for one year only. See Appendix Table A3 for the sources and definitions of variables.

Table A3: Variables' description and sources.

	Source	Description
Road fatalities	International Transport Forum	Road fatalities per 100,000 inhabitants.
Alcohol, joyriding, overspeed, benefits, transport, bribe	World Values Survey (2020) and European Values Study (2015, 2020)	Share of respondents who answer " never justifiable" to the following question "Please tell me for each of the following statements whether you think it can always be justified, never be justified, or something in between, using this card". Proposed answers range from 1 for "Never justifiable", to 10 for "Always justifiable". Statement used are "Driving under the influence of alcohol", "taking and driving away a car belonging to someone else", "speeding over the limit in built-up areas", "claiming government benefits to which you are not entitled", "avoiding a fare on public transport" and "someone accepting a bribe in the course of their duties".
Per capita GDP	World Development Indicators	Per capita GDP in constant thousand US$.
Life expectancy	World Development Indicators	Life expectancy at birth.
Motor vehicles	International Transport Forum	Road motor vehicles per one thousand inhabitants
Population aged 15-64	World Development Indicators	Share of population aged 15-64.
Population above 65	World Development Indicators	Share of population above 65.
Population density	World Development Indicators	Population density in people per sq. km of land area.
Unemployment rate	World Development Indicators	Unemployment rate from ILO estimates.
Education	World Development Indicators	Share of population aged 25 or more that at least completed upper secondary education.

Table A4: Summary statistics.

	# of countries	Obs.	Mean	Std	Min	Median	Max
Road fatalities	40	222	10.88	5.84	2.01	9.94	32.93
Alcohol	35	61	0.78	0.09	0.54	0.78	0.95
Joyriding	37	106	0.84	0.10	0.43	0.86	0.97
Overspeed	28	28	0.56	0.13	0.29	0.56	0.93
Benefits	39	219	0.62	0.15	0.02	0.64	0.92
Transport	39	205	0.56	0.13	0.22	0.56	0.93
Bribe	40	222	0.74	0.11	0.34	0.76	0.98
Per capita GDP	40	222	28.97	19.81	3.23	27.06	108.58
Life expectancy	40	222	76.54	3.84	64.26	76.72	83.98
Motor vehicles	40	222	532.24	184.21	111.84	560.51	906.50
Population aged 15-64	40	222	66.52	2.54	51.39	66.56	73.19
Population above 65	40	222	14.43	3.79	3.86	14.75	27.05
Population density	40	222	148.05	185.61	1.94	97.95	1279.31
Unemployment rate	40	222	7.90	4.33	1.47	7.08	22.67
Education	40	222	62.11	19.76	12.80	66.21	89.77

See Appendix Table A3 for the sources and definitions of variables.

Table A5: Correlation between norms of compliance.

	Alcohol	Joyriding	Overspeed	Benefits	Transport
Joyriding	0.633				
Overspeed	0.540	0.613			
Benefits	0.786	0.598	0.592		
Transport	0.529	0.509	0.474	0.687	
Bribe	0.585	0.545	0.380	0.665	0.716

Correlations calculated using the average of each measure at the country-level. See Appendix Table A3 for the sources and definitions of variables.

Table A6: Correlation between norms of compliance and covariates.

	Alcohol	Joyriding	Overspeed	Benefits	Transport	Bribe
Per capita GDP	-0.050	0.067	-0.336	0.164	0.123	0.229
Life expectancy	0.017	-0.071	-0.317	0.065	0.025	0.248
Motor vehicles	0.016	0.044	-0.148	0.149	0.163	0.263
Population aged 15-64	0.067	-0.096	0.191	-0.094	-0.120	-0.134
Population above 65	0.136	0.159	-0.112	0.088	0.050	0.065
Population density	0.291	0.184	0.547	0.228	0.272	0.122
Unemployment rate	-0.006	-0.010	-0.016	-0.136	-0.127	-0.088
Education	0.150	0.089	-0.103	-0.030	-0.200	-0.007

See Appendix Table A3 for the sources and definitions of variables.

Table A7: Estimated relationship between road fatalities and road-related norms of compliance, including region fixed effects.

Dependent variable: Road fatalities per 100,000 inhabitants

	(1)	(2)	(3)
Alcohol	166.866		
	(103.794)		
Alcohol^2	-121.375*		
	(69.598)		
Joyriding		74.369*	
		(37.252)	
Joyriding^2		-46.986*	
		(25.026)	
Overspeed			100.954*
			(53.255)
Overspeed^2			-96.208*
			(48.102)
Per capita GDP	-0.171	-0.169	-0.022
	(0.238)	(0.132)	(0.312)
Per capita GDP^2	0.002	0.001	0.000
	(0.002)	(0.001)	(0.003)
Life expectancy	-1.324**	-1.038**	-1.593
	(0.628)	(0.397)	(1.318)
Motor vehicles	0.010	0.012*	0.022
	(0.011)	(0.006)	(0.013)
Population aged 15-64	0.923**	0.740***	-0.524
	(0.395)	(0.271)	(1.003)
Population above 65	-0.174	-0.046	-0.699
	(0.363)	(0.272)	(0.454)
Population density	-0.007	-0.010***	-0.003
	(0.005)	(0.003)	(0.006)
Unemployment rate	0.012	0.029	0.284
	(0.148)	(0.173)	(0.274)
Education	0.026	-0.025	-0.024
	(0.055)	(0.044)	(0.126)
Region fixed effects	Yes	Yes	Yes
Observations	61	106	28
Adjusted R-squared	0.558	0.591	0.503
P-value of LR test	0.045	0.065	0.020
Turning point	0.687	0.791	0.525
P-value for non-monotonicity	0.116	0.094	0.047

*** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered by country in parentheses. Estimates of expression (5) supplemented by region fixed effects for Central, Northern, Southern, Western Europe and other countries. The *p-value of likelihood-ratio test* tests the estimated model against the one without the squared norm of compliance of interest. The *turning point* corresponds to the value of the norm of compliance such that the derivative of the dependent variable with respect to the latter equals zero. The *p-value for non-monotonicity* is obtained following Lind and Mehlum (2010). See Appendix Table A3 for the sources and definitions of variables.

Table A8: Estimated relationship between road fatalities and nonroad-related norms of compliance, including region fixed effects.

Dependent variable: Road fatalities per 100,000 inhabitants			
	(1)	(2)	(3)
Benefits	18.980**		
	(8.306)		
Benefits^2	-20.202**		
	(7.769)		
Transport		43.556***	
		(15.641)	
Transport^2		-43.443***	
		(14.371)	
Bribe			45.536**
			(19.886)
Bribe^2			-32.868**
			(14.390)
Per capita GDP	-0.109	-0.171*	-0.150
	(0.098)	(0.089)	(0.100)
Per capita GDP^2	0.001	0.001*	0.001
	(0.001)	(0.001)	(0.001)
Life expectancy	-0.859***	-0.804***	-0.768***
	(0.256)	(0.258)	(0.277)
Motor vehicles	0.009**	0.009**	0.009**
	(0.004)	(0.004)	(0.004)
Population aged 15-64	0.692***	0.813***	0.811***
	(0.181)	(0.194)	(0.197)
Population above 65	0.186	0.288*	0.057
	(0.130)	(0.159)	(0.148)
Population density	-0.006***	-0.002	-0.007***
	(0.002)	(0.003)	(0.002)
Unemployment rate	0.099	0.086	0.073
	(0.117)	(0.115)	(0.126)
Education	0.001	-0.015	0.011
	(0.037)	(0.038)	(0.041)
Region fixed effects	Yes	Yes	Yes
Observations	219	205	222
Adjusted R-squared	0.676	0.670	0.653
P-value of LR test	0.005	0.000	0.019
Turning point	0.470	0.501	0.693
P-value for non-monotonicity	0.014	0.005	0.020

*** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered by country in parentheses. Estimates of expression (5) supplemented by region fixed effects for Central, Northern, Southern, Western Europe and other countries. The *p-value of likelihood-ratio test* tests the estimated model against the one without the squared norm of compliance of interest. The *turning point* corresponds to the value of the norm of compliance such that the derivative of the dependent variable with respect to the latter equals zero. The *p-value for non-monotonicity* is obtained following Lind and Mehlum (2010). See Appendix Table A3 for the sources and definitions of variables.