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An assessment of the effects of alcohol consumption and prevention policies on traffic fatality rates in the enlarged EU. Time for zero alcohol tolerance?

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ABSTRACT

Some similarities can be seen in the drink driving policies of European Union (EU) countries but there are also some major differences. Although all member States are aware of the need to address the problem, there are considerable differences in aspects such as blood alcohol limits, alcohol prices and the enforcement of alcohol control laws. Considering that these policies are in place in specific economic and cultural contexts, we evaluate the effectiveness of the set of control policies implemented in the EU in terms of traffic fatality rates following the recent enlargement process. For this, we use a panel during the period 1999–2012 controlling for several explanatory economic, demographic and geographical attributes. We find that policies that may be effective for reducing alcohol consumption among young drivers may lead to improvements in road safety. Our results also show that zero approach maximum alcohol concentration rates do not seem to be a panacea for this problem, since the countries with the strictest limits do not achieve better road safety outcomes. Finally, the influence of alcohol consumption on traffic fatalities seems to be particularly relevant for the male population.

1. Introduction

The European region is well known for its traditional heavy alcohol consumption, especially in Central and Eastern countries (Popova, Rehm, Patra, & Zatonski, 2007), which attracts academic attention to the health implications of its abuse. Much of the research has focused on the association between alcohol consumption and driving (Driving Under the Influence, DUI) (Skog, 2001a, 2001b; Taylor & Rehm, 2012; Taylor et al., 2010), and the influence of alcohol consumption on individual risk perception of traffic accidents (Elias & Shiftan, 2012).

The harmful consequences of alcohol consumption constitute a global health problem, but all European Union (EU) countries apply national laws and policies to control DUI within a concrete framework that determines alcohol consumption patterns and leads to different degrees of effectiveness (Bloomfield, Stockwell, Gmel, & Rehn, 2003; Skog, 2001a). As Ruhm (1996) suggests, characteristics such as driver behavior and cultural drinking tolerance could explain this heterogeneity.

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Furthermore, Britton et al. (2003) point to differences in alcohol consumption levels that could in part explain variability in alcohol-associated mortality.

In this context, whereas previous studies focus on the individual case study of one specific country, we investigate the impact of alcohol consumption and drinking patterns on traffic mortality rates for a panel of EU countries during the 1999–2012 period, controlled by moderator variables relating to economic activity, mobility patterns, demography and geographical situation, and road safety strategies. Our goal is to assess the effectiveness of the different national alcohol control strategies (based on DUI consumption limit laws, economic mechanisms for deterrence determined by alcohol price, minimum age requirements for alcohol consumption) applied by each EU member. This is done taking into account the EU enlargement process including the accession of Baltic and Eastern countries, which are characterized by higher levels of alcohol drinking (see e.g., Popova et al., 2007) while also being well known for being "zero tolerance countries", due to their stricter alcohol control laws.

Our study is opportune and justified because, following Hughes et al. (2011), although a number of European studies have recently been conducted on this topic, further research is needed, as drinking behaviors, price contexts and actions to control alcohol may change over time and may significantly differ from one country to the next, all of which may affect road safety performance. All EU members have developed drink driving control policies (for example, Blood Alcohol Content –BAC- limits; minimum legal age limits for alcohol purchase and consumption; enforcement), but there is a lack of harmonization among members, and political, geographical, cultural, and economic factors may affect both alcohol consumption and health impacts. Furthermore, Vukina and Nestić (2015) find evidence that the enforcement of restrictions on alcohol use does not appear to be efficient at reducing accidents and traffic violations in several European countries.

One example that illustrates the great difference in regulations between States is the national policy on BAC limits, which ranges from zero in countries such as Sweden to 0.8 g/L in others, such as the United Kingdom, while most countries apply the 0.5 g/L rate in line with the European Commission (EC) Recommendation issued in 2003.

This recommendation has been reinforced by the 4th European Road Safety Programme (ERSAP), entitled "Towards a European road safety area: policy orientations on road safety 2011–2020", in which the EC stresses the need for the stronger enforcement of drink driving regulations and preventative measures such as the installation of alcohol interlock devices in vehicles, with mandatory adoption in professional transportation, for example.

Table 1 presents a comparison of the current legal BAC limit and other control alcohol actions in force in the 28 EU member States considered in this paper. As noted above, the applied BAC rates vary considerably, while MDLA (Minimum Legal Drinking Age) laws are predominantly in the range of 16 (Central European countries) to 18 (the majority of States). A tendency for lower BAC limits can be observed in the so-called Eastern EU countries. A mandatory zero tolerance approach for all road users has been in force in the Czech Republic, Hungary, Romania and Slovakia for decades. Meanwhile, the United

Table 1
Alcohol control in 2012.

EU COUNTRY	Minimum legal drinking age limit in years	Maximum permitted BAC rate in g/L (for standard drivers)	Harmonized price index for alcoholic beverages, spirits, wine, beer (annual average 2005 = 100)
Austria	16	0.5	85.99
Belgium	16	0.5	82.07
Bulgaria	18	0.5	119.76
Croatia	18	0.0	93.11
Cyprus	17	0.5	79.09
Czech Republic	18	0.0	86.78
Denmark	16	0.5	86.53
Estonia	18	0.2	105.87
Finland	18	0.5	97.99
France	18	0.5	86.54
Germany	16	0.5	84.25
Greece	18	0.5	103.45
Hungary	18	0.0	110.24
Ireland	18	0.5	68.00
Italy	16	0.5	87.28
Latvia	18	0.5	109.97
Lithuania	18	0.5	97.69
Luxembourg	16	0.5	86.31
Malta	17	0.8	78.72
Netherlands	16	0.5	80.34
Poland	18	0.2	83.43
Portugal	16	0.5	86.95
Romania	18	0.0	93.82
Slovakia	18	0.0	88.69
Slovenia	18	0.5	100.92
Spain	18	0.5	87.05
Sweden	18	0.2	78.60
United Kingdom	18	0.8	93.45

Kingdom and Malta still have a 0.8 g/L BAC limit, which is higher than the EC recommendation of 0.5 g/L. Notwithstanding, according to the SafetyNet project, which analyzes alcohol-related fatalities in the EU (see Podda, 2012 and Rocakova-Filemon & Eksler, 2008), States with zero BAC limits present average numbers of alcohol-related fatalities, while Scandinavian countries with a 0.2 g/L BAC rate present the highest numbers.

Following Rocakova-Filemon and Eksler (2008), it should be noted that the lowest limits have mainly been implemented in former communist EU countries, while the countries with highest limits are for the most part located in the western part of the continent. The motivation for implementing these different limits in each country seems to depend not only on accidents rates but also on specific countries' socio-economics, historical contexts and cultural aspects.

Bearing this context in mind, we aim to answer the following research questions: at an aggregated-level across EU countries, how does alcohol consumption behavior affect road safety? Is this finding influenced by gender and population age groups? How effective are alcohol policy strategies in terms of their effects on road safety considering the EU enlargement process? Are there different socio-cultural, geographical or economic factors that determine the effectiveness of these measures? Is it effective to have a strict limit – zero BAC? Do stricter control strategies lead to better results?

In summary, we believe that by answering these questions we can contribute some recommendations for improving safety through alcohol control policy management.

The paper has the following structure: after this introduction, a review of the recent literature is presented in Section 2; the empirical framework is set out in Section 3; Section 4 discusses the results; finally the conclusions are presented in Section 5, followed by references.

2. Recent research

The recent literature on alcohol consumption and drinking habits has focused on three fields. First, factors that influence consumption patterns (systematic review in Hughes et al., 2011): geographical-cultural aspects (Bloomfield et al., 2003; Room et al., 2012), for example. Second, individual characteristics: gender (Mäkelä et al., 2006; Wilsnack, Vogeltanz, Wilsnack, & Harris, 2000); age (Engels & Knibbe, 2000; McCarthy, 2005; Watling & Armstrong, 2015; Wells & Macdonald, 1999); and beverage preferences (Dey, Gmel, Studer, Dermota, & Mohler-Kuo, 2013), for example. Third, effectiveness of public and police interventions (see Chang, Lin, Huang, & Chang, 2013; Cook, Bond, & Greenfield, 2014; Warner & Forward, 2016): minimum legal age for alcohol purchase or consumption (Loeb, 1987; Plunk, Cavazaos-Rehg, Bierut, & Grucza, 2013; Subbaraman & Kerr, 2013); prices and taxation of alcoholic beverages (Chaloupka, Grossman, & Saffer, 2002; Lhachimi et al., 2012), for example.

Researchers such as Rehm et al. (1996) and Rehm, Greenfield, and Rogers (2001) have reported the adverse health consequences of drinking patterns in general. In this regard, the relationship between alcohol consumption and road traffic accidents (RTA) has attracted attention in recent years, although according to the meta-analysis performed by Taylor et al. (2010), a high heterogeneity can be found among studies due to the different outcome measures of alcohol-related accident involvement that they use. In general, worldwide studies concur in demonstrating the existence of a J-shaped curve, in the sense that the risk of having an accident increases exponentially with an increase in alcohol consumption (Elliot et al., 2009; Keall, Frith, & Patterson, 2004; Knott, Coombs, Stamatakis, & Biddulph, 2015; Ogeil, Gao, Rehm, Gmel, & Lloyd, 2016; Pereira et al., 2011; Zador, Krawchuk, & Voas, 2000). Furthermore, the greater risk of younger drivers being involved in an accident when under the effects of alcohol is stressed in the United States (Brady & Li, 2014); Canada (Callaghan, Gatley, Sanches, Benny, & Asbridge 2016); Australia (Begg, Brookland, & Connor, in press) and European countries (Legrand et al., 2014; Skog, 2001b), due to their lack of driving experience and natural predisposition to risk taking and accident involvement. Similarly, previous recent studies have found that the role of alcohol in traffic injury mortality also varies between different gender groups, with a much greater effect on male than female mortality (Alcañiz, Santolino, & Ramon, 2016; Scott-Parker, Watson, King, & Hyde, 2014; Skog, 2003; Tay, 2005).

There is broad recent evidence available from analyses of the effectiveness of DUI prevention interventions and explorations of a variety of issues (see, for example, the comprehensive analysis by Treno, Marzell, Gruenewald, & Holder, 2014). Some researchers have studied alcohol-related laws and policies such as Blood Alcohol Content (BAC) limits, which are the most widespread strategies according to WHO (2009). These have shown that alcohol-related RTA reduce when BAC is first introduced (Mann et al., 2001), whereas the magnitude of estimated effects may vary considerably when BAC limits are lowered. Lowering BAC limits from 0.10 g/L to 0.8 g/L seems to bring down road traffic injuries and fatalities, although the extent of its impact varies (see e.g., Fell & Voas, 2006 and Wagenaar, Maldonado-Molina, Ma, Tobler, & Komro, 2007 for the US case); lowering limits from 0.8 g/L to 0.5 g/L or under helps reduce traffic injuries and fatalities, although only in some specific contexts and to a lesser extent than in the previous case (see e.g., Albalate, 2008 for the EU and Blais, Bellavance, Marcil, & Carnis, 2015 for Canada); even so-called zero tolerance laws can help reduce alcohol-related injuries and deaths when they are linked to other measures, such as administrative license revocations (Eisenberg, 2003).

Moreover, evidence shows that the effects of introducing or reducing maximum BAC levels may be strengthened when combined with law enforcement behavior: with random breath testing (Fell & Voas, 2003); mass media information campaigns (Elder et al., 2004) or public education programs (Martineau, Tyner, Lorenc, Petticrew, & Lock, 2013), for example.

Apart from BAC laws, scholars have recently explored other regulations such as the Minimum Legal Drinking Age. Authors including Albalate (2008), Voas, Tippetts, and Fell (2003) and Shults et al. (2001) demonstrate that there is evidence that MLDA laws, particularly those that increase MLDA to the age of 20–21, are effective at preventing alcohol-related RTA for the US case, although e.g., following Lindo, Siminski, and Yerokhin (2016), in Australia this positive impact does not seem to be so obvious.

Other economic deterrence mechanism-based measures forming part of comprehensive action to reduce alcohol-impaired driving, such as public policies affecting the price of alcoholic beverages (through taxes), seem to have significant effects on alcohol-related RTA and associated fatalities and injuries (Chaloupka et al., 2002; Saar, 2015; Wagenaar, Livingston, & Staras, 2015).

In short, most of the literature that explores both the influence of drinking patterns on road safety and the effectiveness of alcohol policies considers the US or other individual countries, such as Australia, as case studies (due to the recent regulatory changes in both these countries) and the results are not often controlled by any other variables.

As far as our case study (EU countries) is concerned, there are several studies on the impact of lowering BAC limits to 0.5 g/L or less (0.2 g/L). However, they are for single countries (e.g., Mathijssen, 2005 for the Netherlands; Bernhoft & Behrensdorff, 2003 for Denmark; Norstrom & Laurell, 1997 for Sweden) or are not based on robust methodologies but on simple before-after analyses (Bartl & Esberger, 2000). We therefore believe that Albalate (2008) is possibly the most recent and relevant study on the effects of the reduction of legal BAC limits from 0.8 g/L to the 0.5 g/L. Taking into account a number of variables that could affect the results (such as economic growth, road infrastructure, enforcement level and other simultaneous road safety policies), said author found that the reduction of the BAC limit to 0.5 in EU15 countries during the 1991–2003 period significantly improved fatality rates per capita and per km driven (not for the whole population), although with different degrees of effectiveness depending on gender and age.

Nevertheless, the sample analyzed by Albalate (2008) was for EU-15 countries and the analyzed period did not extend beyond 2003. Thus this author did not consider the subsequent EU enlargement that included Baltic and Eastern countries (with the accession of Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia in 2004; Bulgaria and Romania in 2007; and finally, Croatia in 2013).

Our current study therefore contributes to the prior literature in several respects. First, to our knowledge this is the first evaluation of alcohol control policies (not only BAC) to date for a panel data of EU28 countries that considers the main EU enlargement process. Second, this wide panel introduces a set of explanatory variables and major policy interventions that enable us to examine the aspects that affect the relationship between alcohol consumption and traffic fatality rates in the EU and considers several economic deterrence factors not previously tested for the EU case, such as alcohol prices. Third, we think that one of the paper's main strengths is its analysis of this association's geographical influence, with the inclusion of member States that have recently joined the EU and well known 'zero tolerance' countries. All this enables us to offer the first evidence as to how EU's alcohol control policy affects road safety at the aggregate EU level.

3. Empirical analysis

We construct an original panel of EU28 country data from 1999 to 2012. The unit of observation is the country-year pair. However, data for some alcohol-related variables are unavailable for some countries (Bulgaria, Croatia, Cyprus, Latvia, Lithuania, Malta and Romania). Consequently, our sample study includes the following countries that joined the EU in the 21st century: the Czech Republic, Estonia, Hungary, Poland, Slovenia and Slovakia. All of these countries except Slovenia present high levels of alcohol consumption and BAC legal limits of under 0.5 g/L.

This must be taken into account when interpreting the results, as the results for the control variables could differ from complete data for all EU28 countries. The final sample comprises 294 observations.

Our model takes this form for country *i* during period *t*:

$$Y_{it} = \alpha + \beta_k X_{it} + \gamma_k Z_{it} + \lambda_k W_{it} + \nu' Year_t + \varepsilon_{it} \quad (1)$$

Y_{it} is the log of the total per capita fatality rate[1] (within 30 days of the accident, as per the Vienna Convention definition); X_{it} contains the vector of the country's economic, geographical and demographic attributes; Z_{it} are alcohol consumption and alcohol policy-related variables; and W_{it} are other road safety policy-related variables. We also include dummies for some years to control for the common trend in all countries in the dataset and ε_{it} is a mean-zero random error.

Tables 2 and 3 provide information about the variables and their descriptive statistics, respectively.

The relationship between a country's economic development and road traffic fatalities may be non-linear (Anbarci, Escaleras, & Register, 2006; Kopits & Cropper, 2005; Law, Noland, & Evans, 2011; Nishitateno & Burke, 2014). Fatality rates may well increase with economic development in very poor countries, due to increased exposure to RTA. However, the relationship between economic development and traffic fatality rates may become flat or even invert after reaching a certain wealth threshold. We test the hypothesis of non-linearity between GDP and traffic fatalities by including GDP and the square of the GDP as explanatory variables. Following the systematic review by de Goeij et al. (2015), we think that this GDP

[1] It would be extremely useful to be able to use alcohol related fatality data. Unfortunately, data in UNECE is only available up to 2009 and values are missing for many countries. Thus, our sample would be too small to perform a robust econometric analysis.

Table 2
Variables: information.

Variables	Description and units	Source
Fatalities per capita	Number of traffic fatalities per billion (1.000.000.000.000) passenger cars-km	CARE database
Motorization	Number of registered passenger cars per thousand inhabitants	UNECE, EUROSTAT
GDP per capita	Per capita gross domestic product in International Comparable Prices (in US$ at 2005 prices and PPP)	EUROSTAT
Motorway density	Number of kms of motorways/km^2 of the country	UNECE, EUROSTAT
Vehicles-km driven	Number of passenger-cars-km expressed in 1000 million km and weighted by national population	EU Directorate General for mobility and transport
Young	Percentage of population between 15 and 24 years old	EUROSTAT
Point system	Index variable that takes a value of 1 if the penalty system driving license is applied; 2 if the demerit system driving license is applied; 0 if no point system is applied	European Transport Safety Council
Speed limits	Maximum permitted speed limits on national highways/motorways expressed in km/h	European Commission Road Safety Website
Male	Proportion of male population expressed as % of males over total population	EUROSTAT
Longitude	Longitude geographical coordinates expressed in decimal degrees	Google maps
Latitude	Latitude geographical coordinates expressed in decimal degrees	Google maps
BAC_05	Maximum permitted BAC rate	European Commission Road Safety Website
Alcohol_consumption	Per capita alcohol consumption expressed in number of liters per inhabitant (age + 15)	OECD
Alcohol_age	Minimum legal age limit for purchasing off premise[a] (low alcoholic beverages) (age in years)	European Commission + International Center for Alcohol Policies
Alcohol_price	Harmonized index of consumer prices (mean annual average for alcoholic beverages, spirits, wine and beer) (year 2005 = 100)	EUROSTAT

[a] Off-premise retail sale refers to the sale of alcoholic beverages for consumption elsewhere and not on the site of sale (for example, in state monopoly stores, wine shops, supermarkets, and petrol stations or kiosks, depending on country regulations).

Table 3
Variables: descriptive statistics.

Variables	Mean	Standard Deviation	Minimum value	Maximum value
Fatalities per capita	102.53	45.26	21	253
Motorization	431.29	111.55	134	686
GDP per capita	25319.24	11610.64	6737	74,128
Motorway density	1.72	1.73	0	6.35
Vehicles-km driven	35.47	294.11	2.18	4248.17
Young	13.22	1.65	10	17.2
Point system (PS)	0.97	0.87	0	2
Speed limits	121.5	13.51	80	130
Longitude	13.92	10.82	−9.00	33.53
Latitude	48.45	6.92	34.84	61.75
BAC_05	0.71	0.45	0	1
Alcohol_consumption	10.83	1.86	6.1	14.8
Alcohol_age	17.35	0.89	16	18
Alcohol_price	78.44	10.02	43.4	119.76

variable can also address the relationship between economic activity and alcohol consumption and, specifically, alcohol-related health problems, such as road traffic accidents.

We also consider the number of passenger cars per capita (motorization), although the expected sign of the coefficient associated with this variable is not clear a priori. Higher levels of motorization may imply higher exposure to RTAs. However, countries with higher levels of motorization may have better infrastructure and vehicles, more advanced policies and more beneficial social attitudes towards road safety (Kopits & Cropper, 2005; Law et al., 2011).

We also take into account the influence of the quality of the transport infrastructure by including a variable for motorway density. In this regard, we may expect a negative relationship between the quality of transport infrastructure and road traffic fatality rates, as found in Albalate and Bel (2012), Jamroz (2012) and Castillo-Manzano, Castro-Nuño, and Fageda (2015, 2016).

Furthermore, we consider the intensity of traffic on the roads by including a variable for the number of passengers-kilometer weighted by country population. The expected relationship between the intensity of traffic and fatalities is not clear a priori. While the overall volume of driving is an indication of the population's exposure to risk of road accidents (Orsi et al., 2012), such a relationship could be dependent upon congestion levels (Li, Graham, & Majumdar, 2012).

Geographical variables relating to the country's longitude and latitude are also included in the empirical analysis as, according to previous researchers such as Rehm et al. (2003) and Room et al. (2012), there are several cultural drinking patterns linked to geographical aspects.

We also consider a variable for the percentage of the population aged 15–24 years. In this regard, we may expect that risk exposure is higher for the younger population because younger road users usually take more risks (Langford, Methorst, & Hakamies-Blomqvist, 2006). Thus, our expectation is that this variable should be positive.

As for road safety policy variables, an explanatory variable is included to examine the effects of any type of driving license point system. This takes a value of one if a penalty driving license system is applied, two if a demerit driving license system is applied, and zero if no point system is applied. We expect a negative sign in the coefficient associated with this variable (following Castillo-Manzano & Castro-Nuño, 2012). Another traffic policy variable is the maximum permitted speed limit on motorways. According to previous studies (Elvik, 2012), we expect a positive sign in the associated coefficient, as the consequence of a higher speed limit may be a greater number of traffic fatalities.

The variables of main interest in our analysis are those related to alcohol consumption and those that are alcohol related. We expect a positive sign in the coefficient associated with our alcohol consumption variable, as higher consumption levels may lead to more accidents.

Following previous studies (Albalate, 2008; Castillo-Manzano, Castro-Nuño, & Fageda, 2013; Castillo-Manzano, Castro-Nuño, & Fageda, 2014; Eisenberg, 2003), we include a variable for the maximum permitted BAC limit.

We also include additional variables for alcohol-related policies that have received less attention in the literature than BAC rates: i.e., a variable that captures the legal age limit for purchasing off-premise alcoholic beverages, and a variable for the price of alcohol. We expect a negative effect on road safety outcomes for both of these variables. Regarding the minimum legal age limit, O'Malley and Wagenaar (1991) and Subbaraman and Kerr (2013) provide evidence that lowering the minimum age limit would increase drinking rates and their harmful consequences. With respect to the price of alcohol, Chaloupka et al. (2002) reviewed the impact of the price of alcohol on drinking and abuse-related outcomes, and supported the Lhachimi et al. (2012) conclusion for 11 EU countries that a price rise would lead to significant reductions in alcohol consumption and health impacts.

We expect a negative sign in the coefficient associated with these variables, namely Alcohol_price and Alcohol_age, when we consider certain age groups, since they may reduce alcohol consumption and the likelihood of risky attitudes by young drivers as, according to Wells and Macdonald (1999), there is a significant link between consumption patterns and RTA among the younger population.

Engels and Knibbe (2000) find geographical patterns for two drinking behaviors: young people from Mediterranean countries characterized as "innovative" and young people from Northern countries with "rebel" behaviors.

Finally, we also consider different gender-related patterns. According to Wilsnack et al. (2000), gender differences in alcohol consumption may be reinforced by certain social gender roles connected with alcohol abuse by men exceeding that of women (Mäkelä et al., 2006) with, as stated by Legrand et al. (2014), drunk drivers more likely to be men, especially in European countries. We run two additional regressions to account for gender differences, in which the dependent variables are the traffic fatality rates for men and women, respectively.

4. Estimates and results

Table 4 shows the correlation matrix of the variables used. Some variables are highly correlated and may cause a multicollinearity issue that could increase estimates of the parameter variance and distort its statistical significance or even, in the most severe cases, produce parameter estimates of implausible magnitude. In this regard, there is a high correlation between GDP and motorization, while motorway density and the geographical variables are highly correlated with several variables.

Variance Inflation Factor (VIF) is a widely used measure for examining the degree of multi-collinearity between explanatory variables. Several rules of thumb associated with VIF have been considered as a sign of severe multi-collinearity. The usual rule of thumb considered in the econometric textbooks is 10, although practitioners may ultimately use lower threshold values, with 5 a being common value. Table 5 shows that VIFs are below 5 for all the variables. However, we report additional regressions excluding one or several of the variables (motorization, motorway density, geographical variables) that may distort the statistical significance of the alcohol-related variables.

Estimates may present problems of heteroscedasticity and temporal autocorrelation in the error term. Indeed, the Wooldridge test for autocorrelation in panel data shows that there may be a problem of serial autocorrelation, while the Breusch-Pagan/Cook-Weisberg test indicates that we may also have a heteroscedasticity problem.

Taking these test results into account, we performed the estimation using the negative binomial method, given that the dependent variable should be considered as a count variable (Anbarci et al., 2006). Note that standard errors are robust to heteroscedasticity and we also assume an AR (1) process in the error term.

Table 6 gives the determinants of the traffic fatalities equation with all variables, while Table 7 shows the regressions that exclude some explanatory variables that could cause a multicollinearity problem.

The sign of the GDP variables suggests a non-linear relationship between traffic fatality rates and economic development. However, the GDP variables seem to have only a modest influence in the context of our data, as they are not statistically significant.

We also find that a higher level of motorization leads to fewer traffic fatalities. Interestingly, this result does not hold when the dependent variable is the traffic fatalities rate for women. Furthermore, the coefficient associated with motorway

Table 4
Correlation matrix.

Variables	Fatal.	Motor.	GDP	Density	Vehicles	Young	PS	Speed	Male	Long.	Lat.	BAC	Alc_cons.	Alc_age	Alc_price
Fatalities per capita	1														
Motorization	−0.26	1													
GDP per capita	−0.36	0.74	1												
Motorway density	−0.21	0.58	0.59	1											
Vehicles−km driven	0.05	0.0005	0.0005	0.009	1										
Young	0.04	−0.63	−0.44	−0.51	−0.13	1									
Point system (PS)	−0.20	0.14	0.14	0.10	−0.03	−0.14	1								
Speed limits	0.15	0.11	0.11	0.28	0.07	−0.10	0.34	1							
Longitude	0.16	−0.35	−0.34	−0.41	0.01	0.13	−0.11	0.01	−0.33	1					
Latitude	−0.38	0.13	0.13	−0.17	−0.11	0.14	−0.19	−0.43	0.04	0.39	1				
BAC	−0.17	0.52	0.55	0.53	0.07	−0.45	0.26	0.21	0.45	−0.54	−0.31	1			
Alcohol_consumption	0.20	0.11	0.11	0.07	−0.13	0.19	0.09	0.11	−0.19	−0.32	−0.08	0.13	1		
Alcohol_age	0.12	−0.47	−0.47	−0.73	−0.14	0.53	0.04	−0.29	−0.15	0.29	0.14	−0.49	0.17	1	
Alcohol_price	−0.43	0.13	−0.02	−0.05	−0.07	−0.34	0.12	−0.09	−0.12	0.23	0.10	−0.03	−0.15	0.09	1

Table 5
VIFs of the variables.

Variables	Variance Inflation Factors
Motorization	4.44
GDP per capita	4.38
Motorway density	3.00
Vehicles-km driven	1.13
Young	2.74
Point system	1.47
Speed limits	2.05
Longitude	2.56
Latitude	2.33
BAC	2.50
Alcohol_consumption	1.29
Alcohol_age	1.42
Alcohol_price	1.42
Mean	2.47

Table 6
Estimates with different dependent variables (negative binomial with an AR-1 distribution).

Independent variables	Dependent variable: Traffic fatalities per billion passengers-km (all)	Dependent variable: Traffic fatalities per billion passengers-km (male)	Dependent variable: Traffic fatalities per billion passengers-km (female)
Motorization	−0.0009 (0.0005)*	−0.0010 (0.0004)**	−0.0003 (0.007)
GDP per capita	0.000013 (0.00002)	0.00002 (0.00002)	0.00002 (0.00003)
GDP per capita^2	−2.20e−10 (2.41e−10)	−2.48e−10 (2.42e−10)	−4.98e−10 (4.40e−10)
Motorway density	−0.27 (0.08)***	−0.25 (0.08)***	−0.30 (0.12)***
Vehicles-km driven	−6.31e−06 (0.00003)	−4.20e−06 (0.00002)	−0.00001 (0.00004)
Young	0.08 (0.03)**	0.08 (0.03)**	0.07 (0.05)
Point system	−0.02 (0.02)	−0.02 (0.02)	−0.03 (0.04)
Speed limits	0.06 (0.03)*	0.06 (0.03)*	0.07 (0.03)*
Longitude	−0.05 (0.02)**	−0.04 (0.02)*	−0.05 (0.02)**
Latitude	0.03 (0.04)	0.02 (0.04)	0.04 (0.04)
BAC	1.78 (1.31)	1.58 (1.32)	1.56 (1.38)
Alcohol_consumption	0.04 (0.01)***	0.05 (0.01)***	0.01 (0.02)
Alcohol_age	0.11 (0.27)	0.15 (0.27)	0.07 (0.2)
Alcohol_price	−0.008 (0.003)***	−0.008 (0.003)***	−0.01 (0.005)***
Intercept	−7.65 (8.33)	−8.89 (8.46)	−9.79 (8.97)
Test joint sign	72.07***	82.99***	42.03***
Breusch-Pagan/Cook-Weisberg test for heteroscedasticity (Ho: Constant variance)	155.80***	110.11***	79.91***
Wooldridge test –autocorrelation (Ho: First-order autocorrelation)	370.87***	166.16***	196.62***
Number of observations	294	267	267

Note 1: Standard errors in brackets.
Note 2:
*** Statistical significance at 1 per cent.
** Statistical significance at 5 per cent.
* Statistical significance at 10 per cent.

density is negative and statistically significant, which confirms that the quality of transport infrastructure has a significant effect on road safety, as found in Jamroz (2012).

Another result of our analysis is that the vehicles-kilometer driven variable is not statistically significant. In the line of Li et al. (2012), more traffic on the roads implies higher exposure to accidents, but this effect may be partially compensated for by lower speeds (and therefore less severe accidents) due to congestion.

Results for the geographical variables suggest that traffic fatalities are higher in Eastern countries. This finding is surprising bearing in mind that, as we have stressed in previous pages, within the EU they are known as the "zero tolerance" countries, due to the stricter BAC limits laws implemented there. Factors such as their higher levels of alcohol consumption and relatively lower alcohol prices due to them having the lowest tax rates (see Popova et al., 2007; Rocakova-Filemon & Eksler, 2008; Solov'ev, 2016) and, above all, the lack of an appropriate enforcement-sanctioning system or drunk driving legislation (as Podda, 2102 demonstrates) may help to explain this finding. We believe that the case of the Czech Republic amply illustrates this point. As said author explains, while this country pioneered the implementation of a zero BAC limit in 1953, systematic breath testing was not introduced until January 2010.

Table 7
Estimates with different explanatory variables (negative binomial with an AR-1 distribution).

Independent variables	Dependent variable: Traffic fatalities per billion passengers-km (all)			
	(1)	(2)	(3)	(4)
Motorization	−0.0006 (0.0003)*	–	–	–
GDP per capita	6.60e−06 (0.00001)	1.28e−06 (0.00001)	0.00001 (0.00001)	−5.15e−06 (7.25e−06)
GDP per capita^2	−1.59e−10 (1.66e−10)	−1.21e−10 (1.76e−10)	−2.20e−10 (2.17e−10)	–
Motorway density	−0.33 (0.05)***	−0.33 (0.06)***	–	–
Vehicles-km driven	−5.27e−06 (0.00002)	−3.90e−06 (0.00002)	−3.61e−06 (0.00002)	−3.81e−06 (0.00003)
Young	–	–	0.13 (0.03)***	0.13 (0.03)***
Point system	−0.02 (0.01)	−0.02 (0.02)	−0.03 (0.03)	−0.02 (0.02)
Speed limits	0.05 (0.02)**	0.06 (0.02)**	0.06 (0.02)**	0.06 (0.02)**
Longitude	–	–	–	–
Latitude	–	–	–	–
BAC	3.26 (1.18)***	3.15 (1.17)***	2.62 (1.17)**	2.74 (1.17)***
Alcohol_consumption	0.03 (0.01)***	0.03 (0.01)***	0.04 (0.01)**	0.04 (0.01)**
Alcohol_age	0.18 (0.26)	0.17 (0.26)	0.39 (0.25)	0.39 (0.25)
Alcohol_price	−0.01 (0.002)***	−0.01 (0.002)***	−0.01 (0.003)***	−0.01 (0.004)***
Intercept	−6.31 (6.90)	−6.33 (6.91)	−13.09 (6.83)*	−12.90 (6.82)*
Test joint sign	181.63***	144.01***	40.48***	40.48***
Breusch-Pagan/Cook-Weisberg test for heteroscedasticity (Ho: Constant variance)	160.46***	133.31***	116.21***	11.95***
Wooldridge test –autocorrelation (Ho: First-order autocorrelation)	370.87***	386.84***	422.41***	484.52***
Number of observations	294	294	294	209

Note 1: Standard errors in brackets.
Note 2:
*** Statistical significance at 1 per cent.
** Statistical significance at 5 per cent.
* Statistical significance at 10 per cent.
Note 3: In regressions (1) and (2) the Young variable is not included because the model does not converge to any value with this variable.

The variable for the percentage of young population is positive and statistically significant, which confirms that the younger population is subject to higher risk exposure. Furthermore, the speed limits variable is positive and statistically significant, so there are fewer traffic fatalities in countries with stricter limits. Note here that this variable is not statistically significant when the dependent variable is the traffic fatality rate for women.

As for the alcohol-related variables, the maximum BAC variable is always positive. However, it is only statistically significant in the regressions that exclude the geographical variables, motorization and motorway density. Note that the correlation of the BAC variable with these other variables is about 0.50. Hence, such high correlation may explain why we do not obtain a statistically significant value when we consider all the explanatory variables. Overall, our results suggest that the imposition of strict BAC rates is effective for reducing traffic fatalities. This is in line with what it is found in previous studies (Dee, 1999; Eisenberg, 2003 and, specifically, Albalate, 2008 for the EU).

However, this finding should be smoothed by the fact that (according to the previously analyzed results for Eastern members with stricter BAC laws in force) lower BAC limits applied exclusively without any other support policies apparently do not necessarily lead to a better road safety outcome.

In terms of elasticities, a 10% increase in permitted BAC rates leads to a 7% increase in traffic fatalities. Values increase up to 11% in the regressions that exclude variables that correlate with BAC rates. In contrast, we find evidence for the effectiveness of the policy to impose stricter legal age limits on alcohol purchase.

The alcohol consumption variable is positive and statistically significant, supporting the generally-held hypothesis that alcohol consumption is one of the main causes of RTA, as posited by Britton et al. (2003), Rehm et al. (1996) and Skog (2001a, 2001b). In terms of elasticities, a 10% increase in alcohol consumption leads to an approx. 5% increase in the traffic fatality rate.

Note also the interesting result that the alcohol consumption variable is not statistically significant when we consider the traffic fatality rate for women. This result corroborates previous findings from other studies, such as Fitzgerald, Angus, Emslie, Shipton, and Bauld (2016), on changes in per capita consumption in Europe being largely driven by changes in male drinking habits, and gender differences may be connected with differences in risk taking by gender.

Finally, as we had anticipated following previous studies by Chaloupka et al. (2002) and Lhachimi et al. (2012), the variable for the price of alcohol is negative and statistically significant. In terms of elasticities, a 10% increase in the price of alcoholic beverages leads to a 7% reduction in traffic fatalities.

5. Conclusions

With the purpose of developing evidence to support the application of alcohol control policies in EU, in the current paper we have explored the econometric association between alcohol consumption and traffic fatality rates per capita, controlled by a set of moderator variables. In fact, this study provides the most in-depth empirical evaluation of the topic conducted to date, both as to the number of control variables used and the number of countries taken into consideration (EU28). The wide panel of countries used and their wide ranging socio-economic and geographical circumstances, together with the large number of control variables used, allow us to be optimistic that the main findings on the effects of alcohol and the policies to prevent alcohol abuse can be extrapolated to areas outside the EU and even outside Europe.

The conclusions are robust irrespective of the estimation method used. They specifically show a clear relationship between the population's alcohol consumption and a higher mortality rate on the roads, and this alone would legitimize the existence of alcohol policies. This relationship may be affected by economic, geographical, and cultural contexts. Specifically, this may be suggested by the significance of the longitude variable. Furthermore, the alcohol consumption variable is not relevant when we focus our attention on women. This result offers an empirical basis for boosting targeted campaigns to prevent alcohol consumption among young males (see Table 6).

The second research question addressed in the current study is related to an evaluation of the effectiveness of alcohol policies to reduce accident-related mortality. Our findings show that specific control strategies that seek to limit alcohol consumption are clearly effective in reducing traffic accidents, even more effective than other more general road safety strategies, such as speed limits.

To be specific, the results of this paper would support a rise in the price of alcohol, through higher sales taxes, for example (in view of the significance of the Alcohol_price variable). This is an interesting proposition given the need of certain EU members to increase their indirect taxes on food & beverages in the current economic situation in order to comply with the public deficit requirements set by Brussels (see for example, Fernandes & Mota, 2011 on differences in performance concerning deficit criteria shown by certain southern and peripheral European countries).

Finally, regarding road safety policy, our findings agree with earlier studies that support the lowering of legal BAC limits. In line with previous research, this study has demonstrated that the policy to lower legal BAC levels to 0.5 g/L seems to be effective in Europe. Nevertheless, considering our findings, the EU's recent enlargement and the incorporation of Eastern European countries show that stricter BAC limits alone are not enough to bring about better road safety outcomes as long as support measures based on economic deterrence mechanisms (higher tax rates) and an appropriate and immediate punitive enforcement system are not in place.

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