Lowering Blood Alcohol Content Levels to Save Lives: The European Experience

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Abstract

Road safety is of increasing concern in developed countries because of the significant number of deaths and large economic losses. One tool commonly used by governments to deal with road accidents is the enactment of stricter policies and regulations. Drunk driving is one of the leading concerns in this field and several European countries have decided to lower their illegal Blood Alcohol Content levels to 0.5 mg/ml over the last decade. This study uses European panel-based data (CARE) for the period 1991–2003 for the first time to evaluate the effectiveness of this transition by applying the differences-in-differences method in a fixed effects estimation that allows for any pattern of correlation (Cluster-Robust). The results show positive policy impacts, particularly on certain groups of victims, such as young males in urban zones. However, there are reasons to expect a short lag in that effectiveness. © 2008 by the Association for Public Policy Analysis and Management.

INTRODUCTION

Road accidents are the fourth leading cause of death worldwide for persons between the ages of 15 and 59, and are expected to reach the third position for the entire global population by 2020 (World Health Organization, 2003). Indeed, this is a public policy concern that affects low- and high-income countries, and both the United States and the European Union (EU) are currently involved in efforts to reduce accidents and their consequences.

According to the Directorate of Energy and Transportation of the European Commission, more than 41,000 people died and 1.9 million were injured on European roads in 2005. In the United States, more than 43,000 road users died and 2.5 million were injured in that same year. This huge number of victims alone may be a compelling reason to make the reduction of such crashes an important objective for government, leading to the implementation of costly measures. Support for active policies also may be bolstered by the economic consequences of road accidents. In fact, the European Commission has estimated the yearly losses related to road accidents at 45 million euros and this estimation increased after the EU enlargement to 200 million—approximately 2% of the European GDP—in 2005.[1, 2]

During the last 15 years, several measures have been implemented to improve and promote road safety in the United States and Europe. Nevertheless, the fatality

[1] COM (97) 131. Promotion of road safety in the European Union 1997–2001.

[2] The direct economic cost of world road crashes has been estimated by Peden et al. (2004) at US$518 billion a year.

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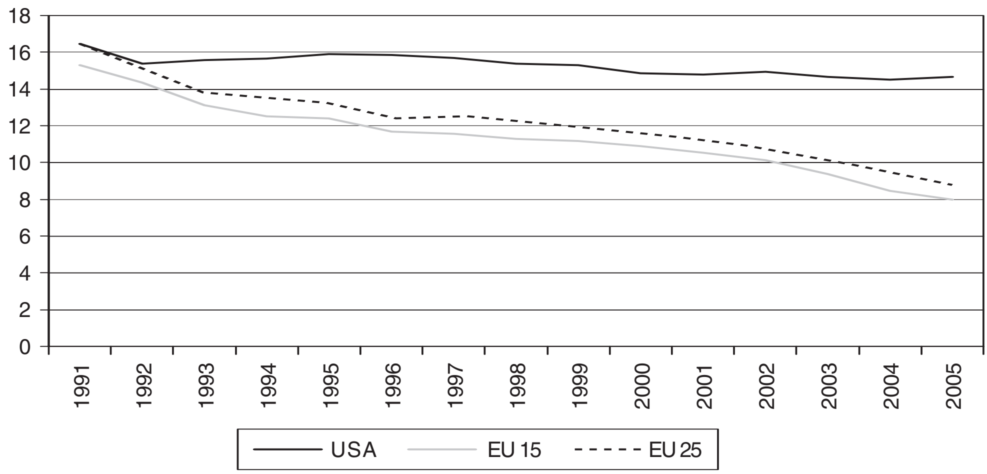


Source: FARS, NHTS, and Eurostat.

Figure 1. Road fatalities: Fatality rate per 100,000 population (1991–2005).

rates per population for the two areas have followed different trends, as shown in Figure 1. In the United States, the fatality rate per population decreased only slightly after 15 years, whereas in the European Union countries (EU15 and EU25), there was a significant decline during the same period. This success suggests that American policymakers might benefit from looking more closely at European policies.

That alcohol consumption has a dramatic impact on a driver's ability to drive is both well demonstrated and socially accepted. In 2003, the European Commission estimated that at least 10,000 road users died every year in alcohol-related accidents, resulting in about 10,000 million euros lost in social value. Although U.S. alcohol consumption per capita is only about three-quarters of European rates, the absolute number of victims is higher in the United States, where more than 17,500 people died in alcohol-involved accidents in 2006 (40 percent of all road fatalities).[3] Thus, governments in both areas have tried to discourage drunk driving with specific regulations.

One common response in developed countries has been to set or lower Blood Alcohol Content (BAC) limits.[4] In the United States, for instance, several states had lowered their BAC limit to 0.8 mg/ml by the end of 1998. This BAC limit was already common in Europe during the 1970s and 1980s. Since 1994, the region has experienced an imperfect trend toward a lower limit.[5] Since that year, most former EU15 countries have lowered their illegal BAC limits, usually from 0.8 mg/ml to 0.5 mg/ml, the limit that had already been established in a few countries. This process is almost complete. This study evaluates the effectiveness of lowering illegal BAC limits to 0.5 mg/ml as means of reducing road fatalities in Europe.

This study contributes to the literature in being, as far as I know, the first evaluation of BAC policies that uses international panel-based data for the former EU15

[3] The latest available data on alcohol consumption per capita shows that in 2003 the United States consumed 8.4 litres per capita, whereas in Europe (EU15) this quantity was 11.0 litres. This difference has been steady for the last 20 years, always showing a three-point gap (OECD Health Data, 2006).
[4] A BAC level is the number of grams of ethanol per litre of blood.
[5] I call it an imperfect process of homogenization because some countries never lowered that limit and still have an illegal BAC limit of 0.8 mg/ml.

countries while taking into account fixed effects and cluster-robust estimation procedures. Moreover, this research aspires to fill the gap created by the lack of econometric studies evaluating the transition from higher BAC limits to the 0.5 mg/ml level.[6]

My main results show that lowering BAC limits to 0.5 mg/ml has been an effective tool for saving lives in some road user groups. Of these groups, we emphasize the cases of males, especially in urban areas, and all drivers between 18 and 49 years old. However, the 0.5 mg/ml BAC limits are not found to be statistically significant for the whole population when one controls for other concurrent policies and infrastructure quality, which can confound policy effects. Moreover, I find some reasons to believe that a short time lag exists, and the biggest impacts are not achieved until the third year following adoption of new BAC limits.

This study is organized as follows. First, I describe the evolution of the legislative process that led to the homogenization of BAC limits, emphasizing the role taken by national and European institutions. The next section introduces the related literature that has studied the effectiveness of setting and lowering BAC levels, focusing attention on the most recent and accurate studies that use panel-based data and differences-in-differences as a method of evaluation and the European studies that treat BAC policies. The fourth and fifth sections explain the methods, data, and variables employed, whereas the next provides the main results. Finally, some concluding remarks are reported in the last section.

EUROPEAN AND NATIONAL LEGISLATIONS ON BAC LIMITS

In Europe, illegal Blood Alcohol Content (BAC) levels have always been established by national legislatures. However, European institutions have not remained indifferent, and in 1988, the European Commission (EC) proposed a draft directive to harmonize illegal BAC limits at 0.5 mg/ml in all member states.[7] Only Finland, the Netherlands, Portugal, and Sweden had already legislated this limit. The proposal failed because several member states denied the competence of the European legislation.[8] Although the directive did not prosper, many member states with higher BAC limits decided to adjust them to the level recommended during the following decade (Table 1). Supposing that those decisions were simply a result of the directive would be naive, especially if we take into account that the first reforms had to wait until 1994. However, it is fair to see the EC's proposal as the first important attempt to push for a reduction across Europe of BAC limits to the level of 0.5 mg/ml.

Belgium and France followed the EC's lead in 1994 and 1995, respectively. Later, in April 1997, the EC launched a new program to promote road safety, which included a revival of the 1988 draft.[9] Again, the program called for a reduction in illegal BAC limits, but responsibility was left to national legislatures. In the first two active years of the program, five countries (Austria, Denmark, Germany, Spain, and Greece) decided to join the 0.5 mg/ml group, making a general convergence toward a common prohibited BAC level evident.

[6] The literature was mainly focused in the American experience when several states lowered their illegal BAC levels to 0.8 mg/ml by the end of 1998. None of them established a lower limit.
[7] COM (88) 707. The Commission explains that this level was chosen after some studies and investigations and took into account the public acceptance that the new limit would have and the effectiveness of the reduction.
[8] This proposal was rejected by the Council of Transport Ministers in 1989, when the member states that were against the proposal (the United Kingdom, the Netherlands, and Germany) claimed that there was no community competence to act and no sound justification.
[9] Promotion of road safety in the European Union 1997–2001. COM(97)131.

Table 1. Changes adopted in the illegal BAC limits: EU15 countries.

Country	Changes in Illegal BAC Limits during 1991–2003	BAC Limit (mg/ml) in 2007
Austria	January 1998	0.5
Belgium	December 1994	0.5
Denmark	March 1998	0.5
France	July 1994 / August 1995	0.5
Finland	–	0.5
Germany	April 1998	0.5
Greece	March 1999	0.5
Luxembourg	–	0.8
Ireland	April 1994	0.8
Italy	July 2002	0.5
Netherlands	–	0.5
Portugal	–	0.5
Spain	May 1999	0.5
Sweden	–	0.2
United Kingdom	–	0.8

The final push came in 2001 when, during the last year of the road safety program, the EC published a recommendation that included the reduction of BAC limits as one of the most important measures to promote road safety. In that recommendation, the EC established the suggested BAC limit for the European Union at 0.5 mg/ml.[10] The EC further suggested that countries already enforcing the recommended level should continue the trend and reduce the limit as much as possible. For the rest, the Commission invited them to join the group at 0.5 mg/ml. Italy was the only member to reduce its BAC limit to 0.5 mg/ml following the Commission's recommendation, whereas Ireland, Luxemburg, and the United Kingdom preferred to keep the 0.8 mg/ml BAC limit.[11]

As a result of the process of reform, 12 member states of the former EU15 have a BAC limit equal to or lower than 0.5 mg/ml.[12] Three countries met this level before 1991, and eight changed their laws to the European standard between that year and 2003. Figure 2 compares the evolution of the fatality rate in the EU15 countries with the size of population under a 0.5 (or lower) BAC limit.

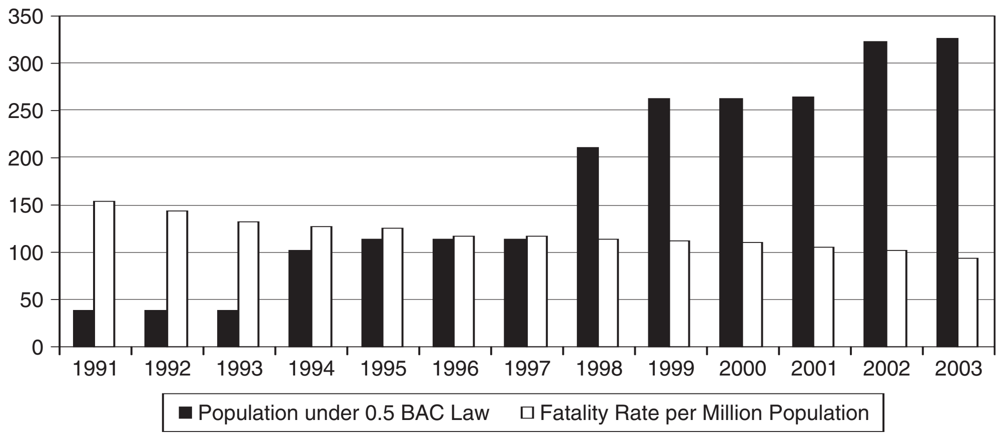
Finally, the chronology reported in Table 1 suggests that, alongside the EC's activity and national politics and interests, regional peer networks seem to have been operating in the expansion of the policy. Belgium and France lowered their limits between 1994 and 1996, whereas the Netherlands already had this limit. Austria, Germany, and Denmark all homogenized their limits in early 1998. Finally, the Mediterranean countries—Greece, Spain, and Italy—were the last nations to switch to the common BAC limit.[13] The United Kingdom and Ireland never reduced their limits to the recommended level, whereas Sweden and Finland have had low BAC limits long before 1991.

[10] European Commission's Recommendation 2001. Official diary L 43 de 14.2.2001.

[11] Looking at Table 1, the reader can notice a change occurred in Ireland 13 years ago. Ireland had a higher illegal BAC level before 1994 and decided to lower it to the level of 0.8 mg/ml. Although there is some discussion in the country about the convenience of lowering it again, no decision has been taken yet.

[12] The only country that established a lower BAC limit is Sweden, whose limit had been 0.5 mg/ml since 1957. Sweden decided to decrease it again, to 0.2 mg/ml. Portugal also passed a reduction in 2001, in an effort to force zero consumption, but after 1 year they returned to the 0.5 mg/ml. level because of economic pressures and no significant effectiveness.

[13] Spain and Greece also lowered their illegal BAC limit in the same year, 1999, to 0.5 mg/ml. Portugal and France already had this limit.



Source: Eurostat.

Figure 2. Population under 0.5 BAC law and fatality rate, EU15 countries.

In conclusion, we have seen how the European countries, inspired by the European Commission's activity, have individually decided to harmonize their BAC limit to 0.5 mg/ml using national legislation. A peer effect based on regions seems to have been relevant as well. This process, which started in the middle of the last decade of the 20th century, is almost finished, and only three countries have not followed the trend.

RELATED LITERATURE

The policy analysis literature has been interested in road accidents for a long time. Recent studies usually attempt to evaluate the effectiveness of public policies and regulations in diminishing road fatalities. Mandatory seat belt devices, vehicle safety inspections, or speed limits are some recurrent examples. It is now socially accepted that alcohol consumption is one of the main determinants of road crashes, and policy analysis and the medical literature also support this idea.[14] As a consequence, policies that were designed to fight drunk driving have been of great relevance in the last two decades, becoming a favourite target for policy evaluators.

Some researchers have recently analyzed several alcohol-related laws and measures. Baughman, Conlin, Dickert-Conlin, and Pepper (2001) and McCarthy (2003), for example, devoted their works to the effects of alcohol availability and alcohol access laws on road safety outputs. Saffer (1997) studied the role of alcohol advertising as a contributing factor of road fatalities, whereas taxes, prices, and other drinking laws have been explored by Ruhm (1996), Benson, Mast, and Rasmussen (1999), and Young and Likens (2000).

Apart from the laws mentioned earlier, the Minimum Legal Drinking Age (MLDA) laws and BAC limits are the two regulations most often treated in the literature. The huge number of alcohol-related accidents suffered by young drivers

[14] Levitt and Porter (1999); Moskowitz and Fiorentino (2000); Zador, Krawchuck, and Voas (2000); Compton, et al (2002); and Keall, Frith, and Patterson (2004) are just some recent examples of scientific studies and medical reviews that prove the negative effects of alcohol consumption on drivers' skills.

and recent regulatory changes undertaken in the United States, Europe, and Australia could explain the particular significance that these regulations enjoy in the literature.[15]

Recent 0.8 BAC literature

Research into the effectiveness of 0.8 mg/ml BAC limit has shown mixed results.[16] As Eisenberg (2003) points out, this is not surprising because of the limitations and varying levels of accuracy of those studies. Most based their analyses on weak research designs, small samples, comparison problems, and limited data, making it impossible to get solid conclusions. Others use data from excessively short postpolicy periods or do not control for simultaneous policies that can confound the real effectiveness of lowering illegal BAC levels. In addition, few studies have tried to use a wide set of explanatory variables to control for unobserved characteristics that can vary from one state to another. However, it is not possible to capture all the heterogeneity by adding a large number of covariates. As a result of at least one of these problems, no study has achieved a robust evaluation (for example, Johnson & Fell [1995]; Rogers [1995]; NHTSA [1991, 1994]; Hingson, Heeren, & Winter [1996, 2000]; Foss, Stewart, & Reinfurt [1998]; Apsler, Char, Harding, & Klein, [1999]; and Shults, Elder, Sleet, Nichols, Alao, Carande-Kulis, et al. [2001]).

Dee (2001) and Eisenberg (2003) do not suffer the drawbacks mentioned earlier and represent, as far as I know, the most technically rigorous and accurate studies published to date. They use a large panel of annual state-level data covering the period 1982–2000 for U.S. states and introduce fixed effects to capture the unobserved heterogeneity.[17] Moreover, several concurrent policies (minimum legal drinking age, seatbelt laws, administrative license revocation, etc.) are introduced in the analysis to avoid confounding factors that could bias the estimates. Other time-varying covariates such as unemployment and vehicle-miles driven are also used. In both studies, results seem to support the effectiveness of lowering illegal BAC levels to 0.8 mg/ml.[18] Dee (2001), for instance, finds a 7.2 percent reduction in the total fatality rate resulting from the new illegal BAC level, whereas Eisenberg (2003) estimates the incremental effect of going from 1.0 to 0.8 mg/ml and finds a reduction of 3.1 percent in the fatal crash rate. In particular, the policy seems to be especially effective in the reduction of fatalities among young people, on weekends, and at night. The last contribution, offered by Eisenberg (2003), was a timing effects evaluation. He found a delay of 6 years in achieving effectiveness, which does not strictly contradict the main result but introduces some doubts about how the policy works.

There is, however, one concern. Dee (2001) and Eisenberg (2003) did not take into account: the possible serial correlation that can arise using differences-in-differences methods with a large panel and a highly time-correlated dependent variable. For that reason, their estimates can overstate significance, as is explained and shown in Bertrand, Duflo, and Mullainathan (2004).

[15] Cook and Tauchen (1984); Asch and Levy (1990); DuMuchell, Williams, and Zador (1987); Saffer and Grossman (1987); and Wagenaar (1993) are some of the interesting studies and reviews of the evaluation of changes in MLDA in the United States.
[16] See Fell and Voas (2003) and Eisenberg (2003) for a literature review on the evidence of lowering BAC laws.
[17] Cook and Tauschen (1984) and Evans and Graham (1988) are probably the first studies that introduced fixed effects in the road safety literature. Ruhm (1996), for example, shows the efficacy of this methodology in the evaluation of road safety measures.
[18] They also find the implementation of 1.0 BAC limits statistically effective in places where no BAC legislation existed before. Eisenberg (2003) finds a higher effect associated with the 0.8 BAC level.

Recent 0.5 (or lower) BAC literature

Unfortunately, studies of the effectiveness of lower BAC limits are scarcer. Many of these works are simple national or regional reports that support the reduction of illegal BAC limits by comparing pre- and poststatistical data. Other studies present the same technical limitations mentioned earlier in the description of the 0.8 BAC literature.

Bartl and Esberger (2000), for instance, compare pre- and poststatistical data for two different BAC reductions that took place in Austria in 1992 and 1998. The first affected novice drivers by lowering their illegal BAC limit from 0.8 mg/ml to 0.1 mg/ml and the second affected the rest of drivers by lowering their limit to 0.5. A decrease of 31 percent in drunk drivers involved in accidents was found after 4 years within the novice group, compared with a concurrent drop for other drivers of only 6 percent. The second BAC reduction achieved a significant 9.4 percent decrease in the total number of drunk driving accidents, according to the authors. In a study of the French province of Haute-Savoie, Mercier-Guyon (1998) concludes that lowering the BAC limit to 0.5 reduced alcohol-related crashes from 100 to 64 immediately after the law changed.

The particular experience of Sweden was treated early, in Aberg (1993) and Norström and Laurell (1997), who found encouraging support for the lowest general BAC limit established in Europe (0.2 mg/ml) using a time-series analysis. After 6 years, the law achieved a 9.7 percent reduction in fatal crashes. Borschos (2000) confirmed that result and added that severe personal injury crashes also decreased by 12 percent.

Noordzij (1994) finds that the proportion of weekend nighttime drivers with illegal BAC levels dropped from 15 percent to 5 percent only 1 year after the 0.5 limit was established in the Netherlands. Unfortunately, this proportion increased again in the following year. Mathijssen (2005) recently confirmed that result. Indeed, the success experienced in the Netherlands between 1970 and 2000 is attributed not only to statutory BAC limit introduction but also to random breath testing, publicity, and police enforcement. In discussing the introduction of the illegal BAC level of 0.5 mg/ml in 1974, Mathijssen confirmed huge effects immediately after enactment, which faded after only 1 year. However, substantial long-term effects have been found to be statistically significant in this recent work.

Not all of the European literature is so optimistic. In Denmark, for example, Bernhoft and Behrensdorff (2003) conclude that only minor changes in the proportion of drunk driving accidents can be found after lowering BAC limits. Nevertheless, a very short postpolicy period is used, which fails to capture the long-term effects of this measure.

Recently, Vollrath, Krueger, and Lōbmann (2005) took advantage of the German political reunification process to study the inverse policy direction: the effect of relaxing BAC levels. Although unification began in 1989, East Germany did not raise its BAC limit to the level established in the West (from 0.0 mg/ml to 0.8 mg/ml) until 1993. According to the authors, the reunification was followed by an important increase in traffic density (1989–1993), which resulted in an increase in crashes, including an increase of the proportion of alcohol-related accidents, especially those involving young drivers. The authors used surveys and interviews to assess the short-term and long-term effects of raising this BAC limit by comparing East regions with West regions where no such legal change had been enacted. Finally, they concluded that the introduction of the 0.8 BAC limit in 1993 did not significantly change the number of alcohol-related crashes.

Finally, leaving Europe, the case of Australia has also been examined in several studies. Henstridge, Homel, and Mackay (1997) use a time-series analysis and find a significant 18 percent reduction in fatal collisions in Queensland and 8 percent in New South Wales.[19] In South Australia, Kloeden and McLean (1994) and Kloeden, McLean, McColl, and Laslett (1995) reported a 14 percent decline in nighttime drinking drivers. However, the lowered BAC limit did not significantly affect the number of legally impaired fatalities.

To conclude, it is important to highlight the purpose of the current research. Because none of the works mentioned uses an international European panel to study this transition in BAC limits, a great opportunity to fill that gap is provided by international databases. In addition, the previous literature also shows some estimation strategies that provide a better understanding of the problem analyzed. This knowledge must be extended and used in current research, but it is also crucial to overcome some of the weakest strategies to get a more robust result. The current study tries to meet both challenges.

EMPIRICAL STRATEGY

This study uses several fatality rates for the former EU15 countries for the period 1991–2003 to evaluate the impact of the reduction of BAC limits that some countries legislated during that time interval. The method chosen is a slight extension of the differences-in-differences estimation procedure specified as a two-way fixed effects model that takes the following form:

$$Y_{st} = X_{st}\beta + \delta Z_{st} + w_s + v_t + \varepsilon_{st} \tag{1}$$

where Y_{st} is the chosen dependent variable (fatality rate), X_{st} contains the vector of time-varying control covariates, and Z_{st} is the policy dummy variable to be evaluated. As usual, w_s and v_t are country-specific and year-specific fixed effects and ε_{st} is a mean-zero random error. Country fixed effects control for time-invariant country-specific omitted variables and year dummies control for national trends. The key element of this differences-in-differences model is the parameter δ, which measures the difference between the average change in the fatality rates of the treatment group (countries that have a BAC level of 0.5 mg/ml or lower at some point during the period studied) and the average change in the fatality rates of the control group (those countries that kept a higher BAC level).

Specifically,

$$\delta = [E(Y_A / G = 1) - E(Y_B / G = 1)] - [E(Y_A / G = 0) - E(Y_B / G = 0)] \tag{2}$$

where Y_B and Y_A denote the road fatality rate before and after the reform and $G = 1$ and $G = 0$ denote treatment and control group observations, respectively.

One of the most basic assumptions of differences-in-differences models is that the temporal effect in the two groups of countries is the same in the absence of intervention. This is called the fundamental identifying assumption and it is described as the equality between average changes in the two groups in the absence of intervention. As in Galiani, Gertler, and Schargrosdky (2005), I test for the equality between average changes in the two groups in the pretreatment period to assess the plausibility of the fundamental identifying assumption. This endogeneity test is as important as it is forgotten in the differences-in-differences applied literature.

The strategy consists of considering only the pretreatment years from each treated country, excluding observations from the treated years. In addition, I add

[19] Still in Queensland, Smith (1986) emphasized the good performance of this law on nighttime accidents some years before.

Table 2. Rates of change in the fatality rate before the 0.5 BAC limit enactment (treated countries).

Country	Change Last Year[1]	Change Last Two Years[2]	Annual Average Change since 1991[3]
Austria	7%	−9%	−6%
Belgium	−1%	−12%	−6%
Denmark	−5%	−17%	−4%
Germany	−3%	−10%	−5%
Greece	3%	1%	0%
Spain	6%	8%	−5%
France	−2%	−10%	−5%
Italy	0%	5%	−2%

[1] Change in the fatality rate suffered in the last year before setting the 0.5 BAC limit.
[2] Change in the fatality rate observed in the last two years before setting the 0.5 BAC limit.
[3] Average rate of variation in the fatality rate since 1991 until the enactment year.

the observations from each control country for the whole period.[20] Once I have the observations of interest, I estimate Equation 1, but now with two important changes. First, I use separate time dummies for treatment and control countries because it allows us to check whether the time trends in the pretreatment period were the same; and, second, I drop out the policy dummy variable.

The results of the test tell us that we cannot statistically reject the hypothesis of having the same time trends in the pretreatment period for control and treatment groups and this reaffirms the robustness of the identifying strategy.[21]

Although Bertrand and colleagues (2004) point out that differences-in-differences models can avoid many of these endogeneity problems, they can still have one important limitation. As Besley and Case (2000) state, policy change is purposeful action and can rarely be treated as experimental data. Therefore, further research is needed to understand what drives policymakers in each case under study.

In this case, I cannot test a policy equation, but I can try to find whether any pattern in the evolution of fatality rates and the decision of lowering BAC levels exists. One could reasonably think that countries that undertook the policy might have suffered a sudden rise in fatalities in their recent past.

The rates of variation constructed, taking into account the last pretreatment years for each treated country and reported in Table 2, reveal that we cannot clearly identify such a pattern. Only a few countries set new illegal BAC levels after suffering positive rates of variation in the last pretreatment years. It is true that the rate of change observed for the last pretreatment year is slightly lower than the annual average change since 1991 for most of the countries. However, all countries, except Spain and Greece, showed decreasing deaths for the 2 years before the change, making it unlikely that governments perceived an important trend change. Moreover, only Austria and Spain suffered a significant growth in the fatality rate in the last pretreatment year. For these reasons, it seems unlikely that BAC limits were lowered generally because of bad shocks in the recent past.

Two other possible explanations are the peer effect and the European Union fight against road fatalities. The detailed description of the legal chronology exposed in

[20] We can use the whole period for the control countries because some countries that still keep high BAC limits (the United Kingdom, Ireland, and Luxembourg) never changed the law during the period considered.
[21] Results on this test and other robustness checks on the estimations later in this article are posted to the Appendix. All appendices are available at the end of this article as it appears in JPAM online. Go to publisher's Web site and use search engine to locate article at http://www3.interscience.wiley.com/cgi-bin/jhome/34787.

the previous section shows how regions seem to have had relevance in the enactment process of BAC limits. At the same time, we cannot ignore the European Commission program launched to promote road safety in 1997, which recommended the 0.5 BAC limit and was followed by several countries. Fortunately, both explanations have nothing to do with endogeneity problems.

In the last effort to overcome endogeneity concerns, I follow the strategy of Eisenberg (2003) and check the time pattern of policy effects with respect to the date of adoption in order to address unobserved factors like attitude shifts that can be partly responsible for the enactment of stricter policies. In addition, these unobserved factors could also explain the prepolicy decrease in fatal crash rates shown for several countries in Table 2. This test consists of the same basic model (1) introduced earlier but now using binary variables related to the time distance in respect to the adoption year instead of the policy dummy. Results of the test tell us that no significant time patterns are found before the enactment.[22]

Finally, Bertrand, Duflo, and Mullainathan (2004) find that most papers that employ differences-in-differences estimation ignore serial correlation problems even when they use many years of data and dependent variables likely to be serially correlated.[23] We cannot forget that the estimated effect of the policy is the common OLS estimate. This generates standard errors that severely understate the standard deviation of a differences-in-differences estimator in the presence of serial correlation. In order to correct this bias, Bertrand and colleagues propose different solutions depending on sample characteristics.

Given the number of countries in this study, the method that performs better according to their Montecarlo simulations is allowing for an arbitrary variance-covariance matrix.[24] For that reason, the results exposed here take into account not only heteroskedasticity but also serial correlation within countries, and this represents one important difference between this study and the works of Dee (2001) and Eisenberg (2003).[25] As is well known, this method is based on the estimation of the variance-covariance matrix, allowing for all types of correlation. The estimator used takes the following form:

$$V = (X'X)^{-1}\left(\sum_{i=1}^{N} u_i' u_i\right)(X'X)^{-1} \qquad (3)$$

$$u_i = \sum_{t=1}^{T} e_{it} x_i$$

where V represents the variance-covariance estimator, X the matrix of independent variables, and N the number of groups (countries). By contrast, e_{it} is the country-year specific residual and x_{it} the vector of independent variables.[26, 27]

[22] This test and other robustness checks are posted to the Appendix. All appendices are available at the end of this article as it appears in JPAM online. Go to publisher's Web site and use search engine to locate article at http://www3.interscience.wiley.com/cgi-bin/jhome/34787.

[23] Three causative factors are found in Bertrand et al. (2004): long time-series, serial correlated dependent variables, and a treatment variable that changes very little within a state over time.

[24] See Bertrand et al. (2004) to check a summary of their Monte Carlo simulations for different number of states.

[25] Dee and Sela (2003) was, as far as we know, the first study that started this estimation strategy in evaluating speed limit changes in the United States.

[26] In fact, this is known as the White-like formula to compute standard errors (White, 1984). Also see Arellano (1987) for a deeper understanding.

[27] Because this method is only valid assymptotically, 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.

DATA AND VARIABLES EMPLOYED

This research is based on the European database CARE (Community database on Accidents on the Roads in Europe), which started collecting data in 1993 and provides information on annual road casualties reported by the countries that form the EU25.[28] The council created this database on road safety outputs (Fatality Rates, Total Fatalities, Total Injuries, etc.) in order to make it possible to identify and quantify road safety problems on the continent.[29] Thus, CARE contains country-level data from 1991 to 2005 for the EU25. However, I am interested in the homogenization in BAC limits that occurred during the decade just before EU enlargement. For that reason, I use only data related to the former EU15 countries. In addition, I only use data up to 2003 because all variables are not available for 2004. As a consequence, I have a sample based on 15 countries during 13 years for Total Fatality Rates (195 observations).

The best characteristic of this database is that CARE allows a high level of disaggregation, making it possible to look at different fatality rates depending on a choice of several victim groups. The available groups are divided by gender, age, zone, and type of road user. Unfortunately, CARE does not contain disaggregated data for Germany. Therefore, I use 14 countries in the analysis of disaggregated dependent variables (182 observations).

The rest of the variables are found in international databases, such as Eurostat, WHO Europe, World Bank Development Indicators, and the World Road Statistics. The policy variables used are found in national and European reports. Table 3 shows the explanatory variables used in this research and their descriptive statistics for the whole sample.

Several dependent variables are used, depending on the age group and gender of the victims, and on the areas where they were killed. These dependent variables are just the fatality rates per million inhabitants of each population group or the fatality rate per 100,000 Km driven.[30] Unfortunately, CARE does not contain the latter. To cover this lack and compare both rates, at least for the aggregated rates, I use data available in the WHO database for Europe.[31]

Before describing the control variables, it is worth noting that including a large list of socioeconomic covariates avoids confounding factors that can bias the impact of the policy by keeping them constant and can also give us a better understanding of which factors may influence road fatalities in Europe.

In Ruhm (1996) we saw that macroeconomic variables can help us to improve our estimation because road fatalities and alcohol consumption are usually procyclical.[32] For that reason, I include unemployment and economic growth rates to account for economic cycle effects.

To the macroeconomic variables I also add some covariates related to transportation and the use of vehicles. These variables are Motorization and Vehicle-Km. I also include infrastructure variables to control the possible effects that road characteristics can have on driving. These variables are Motorways and National Roads (percentage of the total network) and are not usually considered by the literature. The educational background of the population between 15 and 64 years old is also taken into account as an additional socioeconomic covariate.

[28] This database can be consulted online at http://ec.europa.eu/transport/roadsafety.
[29] Council Decision 93/704/EC.
[30] According to Eisenberg (2003), the literature traditionally uses as output measures these fatality rates because of their accuracy and relevance for policymakers.
[31] World Health Organization Regional Office for Europe (HFA-DB Database).
[32] See Evans and Graham (1988) and Ruhm (1995) for a deeper discussion on these relationships.

Table 3. Explanatory variables: Definitions and descriptive statistics.

Explanatory Variables	Description	Mean	S.D.
Unemployment Rate	Unemployment Rate in %.	8.748	4.296
Growth Rate	Rate of change (%) of the Real GDP, PPP$ per capita.	2.750	2.617
Motorization	Number of passenger cars per 1,000 inhabitants.	418.536	93.768
Vehicle-Km Driven	Annual number passenger cars-Km expressed in 1,000 million km and weighted by the national population.	9.146	2.452
Upper Secondary Education	% Population between 16–64 years-old with upper secondary education.	55.911	18.270
Motorways	Proportion in % of Motorways (km) over the total road network.	1.312	0.935
National Roads	Proportion in % of National Roads (km) over the total road network.	8.942	5.105
Minimum Legal Drinking Age	Binary variable: **1** where a minimum legal drinking age exists for any purchase of alcohol. **0** Otherwise.	0.592	0.491
Points License	Binary variable: **1** for countries with driving license that depends on a system based on points. **0** Otherwise.	0.174	0.377
Random Checks	Binary variable: **1** for countries that allow random breath or blood tests on the road. **0** Otherwise.	0.779	0.416
BAC05	Binary variable: **1** Countries with an illegal BAC limit of 0.5 mg/ml or lower. **0** for higher illegal BAC limits.	0.504	0.495

The regulatory binary variables form the last group of covariates. Ruhm (1996), Dee (2001), and Eisenberg (2003) show that it is important to introduce different laws related to road fatalities to avoid confounding effects that may arise in the evaluation of one policy when other legal reforms are simultaneously undertaken. For that reason the Minimum Legal Drinking Age (MLDA) and the Points License are introduced as potentially simultaneous policies. The first takes value 1 for countries in years when they have a defined Minimum Legal Drinking Age for purpose and nonpurpose drinking and for all alcoholic beverages, and 0 otherwise.[33]

The second binary variable takes a value of 1 in country-years in which a system of a driving license based on points is in effect and 0 otherwise.[34] Although I could use other potentially relevant policies, it is important to preserve degrees of freedom. The choice of these two policies is arbitrary but follows the criteria of being comparable across countries and manageable given the differences across national legislations, and of showing within group variation in some countries for the period studied.

[33] The lack of legal homogenization on this limit makes it very difficult to divide this variable on age limits as previous studies have. Several countries define different MLDA for different beverages and for different places. We consider MLDA to have a value of 1 only when all alcoholic beverages have an age limit and when its consumption is not allowed in any place. Fixed effects capture the age limit variability.

[34] The use of Points License as a concurrent policy variable is especially interesting because it is mainly a European policy that has been recently undertaken in some countries and has not been deeply studied so far.

Table 4. Least-squares estimates for semi-logs models: Total fatality rates.

Independent Variables	TFR per Million Population (1)	TFR per 100,000 Km Driven (2)	TFR per Million Population (3)	TFR per 100,000 Km Driven (4)
BAC0.5	−0.0447*	−0.0743*	−0.0339	−0.0429
	(0.0213)	(0.0350)	(0.0271)	(0.0338)
Random Checks	–	–	−0.0040	0.0861
			(0.0758)	(0.0731)
Points License	–	–	0.00556	−0.0618
			(0.0411)	(0.0533)
MLDA	–	–	−0.0121	0.0059
			(0.0215)	(0.0235)
Unemployment Rate	−0.0056	−0.0029	−0.0032	0.0009
	(0.0034)	(0.0052)	(0.0030)	(0.0039)
Growth Rate	0.0096**	0.0048	0.0091*	0.0064
	(0.0042)	(0.0058)	(0.0049)	(0.0059)
Motorization	−0.0024***	−0.0044***	−0.0019**	−0.0040***
	(0.0006)	(0.0004)	(0.0006)	(0.0003)
Vehicle-Km	0.0542	–	0.0381	–
	(0.0399)		(0.0436)	
Upper Sec. Education	0.0074**	0.0074**	0.0046	0.0065*
	(0.0025)	(0.0029)	(0.0030)	(0.0036)
Motorways	–	–	−0.0478***	−0.0464***
			(0.0103)	(0.0124)
National Roads	–	–	0.0033	0.0040*
			(0.0023)	(0.0021)
R-sq.	0.80	0.92	0.81	0.93
Nº observations	195.00	195.00	195.00	195.00

Standard errors are reported in parentheses allowing for clustering by country. Each model also includes time and state fixed effects and a constant term.
* Statistically significant at the 10 percent level; ** at 5 percent level; and *** at 1 percent level.

Finally, the expected key policy variable that serves to evaluate the effectiveness of lowering Blood Alcohol Content legal limits is named BAC0.5. This variable takes a value of 1 in countries and years when a country has an illegal BAC limit of 0.5 mg/ml or lower, and 0 when this limit is higher.[35] A fractional correction is applied for cases in which the policy was implemented at some point during the year. Moreover, Dee (2001) explains that it is not only important to control by policy, but also by the level of enforcement. For this purpose, I use the variable Random Checks to control for the enforcement of this policy. Random Checks identifies countries that authorize and undertake random breath tests on the road.[36]

RESULTS

The estimation results for the total fatality rates are reported in Table 4. Specifications (1) and (2) show that the coefficients associated with the 0.5 mg/ml BAC limit appear to be statistically significant when we do not control for concurrent policies

[35] It is important to point out that Sweden, for example, has a 0.2 mg/ml BAC limit for the whole time series and Portugal presented the same BAC limit in 2001. These facts justify why we control for BAC levels of 0.5 mg/ml or lower.
[36] Alcohol consumption is not included, despite its strong impact on road fatalities, because it is directly affected by the regulation I am evaluating.

and infrastructure quality. On the contrary, in (3) and (4), when those variables are considered, effectiveness declines substantially. In fact, it is not found to be statistically significant for either the total fatality rate per population or the total fatality rate per Km driven for the whole population. However, this does not mean that lowering BAC levels was a neutral policy, as we will see when we move to the disaggregated victim groups.

Macroeconomic variables do not seem to have a strong role on road fatalities in Europe. Only growth rates seem to have an impact on the fatality rate on specifications (1) and (3). Thus, I cannot reject the procyclical effect of road fatalities, but it seems to be weaker than expected.

By contrast, the coefficient associated with motorization is highly statistically significant across specifications. It is worth noting that the negative sign this variable shows can be explained by the level of transport development achieved by the country. There is an important negative correlation between development and accidents, since more developed countries usually enjoy better infrastructures, safer cars, more organized regulations, and more police interventions. Thus, the number of cars per 1,000 inhabitants may be considered as a proxy for the achieved transport development.

Interesting results are obtained regarding the road infrastructure variables. The coefficient associated with Motorways, the best type of road and therefore the safest, is always strongly significant across specifications and presents a negative sign. Moreover, National Roads, roads of a lower quality than motorways but on which users still drive fast, presents a positive sign and statistically significant coefficient in model (4). This result suggests that a road system's quality and characteristics may play a role as well.

Finally, the upper secondary education variable is significant and has a positive impact in several specifications. One possible explanation is that more educated people travel more often and enjoy more leisure. This would act as a proxy of income, a variable that the literature usually finds positively related with accidents because of the positive correlation that exists between income and both alcohol consumption and vehicle use.

Recent works on road fatalities, such as Eisenberg (2003), Dee and Sela (2003), and Grabowsky and Morrisey (2004), have studied the impact of road safety measures on different victim groups. I also follow this strategy in dividing fatalities into age and gender groups. In addition, CARE also allows us to include the difference between urban and non-urban fatalities to check where the policy has been more effective. This last analysis is particularly interesting since Dee (2001) and Eisenberg (2003) do not distinguish by zone.

Table 5 shows the results of applying specification (3) to each disaggregated group. First we consider age groups. Lowering BAC limits seems to be statistically effective for people between 18 and 49 years old but substantive reductions also can be found in other groups. The fatality rates for adults age 18–49 are estimated to fall by a statistically significant 8.2–11.5%. However, fatality effects for older adults are less precisely estimated, but in some cases indicate similarly large reductions—for example, the cases of the 50–59 (9.7 percent) and +70 (7.7 percent) groups.

No important effects are found for the youngest group of teens, but substantial and statistically significant effects are identified for the group between 18 and 25 years old (11.5 percent). This last result is consistent with the estimates of Dee (2001), who finds that 0.8 BAC laws reduced traffic fatality rates by 14 percent among 18- to 20-year-olds and by 9.7 percent among 21- to 24-year-olds.

Gender and zone victim groups are also considered. Males appear to be most affected by the policy, receiving a statistically significant impact of 5.7 percent in

Table 5. Least-squares estimates for semi-logs models: Disaggregated groups (selected results), number of observations (182).

Dependent Variables	BAC 0.5	R^2	Dependent Variables	BAC 0.5	R^2
by age			**by gender & zone**		
14–17	0.0176 (0.1123)	0.32	Males & Urban	−0.0920* (0.0431)	0.64
18–24	−0.1147* (0.0595)	0.57	Males & Nonurban	−0.0470 (0.0361)	0.66
20–29	−0.1050* (0.0515)	0.57	Females & Urban	0.0133 (0.0685)	0.73
30–39	−0.1043** (0.0400)	0.50	Females & Nonurban	−0.0362 (0.0573)	0.42
40–49	−0.0819* (0.0422)	0.44			
50–59	−0.0965 (0.0656)	0.56	**by age & zone**		
60–69	0.0153 (0.0638)	0.64	18–24 & Urban	−0.2067** (0.0849)	0.60
70–79	0.0378 (0.035)	0.58	18–25 & Nonurban	−0.1246** (0.0558)	0.34
+70	−0.0767 (0.0968)	0.41	20–29 & Urban	−0.2794** (0.1049)	0.50
+80	−0.0068 (0.0842)	0.54	20–29 & Nonurban	0.0341 (0.0561)	0.49
by gender			30–39 & Urban	−0.0136 (0.1233)	0.40
Males	−0.0573* (0.0317)	0.73	30–39 & Nonurban	−0.1120* (0.0635)	0.48
Females	−0.0250 (0.0407)	0.73	40–49 & Urban	−0.0972 (0.0771)	0.35
by zone			40–49 & Nonurban	−0.0124 (0.0467)	0.41
Urban	−0.0447 (0.0406)	0.78	50–59 & Urban	−0.1083 (0.0732)	0.50
Nonurban	−0.0362 (0.0573)	0.65	50–59 & Nonurban	−0.0883 (0.0908)	0.46

Two-way fixed effects estimation. Each model includes the rest of explanatory variables, time, and country dummy variables and a constant term. Standard errors allowing for clustering by country are reported in parentheses. The variable motorways is excluded in the models that treat urban road fatalities.
* Statistically significant at the 10 percent level; ** at the 5 percent level; and *** at the 1 percent level.

their fatality rate. On the contrary, females do not seem to receive the benefits of the measure. This result is consistent with the findings of Eisenberg (2003), who states that BAC laws appear to be significant determinants of crash rates for males but not for females.

Urban fatalities also receive a bigger impact than do nonurban fatalities, although it is not statistically significant. This result could be explained by the fact that nonurban fatalities can be caused by other problems more related to speed, sleepiness, and road characteristics. These factors are more likely to be relevant in nonurban than in urban driving, where the speed is usually lower and the characteristics of roads are more homogeneous. Once we introduce the area where the accident happened, the group most affected by the policy is males in urban areas, with an estimated

Table 6. Timing in the effectiveness of lowering illegal BAC levels (selected results), number of observations (182).

Independent Variables After	Males	Urban & Males	Age Group 18–25	Urban & Age 18–25
1 year	0.0180	−0.0076	0.0547	0.0267
	(0.0286)	(0.0425)	(0.0581)	(0.0608)
2 years	−0.0478**	−0.0185	−0.0391	−0.0667
	(0.0207)	(0.0621)	(0.0512)	(0.0956)
3 years	−0.0701	−0.0964*	−0.0852	−0.1451
	(0.0451)	(0.0623)	(0.0669)	(0.1017)
4 years	−0.0759	−0.0937	−0.0875	−0.1957*
	(0.0431)	(0.0628)	(0.0625)	(0.0957)
5 years	−0.0611	−0.1111	−0.1091	−0.1603
	(0.0435)	(0.0617)	(0.1067)	(0.1755)
6 years	−0.0723	−0.1692*	−0.0731	−0.1603
	(0.0555)	(0.0860)	(0.0833)	(0.2252)
7 years	−0.0512	−0.1627	−0.0401	−0.1926
	(0.0567)	(0.1244)	(0.1190)	(0.2234)
8 years	−0.0005	0.0712	−0.0745	0.0057
	(0.0603)	(0.0793)	(0.0969)	(0.1307)
R-sq.	0.74	0.64	0.58	0.59

The same previous models are applied substituting the BAC policy variables by each year after the adoption dummies. Cluster-robust standard errors are shown in parentheses.
* Statistically significant at the 10 percent level; ** at the 5 percent level; and *** at the 1 percent level.

decline of 9.2 percent. The smallest effects are related to female fatalities in both zones.

Finally, a combination of age groups and zones is also treated. Table 5 reports results for the central groups, because no relevant effects are found for 14- to 17-year-old teens and older groups (+60). The young 18–25 group experiences large impacts in both zones, whereas the 20–29 and 30–39 groups only receive this impact in one area. Finally, similar effects apply for the 40–49 and 50–59 groups in both zones. Moreover, urban fatality rates seem to decline more as a result of the adoption of lower BAC levels, with the exception of 30–39 and 40–49, in which this impact only accrues in nonurban zones.

Once I identified the most affected groups, I became interested in evaluating timing effects. Eisenberg (2003) introduced this analysis to this literature and found an important lag of at least 6 years. I replicate the strategy using binary time variables for each year after the enactment of the 0.5 BAC policy. This flexible specification, allowing for each year relative to the adoption year to have its own effect, is applied on male and young fatalities across zones and particularly in urban zones, where higher impacts are found.

Results reported in Table 6 seem to suggest that some short delay in that effectiveness exists. In fact, it is necessary to wait for 2 years or more to observe the biggest impacts on the rate of fatalities. Furthermore, taking into account the coefficient sizes, there is a common pattern that suggests that after the second year of adoption the reduction in the rate of fatalities tends to increase and the biggest impact is achieved between the third and the seventh year. Afterward, and considering the different paths followed by different victim groups, the effect seems to fade off in some groups but remain relevant in others. In conclusion, the benefits from lowering BAC levels are generally expected to be achieved with some delay, but where the highest impacts accrue depends on the victim group. However, substantial long-term effects

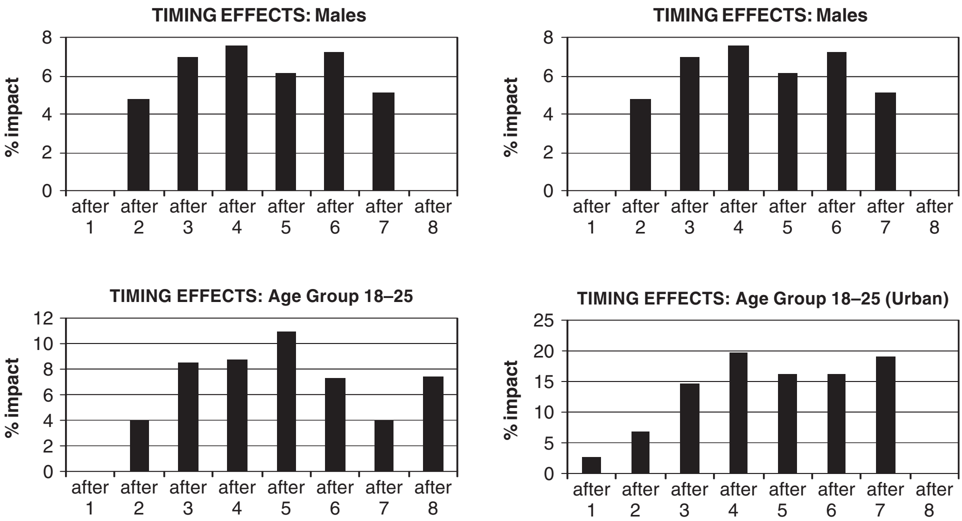


Figure 3. Timing in the effectiveness of lowering BAC levels.

of at least 6 or 7 years are generally confirmed. In Figure 3 the reader can observe these dynamic patterns.[37]

CONCLUDING REMARKS

Fighting drunk driving has been one of the main challenges for European authorities concerned with road safety. Generally, this effort has been translated into stricter policies, which have been promoted by national and European institutions. Lowering BAC levels from 0.8 mg/ml levels to 0.5 has been one of the most common measures undertaken across Europe in the last decade. For this reason, evaluating its results is useful and necessary and may help those countries that did not use this tool to understand its effects.

The current study has shown how lowering illegal BAC levels to 0.5 mg/ml has been an effective policy in Europe. However, I cannot leave this conclusion without further discussion. As I have shown, the policy is not found to be statistically effective for all road users when we control for other concurrent policies and infrastructure quality. In fact, the effectiveness of the policy is heterogeneous depending on the age, gender, and zone of the victim group studied. Therefore, this study can give some guidance to policy makers seeking to understand which groups are more likely to be affected by this and other policies related to drunk driving. The results show that males (5.7 percent) and young road users (11.5 percent), especially in urban zones (9.2 percent and 21 percent, respectively), have clearly been affected by the policy in Europe. Moreover, the drivers from 30 to 49 years old also receive positive and statistically significant impacts from lowering BAC levels. Other groups receive similar large impacts but they do not appear to be statistically significant. We must be careful because these groups are less precisely estimated, but the impact in some cases is nontrivial. In general, these results are consistent with the BAC literature confirming the impact on young and male victims, but they add

[37] Only negative coefficients are considered and appear in the graph in the form of columns. Positive impacts are not considered. That is why some years (mainly the eighth year) does not contain any column.

interesting results by taking into account the area where accidents happened. In this sense, urban fatalities seem more likely to receive the benefits of the policy than nonurban fatalities.

Nevertheless, the effects of the policy do not usually apply in the short run even when substantial long-term effects can be recognized. Previous pre- and poststatistical studies usually found a sharp decline in fatalities right after enactment, but this effect faded off in a single year. However, those studies with long postpolicy periods easily find substantial long-term effects. This is confirmed in the current analysis, in which I find that these effects usually increase after the second year, reaching the highest levels between the third and the seventh year, depending on the group studied.

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