Traffic Accidents in Switzerland: How Hazardous Are “High Risk” Groups? An Analysis Based on Police Protocols

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1. Introduction

According to the World Health Organization, road accidents are among the ten leading causes of death. Officially, each year more than 1.2 million people worldwide lose their live in road accidents and as many as 50 million are injured (Peden, 2004). Road accidents thus claim more lives than malaria or different forms of cancer. On Swiss roads, there were 21,706 officially registered accidents in 2005 with on average 1.25 persons involved (Bundesamt für Statistik, 2006). That is, about every 19 minutes a person was involved in a road accident where, on average, all accidents left at least one person injured. And, every 105 minutes one person was seriously injured and on average every 21.5 hours one person was killed. In comparison to deceased due to cardiac and cardiovascular diseases or cancer (69.7% and 24.8%, respectively, of all deaths), road accidents, however, accounted for less than 1‰ of all deaths in Switzerland.

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Even though the number of road accidents, injured, or even killed persons has declined steadily since the seventies, the death toll on Swiss roads was still 510 persons in 2004 and 409 in 2005 (BUNDESAMT FÜR STATISTIK, 2006). And, about one fourth of all deaths were officially due to drunkenness. While the number of accidents could only be reduced by a little less than 10% since 1984, the number of persons killed could be reduced by about two third (from 1,101 to 409 persons). Despite the growing traffic, there have never been less seriously injured or killed persons on Swiss roads since the start of recording road accidents statistics in 1945. This success is mostly due to safer vehicles, safer roads and reduced speed limits.

Nevertheless, due to the high percentage of drinking drivers involved in accidents, on November 26, 2003, the Swiss federal government approved the conversion of regulations already established in the revised road traffic law (Strassenverkehrsgesetz). One consequence was the reduction of the blood-alcohol content (BAC) from 0.8‰ to 0.5‰ by January 1, 2005. With a BAC of 0.5‰, Swiss legislation is now in line with those of most European Union countries and the demands of the European Union for a BAC of 0.5‰ or even less (for a justification of a reduction to 0.5‰, see for example, DUNBAR, PENTTILA and PIKKARAINEN, 1987).

The argument of the Swiss federal government and the "Schweizerische Fachstelle für Alkohol- und andere Drogenprobleme (sfa)" to introduce a restrictive BAC was based on the argument that lower per mil levels provably increase road safety. Figures for 2005 (BUNDESAMT FÜR STATISTIK, 2006) appear to support this assertion since in comparison to 2004, there were 20% less killed (down from 510 to 409 persons) and 8% less seriously injured (down from 23,218 to 21,695 persons) in 2005. Whether the more restrictive BAC since 2005 reduced the risk and is indeed responsible for the decline in killed and seriously injured persons on Swiss roads, however, has not yet been scientifically demonstrated. It could well be that the fear of the increased road controls by the police and the drastically increased punishment for intoxicated drivers, which accompanied the introduction of 0.5‰-BAC, induced drivers to drink less, to drive more carefully, or to appoint a designated driver. Whether this decline in accidents, injured or even killed persons is a temporary effect or will persist cannot be answered yet since the statistics for 2006 is not yet available.

Medical studies do show that alcohol slows down the quickness of reaction (for a general overview see MOSKOWITZ and FIORENTINO, 2000; for an experimental study see CALHOUN, PEKAR and PEARLSON, 2004). The preventive benefit from low blood-alcohol levels, however, hinges to a high degree on the risk intoxicated drivers represent to themselves and other road users. And, it has not been shown yet that a decreased ability to react due to alcohol has a causal relationship with an increased risk to cause an accident. It would thus be a major contribution if one were able to determine the probability of an accident between drinking drivers and/or sober drivers and to determine the risk drinking drivers pose. Only then, serious conclusions about the effect of reduced blood-alcohol levels can be taken. Especially since more and more people in Switzerland demand an even more restrictive BAC or even call for a zero tolerance policy (i.e., a BAC of zero per mil).

We are not able to establish a relation between the blood-alcohol concentration, the quickness of reaction and the risk of drinking drivers. However, we for the first time can estimate the relative risk posed by drinking drivers for Swiss data.[1] But, estimating a possibly increased risk of causing a fatal crash by drinking drivers is not possible without the knowledge of the fraction of drinking drivers on the road. Attempts to determine this fraction are always subject to distortion. For instance, contrary to Australia (Homel, 1990), the Swiss police never carried out breath tests on all drivers stopped in occasional roadblocks. Due to selectivity and irregularity, police controls cannot deliver a representative impression of road users.

Levitt und Porter (2001a), however, show that by use of a suitable econometric procedure, it is possible to estimate the risk posed by drinking drivers (more precisely, the relative risk of drinking drivers to sober drivers) without knowing the fraction of drivers on the road who have been drinking. The following section presents the essential assumptions and the estimation procedure of Levitt and Porter's approach. In section 3, we present our data and discuss restrictions which the data impose on the estimations. Section 4 then reports, for the first time, results for Switzerland and section 5 discusses restrictions of the model and concludes.

2. Assumptions and Estimation

According to the Swiss Federal Statistical Office (Bundesamt für Statistik, 2006), drunkenness on roads accounts for one fourth of all deaths and for about one sixth of all seriously injured on Swiss roads. If one considers only those accidents which happen during times of the day where consumption of alcohol is assumedly the highest, this share rises considerably. However, measuring the risk

1 Note that the methodology we present (Levitt and Porter, 2001a) is not restricted to drinking drivers but can be applied to all sorts of problems where one group assumedly bears a higher risk than another (e.g., the risk fresh drivers pose compared to experienced drivers).

drinking drivers represent on the road is not possible without the accurate knowledge of their fraction at the total of road users. Therefore, LUND and WOLFE (1991), for instance, rest their estimation of the fraction of drinking drivers on data from roadblocks. LEVITT and PORTER (2001a), on the other hand, propose an entirely different approach without the necessity to know the fraction of drinking drivers. It is simply based on the statistics of traffic accidents involving two cars and makes no restrictive (econometric) assumptions. On the first sight, this estimation procedure appears quite odd. LEVITT and PORTER claim, put in other words, that they are able to determine the respective skills of two soccer players to score penalty kicks simply on basis of the reported number of successful penalty kicks and without knowing the number of attempts each player had. However, the statistics of traffic accidents contains a richness which the penalty kick statistics lacks. The advantage of the former statistics lies in the fact that road accidents often involve more than one driver. This simple fact allows, given the assumptions to be discussed below, to identify the parameters of the model. The important information are concealed in the relative frequency of two-car crashes, that is, accidents involving two sober drivers, two drinking drivers, or one driver of each type. The risk posed by drinking drivers as well as their fraction on the road can be estimated by use of the two-car crash statistics due to the fact that the probability of such an accidents follows a binomial distribution.

2.1. Model Assumptions

Even though this article mainly focuses on drinking vs. sober drivers, the model is not restricted to these two types only. It is more general in the sense that it determines the relative risk of a "high risk" group compared to a "low risk" group. Section 4 will also report results for "high risk" groups other than drinking drivers. The starting-point of the model for two-car crashes are five simple assumptions. It is possible to generalize the model to self-accidents (see LEVITT und PORTER, 2001a). However, we focus on accidents involving two cars only and discuss how to relax the model with respect to different aspects in the concluding section.[2]

Assumption 1: There are only two types of drivers on the road, namely drinking and sober drivers. We label the two types by B and N, respectively. The restriction to two types only is not a necessity but simplifies the framework of the model.

2 Readers familiar with LEVITT and PORTER (2001a) can skip most of section 2.1 through 2.3.

Theoretically, an finite number of distinctions (i.e., types of drivers) would be possible as long as one has sufficient data to identify the parameters. One could, for instance, distinguish four types of drivers by combination of the characteristics "younger vs. older than 21" and "drinking vs. sober". For Switzerland, however, the number of accidents is not large enough and would make an estimation of the model parameters for more than two subgroups difficult.

While the focus on two types only (and within-group heterogeneity with regard to the risk of causing an accident[3]) does not allow for very detailed policy advices, it has a clear advantage. The estimated risk parameters are a weighted average of the drivers' individual risks, with weights determined by the number of drivers of each ability in the population. As will become clear below, however, the simple model only allows to identify the ratio of the means of the distributions rather than the weighted average risk for both groups.

Assumption 2: There is an equal mixing of drinking and sober drivers on the road. This assumption is twofold. First, the number of interactions that a driver has with other drivers is independent of his type. That is, the situation that two cars are close enough that the mistake by one driver could cause a crash is independent of the drivers' types. We thus imply homogeneity with respect to the number of cars a drinking and a sober driver pass. Second, the type of one driver (drinking or sober) does not affect the type of the drivers he interacts with on the road. Formally, we have A_N sober and A_B drinking drivers and thus a total of $A_{total} = A_N + A_B$ drivers on the road.[4] Further define the indicator variable $I = 1$ if two cars interact (i.e. pass on the road) and zero otherwise.

Assumption 3: A car crash involving two drivers results from the error of one driver only. This assumption is necessary for the identification of the model parameters. However, as will be discussed in section 5, the bias introduced by this assumption can be calculated by assuming that both drivers can partly be blamed for the accident.

Assumption 4: The type of drivers involved in one crash (i.e., the possible combination of N and B) is independent of the type of drivers involved in other crashes. There is little reason to think that this assumption is not plausible unless one focuses on crashes on, say, the parking lot of a nightclub.

3 That is, there is a distribution of driver risks in each category.

4 For the empirical analyses, $A_{total} = A_N + A_B$ is the number of drivers and types on the road for a given time period and/or geographical region only.

Assumption 5: Drinking drivers have a (slightly) increased risk to cause a crash. If we denote the probability of driver type i to make an error resulting in an accident by θ_i, assumption 5 states that $\theta_B \geq \theta_N$. There is enough scientific evidence in support of this final assumption.

The following subsections will link the model assumptions and show how to determine the model parameters to allow for conclusions about the relative risk of drinking drivers.

2.2. A Posteriori Probabilities and Driver Type Risks

The probability of an accident is determined by the joint distribution of the probabilities that (i) two cars interact and that (ii) the crash results from the error of one driver only. In a first step, we thus formalize assumptions 2 and 3. We then derive the probability of an accident between two driver types conditional on their interaction. Applying Bayes's rule to these a priori probabilities gives the interesting (a posteriori) probabilities of mixing of driver types conditional on the occurrence of a crash. The latter is finally used to derive the likelihood function and thus the model parameters and its inferences (i.e., standard errors).[5]

Assumption 2 about an equal mixing of sober and drinking drivers on the road is used to determine the joint distribution of two driver types conditional on an interaction. Logically, this is equivalent to the random draw of two balls from a pot of balls labelled N and B:

$$\Pr(i, j \mid I = 1) = \Pr(i \mid I = 1) \cdot \Pr(j \mid I = 1) = \frac{A_i A_j}{(A_N + A_B)^2}. \tag{1}$$

Assumption 3 states that a car crash involving two drivers results from the error of one driver only. Define the indicator variable $U = 1$ if an interaction results in an accident and $U = 0$ otherwise. Formally, assumption 3 reads

$$\Pr(U = 1 \mid I = 1, i, j) = \theta_i + \theta_j - \theta_i \theta_j \approx \theta_i + \theta_j. \tag{2}$$

The probability of a two-car crash conditional on an interaction between type i and j equals the sum of the probabilities that either driver makes an error minus the probability that both drivers make a mistake. Since the probability of making

5 The data available to us contain all road accidents for the time 2001–2005. Even though we restrict ourselves to two-car crashes only, this still is no sample but a census. Nevertheless, we still report standard errors in section 4 despite they lack its usual meaning.

an error is very small, the product of the error probabilities is vanishingly small and can be neglected.[6]

The point of departure for the econometric analyses is the a posteriori probability of driver types conditional on the occurrence of a crash. Its derivation is based on the a priori probability of an accident between two driver types conditional on their interaction. The latter is easily determined by combining (1) and (2).

$$\begin{aligned}\Pr(i,j,U=1\,|\,I=1) &= \Pr(i,j\,|\,I=1)\cdot\Pr(U=1\,|\,I=1,i,j)\\ &= \frac{A_i A_j(\theta_i+\theta_j)}{(A_N+A_B)^2}\end{aligned} \tag{3}$$

To derive the key probability $\Pr(i,j \mid U=1)$, we apply Bayes's rule to eq. (3) to get

$$\begin{aligned}\Pr(i,j\,|\,U=1) &= \frac{\Pr(i,j,U=1\,|\,I=1)}{\Pr(U=1\,|\,I=1)}\\ &= \frac{\Pr(U=1\,|\,i,j,I=1)\Pr(i,j\,|\,I=1)}{\sum_{k\in S_{ij}}\Pr(U=1\,|\,k,I=1)\,Pr(k\,|\,I=1)}\\ &= \frac{A_i A_j(\theta_i+\theta_j)}{2[\theta_B(A_B)^2+(\theta_B+\theta_N)A_B A_N+\theta_N(A_N)^2]},\end{aligned} \tag{4}$$

where $S_{ij}=\{(N,N),(B,B),(B,N),(N,B)\}$ denotes the set of possible combination of driver types. Eq. (4) constitutes the basis for the statistical derivation of the key probabilities: (a) the probability of a car crash between two sober drivers, $\Pr(i=N,j=N \mid U=1)$, (b) the probability of a car crash between two drinking drivers, $\Pr(i=B,j=B \mid U=1)$, and (c) the probability of a car crash between a sober and a drinking driver, $\Pr(i=N,j=B \mid U=1)+\Pr(i=B,j=N \mid U=1)$. The latter probability results, since the order of driver types is irrelevant, from adding up the probability that *i* is sober and *j* is drunken, and the probability that *j* is sober and *i* is drunken.

6 Neglecting the interaction term is unproblematic. Levitt and Porter (2001a, S. 1204) estimate its value, using U.S. data, as 10^{-18}, thus supporting the assumption that the error of one driver only accounts for a crash. The concluding section will discuss the consistency of the estimates if assumption 3 is violated (e.g., a pile-up crash due to the error or accident of the preceding car).

A closer look at eq. (4) shows that we would actually need to estimate four parameters (θ_N, θ_B, A_N and A_B) but only have three equations for the respective probabilities (a), (b), and (c). It is thus not possible to separately identify all four parameters. LEVITT and PORTER (2001a) propose to identify the ratio of the parameters instead. And, since the three equations for (a), (b), and (c) add up to unity (and thus are linearly dependent), in any case only two parameters can be identified separately. By defining the relative risk of drinking drivers as the ratio $\theta = \theta_B/\theta_N$ and the relative share of drinking drivers as $A = A_B/A_N$, we exploit the maximum information possible form the model. Eq. (4) thus reduces to the following three probabilities corresponding to (a), (b), and (c):

$$P_{NN} := \Pr(\theta, A \,|\, U_{NN} = 1) = \frac{1}{\theta A^2 + (\theta+1)A + 1}, \tag{5}$$

$$P_{BB} := \Pr(\theta, A \,|\, U_{BB} = 1) = \frac{\theta A^2}{\theta A^2 + (\theta+1)A + 1}, \tag{6}$$

$$P_{BN} := \Pr(\theta, A \,|\, U_{BN} = 1) = \frac{(\theta+1)A}{\theta A^2 + (\theta+1)A + 1}. \tag{7}$$

Estimation of the model parameters θ and A requires the specification and maximization of the likelihood function.

2.3. Likelihood Function, Parameter Estimation and Inference

Eqs. (5)–(7) provide the likelihoods of specific combinations of driver types conditional on the occurrence of a two-car crash. Define U_{ij} as the absolute number of two-car crashes between driver types i and j. If we assume independence across two-car crashes (i.e., assumption (4)), the joint distribution of driver types involved in two-car crashes is given by the multinomial distribution:

$$\begin{aligned}\Pr(U_{BB}, U_{BN}, U_{NN} \,|\, U_{total}) &= U_{total}! \prod_{(ij)} \frac{P_{ij}^{U_{ij}}}{U_{ij}!} \\ &= \frac{(U_{BB} + U_{BN} + U_{NN})!}{U_{BB}!\,U_{BN}!\,U_{NN}!} (P_{BB})^{U_{BB}} (P_{BN})^{U_{BN}} (P_{NN})^{U_{NN}}. \end{aligned} \tag{8}$$

Maximization of the likelihood function eq. (8), or more precisely, its corresponding log-likelihood function, with respect to P_{BB}, P_{BN} and P_{NN}, respectively, yields the sample statistics of the three population parameters:

$$\hat{P}_{BB} = \frac{U_{BB}}{U_{total}},\ \hat{P}_{BN} = \frac{U_{BN}}{U_{total}} \text{ and } \hat{P}_{NN} = \frac{U_{NN}}{U_{total}}. \tag{9}$$

Those estimates form the basis to solve the model for θ. To do so, however, we need to find a way to eliminate the unknown ratio of drinking to sober drivers, A, which is part of eqs. (5)–(7) and consequently eq. (9). To get rid of A, we exploit a property of the binomial distribution which states that the squared number of crashes between drinking and sober drivers is proportional to the product of crashes between two sober and two drinking drivers. This yields the chain of logically equivalent expressions, where the right-hand side shows that A cancels out:

$$R := \frac{(U_{BN})^2}{U_{BB}U_{NN}} = \frac{(\hat{P}_{BN})^2}{\hat{P}_{BB}\hat{P}_{NN}} = \frac{(\theta+1)^2 A^2}{\theta A^2} = 2 + \theta + \frac{1}{\theta}. \tag{10}$$

The relative risk of drinking drivers can thus be calculated simply on basis of the distribution of two-car crashes. This is a noticeable result since knowledge of the ratio of drinking to sober drivers on the road is not necessary to identify the model. Rearranging terms in eq. (10) and multiplying out both sides by θ yields a quadratic equation in θ

$$\theta^2 + (2-R)\theta + 1 = 0, \tag{11}$$

which roots are given by the quadratic formula

$$\theta = \frac{(R-2) \pm \sqrt{R^2 - 4R}}{2}. \tag{12}$$

For values $R > 4$, that is, the discriminant is positive, there exist two distinct real roots (viz., $\theta_+ > 1$ and $\theta_- < 1$). Since assumption 5 demands that drinking drivers have a risk to cause a crash at least as high as sober drivers, we choose $\theta_+ > 1$ as the only solution. If the discriminant is zero ($R = 4$), the only solution is $\theta = 1$. Since θ is the relative crash risk of drinking to sober drivers, the result implies that drinking and sober drivers are equally likely to cause an accident. For $R < 4$ there are no real roots – both solutions for θ are complex. Complex roots, however, are not consistent with the binomial distribution. If $R < 4$, either assumption 2 of equal mixing is violated or we simply observe to little crashes between a drinking and a sober driver.

Once $\hat{\theta}$ has been calculated, we can plug the solution into eq. (6), making use of $\hat{P}_{BB} = U_{BB} / U_{total}$, and solve for $\hat{A}$. If one has access to the necessary data on the distribution of two-car crashes, one can therefore easily determine the relative risk of drinking drivers ($\hat{\theta}$) and their respective share on the road, since it holds that $A_B / (A_B + A_N) = A / (1 + A)$.[7] However, we are not just interested in θ but also in its standard error. As said earlier, the standard errors in our case are just a mere metric since we deal with a census in section 3.

Standard errors for θ are easily attainable from the Fisher information matrix. To obtain the Fisher information matrix $I(\theta,A;U_{ij})$, we plug eqs. (5)–(7) into eq. (8), the likelihood function $L(\theta,A;U_{ij})$, and take the natural logarithm to arrive at the log-likelihood function $\ln L(\theta,A;U_{ij})$. Twice partial differentiation of the log-likelihood function with respect to θ yields the (a posteriori [e.g., Grambsch, 1982]) observed Fisher information matrix I given the data at hand:

$$\frac{\partial^2 \ln L(\theta, A; U_{ij})}{\partial\theta^2} = \frac{U_{NN} A^2}{(\theta A + 1)^2} - \frac{U_{BB}(2\theta A + 1)}{(\theta^2 A + \theta)^2} - \frac{U_{BN}(1 - A)}{(\theta + 1)^2(\theta A + 1)} - \frac{U_{BN} A(1 - A)}{(\theta + 1)(\theta A + 1)^2}. \tag{13}$$

We approximate the variance of the maximum likelihood estimator $\hat{\theta}$ using the inverse of the observed Fisher information matrix I (Efron and Hinkley, 1978): $\mathrm{Var}(\hat{\theta}) = -\mathrm{I}(\theta, A; U_{ij})^{-1}$. Since we have estimated $\hat{\theta}$ and $\hat{A}$, and possess data on U_{ij}, $i,j \in \{B,N\}$, the number of two-car crashes, the standard error as the square root of the variance of $\hat{\theta}$ is readily calculated.

3. Data

The advantage of the chosen approach has been mentioned repeatedly, namely that we need not know the ratio of drinking to sober drivers on the road. An empirically relevant point which makes it possible to distance oneself from unreliable data collected by the police in, for example, roadblocks. The requirements the data have to meet for the econometric analyses are therefore only moderate.

7 If $R = 4$ or $R < 4$, the share of drinking drivers on the road is proportional to the observed ratio of crashes between drinking and sober drivers. Moreover, we have that $\theta = 1$.

To estimate the risk drinking drivers pose as well as to determine their share on the road, we only need information on the kind of accident (i.e., one-car crash, two-car crash, crash involving more than two cars, crash involving cars and other vehicles, etc.), the precise time and geographical location of the accident as well as the level of intoxication of the drivers involved in the accident. Extending the model to determine the relative risk of driver characteristics other than the level of intoxication, variables such as sex, age, nationality, information on passengers or information on previous involvements in accidents (including the blood-alcohol concentration) would be desirable. The Swiss data available to us are recorded by the police which then must submit them to the Swiss Federal Statistical Office. The variables in the data set offer a sufficient basis for the analyses.

3.1. Road Accidents in Switzerland 2001–2005

The Swiss Federal Statistical Office annually publishes an elaborate report on road accidents in Switzerland. This report, among other things, contains condensed data on crashes, involved persons, injuries, defects on vehicles, or levels of intoxication. Although this report is very detailed, it is not suitable for our purposes.

According to Swiss law, each accident registered by the police must be reported to the Swiss Federal Statistical Office. All accidents on public roads or places involving at least one motorized or unmotorized vehicle are officially counted as a road accident. There is, however, no necessity to report accidents with only pedestrians involved to the Swiss Federal Statistical Office. The comprehensiveness of the data bases on an elaborated protocol which the police has to fill in for each accident.[8] The data available to us consist of these elaborated protocols for all road accidents between 2001 and 2005.

The richness of the data shall be illustrated in a short listing of some of the variables collected. The police makes a detailed report on the circumstances of the accident (e.g., time, place, road conditions, weather), type of the accident (e.g., one-car crash, two-car crash) and the scene of the accident (e.g., in a tunnel, on a bridge). Further, more than twenty different types of vehicles are distinguished and for one-car crashes possible "crash objects" are recorded (e.g., tree, fence, animal). Of special interest are information on the persons involved, their condition and the consequences of the accident. To record information on the driver is prescribed by Swiss law. These information are therefore very detailed.

8 More precisely, there is one protocol for the accident in general, one protocol for each vehicle involved as well as one protocol for each driver and (injured) passenger involved.

Information on passengers need only be recorded in case of injury. The number of passengers, however, is always recorded. The police distinguishes between two levels of injured persons – slightly and seriously injured. Persons with less serious impairments only, for instance, only superficial lesions without loss of blood or only little restriction in their locomotor system, are defined as slightly injured. Seriously injured persons have visible restrictions or interior injuries which require a stay of at least one day in a hospital. A person is registered as killed in an accident if he dies on the scene of the accident or within 30 days after the crash. The most important variable for our analyses, the level of intoxication, is recorded by the police in case of peculiar behavior or in case of other suspicious factors such as, for example, bad breath.[9]

3.2. Limitation of the Data

Due to the considerable number of two-car crashes in the U. S. within the time period under study (1983–1993), LEVITT and PORTER (2001a) can afford the luxury to focus on fatal (i.e., either seriously injured or killed persons) two-car crashes between 20:00 and 5:00 only. The sample still contains 39,470 crashes with only 32.6% crashes where both drivers were sober. Contrary to LEVITT and PORTER's sample, our empirical analyses contain two-car crashes where at least some material damage occurred. Besides crashes with damaged cars, we thus include accidents with slightly or seriously injured as well as killed persons. The reason to focus on almost all two-car crashes is twofold. On the one hand, the federal law to submit data on all accidents involving motorized vehicles entail that we have very detailed data even for those accidents with material damage only. On the other hand, the data available to us do not contain enough fatal two-car crashes for a reliable analysis on the risk of drinking drivers. Moreover, to focus on fatal crashes may underestimate the risk drinking drivers pose. And, if persons involved in a car crash can bilaterally settle the question of who is to blame for the crash as well as agree on the compensation question, the police will not be called. Such a scenario is most likely if drinking drivers are involved in the crash. They have a considerable interest to avoid police interrogation – large fines and possible loss of the driver's license are most likely. Even though the precise impact on the estimated value of θ cannot be determined, it can be assumed that the above scenario will drive the estimates of drinking drivers' risk down.

9 Since the revised road traffic law has been put into service on January 1, 2005, the police can now test on blood-alcohol even without any explicit reason such as, for instance, bad breath.

The data on road accidents for Switzerland in 2001 through 2005 contain a total of 350,711 accidents with at least one motorized vehicle involved. In accordance with the theoretical model, our focus is on two-car crashes only such that 84,437 accidents remain. About every fourth accident on Swiss roads thus happens between two cars.[10] An additional 1,114 crashes are dropped from the data since the necessary information is incomplete. We are thus left with 83,323 two-car crashes for the analyses. In accordance with LEVITT and PORTER (2001a), we limit our sample, for most analyses, to those hours where drinking and driving is most common (i.e., 20:00–5:00). If we only consider this time slot, 12,017 crashes between two cars remain. Of these accidents, 9,834 occur between two sober drivers, 2,109 between a drinking and a sober driver and only 74 between two drinking drivers. Drinking drivers, in accordance with the law, are defined as persons having a blood-alcohol concentration of at least 0.8‰ (2001–04) and at least 0.5‰ (2005), respectively. An amendement of the Swiss law by January 1, 2005, lowered the BAC of being labelled "officially drunk" to 0.5‰. During night times, about 9.4% of all drivers involved in reported two-car crashes are therefore intoxicated. We thus have about three times as many sober drivers as LEVITT and PORTER (2001a). During the rest of the day, that is, between five in the morning and eight at night, only about 1.4% of all drivers (1,945 out of 142,612) involved in two-car crashes have a BAC higher than Swiss federal law would allow.

4. Results

4.1. Relative Risk of Drinking Drivers

The data reveal that 61 crashes between two drinking drivers, 1,750 crashes between a drinking and a sober driver, and 8,229 crashes between two sober drivers were observed for night times (i.e., between 20:00 and 5:00) for the period 2001–2004. We first determine R by inserting above numbers into the left-hand side of eq. (10). Once R has been determined, we solve the quadratic equation for θ and choose, in accordance with assumption 5, the positive root if $R > 4$. Finally, we plug the estimate for θ into eq. (6), solve for $\hat{A}$ to determine the relative share of drinking drivers on the road (viz., $A / (1 + A)$), and compute the standard error of $\hat{\theta}$ via eq. (13). Table 1 reports the results.

10 To be precise, by car we only mean passenger cars but not any other vehicles such as (mini) vans, busses, trucks, tractors or any other agricultural or construction vehicle.

Table 1: Relative Risk of Drinking Drivers with a BAC $\geq$ 0.8‰ between 20:00 and 05:00 for the Period 2001–2004

Type of Drivers	# of Crashes	Percent	Parameter	Estimates
U_{BB}	61	0.61	R	6.1010
U_{BN}	1,750	17.43	$\theta = \theta_B / \theta_N$	3.8406
U_{NN}	8,229	81.96	$se(\theta)$	0.1264
U_{total}	10,040	100.00	$A/(1+A)$	0.0421

Note: BB, *BN*, and *NN* refer to the mixing of driver types in two-car crashes: drunk-drunk, drunk-sober, and sober-sober.

Drinking drivers in 2001–2004 have a crash risk which is almost four times higher than the risk of sober drivers. Given the standard error of 0.1264, the null hypothesis of equal risk can reasonably be rejected. During night times, drinking drivers thus do have an increased risk. Their fraction at the total traffic volume is 4.21%.

The argument of the Swiss federal government to adopt a more restrictive BAC by January 1, 2005 (i.e., from 0.8‰ to 0.5‰) was mainly based on the argument that lower BAC-levels do increase road safety. As we have discussed in the introduction, road accidents as well as injured or killed persons have drastically been reduced in 2005 compared to preceding years. However, no one has yet answered the question whether this fact is due to less drinking drivers on the road (for fear of the more severe penalties since January 1, 2005), to a reduced risk of 0.5‰-intoxicated drivers compared to 0.8‰-intoxicated drivers, or to yet other reasons. To answer this question, we can use the 2005 data to determine the relative risk of drinking drivers with a BAC of at least 0.5‰ and to compare these results to those reported in Table 1. Table 2 reports the respective figures for 2005. Surprisingly, drinking drivers in 2005 still pose a high risk to themselves and other road users even under the BAC of 0.5‰. The share of drivers considered drunk under the new law rises from 4.21% to about 4.55%.

As said earlier, we use census data and therefore no standard errors are needed for inference to the population. It is thus clear from a simple comparison of the $\hat{\theta}$s above, that in 2005, drivers were slightly more risky as in the period 2001–2004.[11] We could thus conclude that drinking drivers with a BAC of at

11 Nevertheless, it makes perfect sense to report standard errors and perform a formal test to have a metric of certainty for the estimated difference. We therefore test the null hypothesis $H_0 : \theta_{0.5+} = \theta_{0.8+}$ (i.e., the 2001–04 against the 2005 data) against the alternative hypothesis

least 0.5‰ are slightly more risky than drinking drivers with a BAC of 0.8‰ or higher. This result, on a first sight, even contradicts the measures taken by the legislator, namely to lower BAC-levels to increase road safety. On basis of this first result, a further decrease in the tolerated blood-alcohol concentration is the only reasonable step to probably increase safety on Swiss roads.

Table 2: Relative Risk of Drinking Drivers with a BAC ≥ 0.5‰ between 20:00 and 05:00 for 2005

Type of Drivers	# of Crashes	Percent	Parameter	Estimates
U_{BB}	13	0.66	R	6.1770
U_{BN}	359	18.16	$\theta = \theta_B / \theta_N$	3.9219
U_{NN}	1,605	81.18	$se(\theta)$	0.2804
U_{total}	1,977	100.00	$A/(1+A)$	0.0455

Note: BB, *BN*, and *NN* refer to the mixing of driver types in two-car crashes: drunk-drunk, drunk-sober, and sober-sober.

However, above reported relative risks are weighted averages within the group of those considered drunk according to the legally valid BAC-levels. Above comparison thus assumes that all drivers with a BAC higher or equal to 0.8‰ (0.5‰, respectively) are equally hazardous. It seems, however, reasonable that the risk a driver poses increases in his blood-alcohol concentration. The legislator's reason to introduces a more severe blood-alcohol limit by January 1, 2005, must have been the consideration that drivers with a BAC between 0.5‰ and 0.79‰ eventually are as hazardous as drivers with a BAC of 0.8‰ or higher, but surely that they are more hazardous than drivers with a BAC below 0.5‰.

$H_1 : \theta_{0.5+} > \theta_{0.8+}$. Since $\theta_{0.5+}$ and $\theta_{0.8+}$ are based on different samples, we can use the following normal distributed test statistic

$$z = \frac{\hat{\theta}_{0.5+} - \hat{\theta}_{0.8+}}{\sqrt{var(\hat{\theta}_{0.5+}) + var(\hat{\theta}_{0.8+})}} = \frac{3.9219 - 3.8406}{\sqrt{0.0786 + 0.0160}} = 0.2643.$$

The test reveals that we cannot reject H_0 and should be cautious to not over-interpret the small difference between $\theta_{0.5+}$ and $\theta_{0.8+}$. Of course, unobserved factors which changed between 2004 and 2005 could account for the estimated difference as well.

To our knowledge, there is no empirical evidence for this legislative step taken by the Swiss legislator. While we surely do not want to advocate driving drunk, we think that far-reaching legislative changes should be reasonable and taken on solide grounds. For a further analysis, we thus subdivide drinking drivers into specific BAC-ranges and compute the risk of these groups relative to the risk of sober drivers (i.e., a BAC below 0.5‰). We take a look at the following per mil BAC-ranges: [0.5,0.8), [0.8,1.0), [1.0,1.2), [1.2,1.4), [1.4,1.6), and 1.6 and higher. Table 3 reports the results.

The number of crashes between two drinking drivers is very small in the first category. However, together with the large number of crashes between a drinking and a sober driver, it is sufficient for a first impression of the relative risk of drinking drivers. First of all, Table 3 reveals an astonishing finding which contradicts the legislator's policy. Drivers with a blood-alcohol concentration between 0.5‰ and 0.79‰ as well as those between 0.8‰ and 0.99‰ are not more hazardous than sober drivers.[12] Their relative share on the road is thus proportional to the observed ratio of crashes between the respective drinking and sober drivers. About 21% of all drivers considered drunk fall within these two ranges.

Table 3: Relative Risk of Drinking Drivers within a Certain BAC-Range Relative to Drivers with a BAC Lower than 0.5‰ for all years (between 20:00 and 05:00)

BAC-Range in ‰	# of Crashes†	R	θ	$se(\theta)$	$A/(1+A)$	Drunk‡
0.5–0.79	2/206/9,684	2.19	~ 1	–	$A \propto U_B/U_N$	8.92%
0.8–0.99	8/271/9,684	0.95	~ 1	–	$A \propto U_B/U_N$	12.17%
1.0–1.19	1/263/9,684	7.14	4.9402	0.3702	0.0046	11.49%
1.2–1.39	1/250/9,684	6.45	4.2168	0.3332	0.0050	11.27%
1.4–1.59	1/282/9,684	8.21	6.0465	0.4247	0.0041	12.47%
larger than 1.6	6/973/9,684	16.29	14.2234	0.5103	0.0066	43.68%

Note: Drivers with a BAC lower than 0.5‰ are considered sober in accordance with the current law.

† Absolute number of crashes between specific mixing of driver types: drunk-drunk/drunk-sober/sober-sober.

‡ Percentage of drivers with a BAC in the respective range at the total of drivers with a BAC of at least 0.5‰.

12 A comparison of drivers within the 0.5‰ to 0.79‰ BAC-range to drivers with a BAC below 0.5‰ for the period 2001–2004 only, reveals that the former were not more hazardous than the latter ($R = 2.75$).

An increased risk of causing an accident is only found for intoxicated drivers with a BAC of 1‰ or higher. More precisely, drivers falling within the three ranges between 1‰ and 1.59‰ (rows 3 through 5 in Table 3) all show a risk which is about 4 to 6 times higher than the risk of sober drivers. About 35% of all drinking drivers are evenly distributed across these three groups. Extremely dangerous are the remaining roughly 44% of drinking drivers with a BAC of 1.6‰ or higher. Note, however, that the reported $\hat{\theta}$ of 14.22 again is an average for this group. Since this group of drinking drivers clearly poses a high risk, we see no gain in looking at more fine grained ranges for blood-alcohol concentrations above 1.6‰.

The results reported in Table 3 touch on a sensitive point in the public discussion on the risk of drinking drivers. Our results run contrary to the public opinion, advices by medical experts, and the legislator's rigorous position against drinking drivers. Our findings suggest that the step taken by the legislator on January 1, 2005 seems reasonable only because additional measures have also been taken (harsh fines for driving drunk, loss of driver's license) and not because the risk intoxicated drivers pose has been reduced. Simply on basis of our results and the relative risk drinking drivers pose, a further decrease in the tolerated blood-alcohol concentration cannot be reasonably supported (for further analyses see Section 4.1.1).

Furthermore, we compared sober drivers with a BAC < 0.8‰ to both drunken drivers with 0.8‰ ≤ BAC ≤ 1‰ and BAC > 1‰, respectively. We ran this analysis separately for the years 2001–2004 and 2005. During the years 2001–2004 and 2005, drivers with 0.8‰ ≤ BAC ≤ 1‰ posed no higher risk than sober drivers during night times. Contrary, for the years 2001–2004, drivers with a BAC > 1‰ posed a 6.9 ($se(\hat{\theta}) = 0.22$) times higher risk during night times than sober drivers with a BAC < 0.8‰. This implies a share of drunken drivers of 2.22%. We obtained similar hazard ratios for the year 2005 – drivers with a BAC > 1‰ posed a 5.9 ($se(\hat{\theta}) = 0.46$) times higher risk during night times and contributed a share of 2.2%.

Let us in short focus on the analyses of subsamples of drinking vs. sober drivers. Most people go out (drinking) on Friday and Saturday nights. It is thus interesting whether these two nights show an increased share and/or risk of drinking drivers on the road. Table 4 summarizes the results. Astonishingly, while the share of drinking drivers on the road is the highest on Friday nights, drinking drivers pose the lowest risk on Friday night compared to Saturday night and the average of the remaining five nights. However, neither Friday nor Saturday night show the highest risk of drinking drivers but rather the remaining nights. A reasonable guess for this finding could be that during week days, even though less drunk drivers are on the road, they drive more reckless due to less fear of police control.[13] This would, in turn, imply that on weekends drunk drivers know how to avoid accidents or popular and crowded roads. Also, the relative risk for Friday night, Saturday night, and the remaining nights, respectively, are significantly different for at least $p = 0.05$.

Table 4: Relative Risk of Drinking Drivers with a BAC ≥ 0.8‰ (2001–2004) and ≥ 0.5‰ (2005), Respectively, between 20:00 and 05:00 for Special Nights and Selected Cantons

Subsample	# of Crashes †	θ	$se(\theta)$	$A/(1+A)$
Friday Night	26/628/2,787	3.1223	0.1765	0.0547
Saturday Night	23/613/2,774	3.6128	0.2005	0.0479
Remaining Nights	21/939/6,199	4.5535	0.1916	0.0273
Bern	9/193/673	3.8929	0.3874	0.0586
Aargau	3/110/563	4.9625	0.6110	0.0328
Geneva	2/192/779	21.6148	1.8137	0.0109
Lucerne	2/86/294	10.4828	1.3921	0.0255
St. Gallen	1/135/551	31.0440	3.0674	0.0077
Wallis	7/170/107	36.5574	4.5940	0.0423

† Absolute number of crashes between specific mixing of driver types: drunk-drunk/drunk-sober/sober-sober.

Table 4 also reports relative risks of drinking drivers for selected Swiss cantons. While we cannot find empirical evidence that drinking drivers are more dangerous than sober drivers for most cantons,[14] there are also some Swiss regions where

13 An analysis of the 2001–2004 data only, shows that the highest risk under the then valid, less restrictive 0.8‰-BAC law was indeed found for Saturday nights ($\hat{\theta} = 5.0199$ with $se(\hat{\theta}) = 0.2904$). Since we know that BAC-levels in the range [0.5,0.8) are not more hazardous than BAC-levels below 0.5‰ (viz., Table 3), the drop in the relative risk for Saturday nights reported in Table 4 thus results, most likely, due to fear of police controls and, therefore, more careful driving in 2005. An analysis of the 2005 data reveals, not surprisingly though, that for Saturdays, drinking drivers did not have an increased risk relative to sober drivers.

14 That is, we have an $R < 4$ and thus two complex roots only for eq. (12). There are two reasons, either assumption 2 of equal mixing is violated or we observe too little crashes between a drinking and a sober driver. For those cantons we thus have $\theta = 1$ and a relative share of drinking to sober drivers on the road which is proportional to the observed crashes between drinking and sober drivers.

drinking drivers show a remarkably high relative risk. Table 4 reports the estimates for some of the most interesting cantons. For instance, two-car crashes in the canton Bern reveal an average risk of drinking drivers (in comparison to the estimates reported in Table 1 and Table 2). The canton Aargau, whose drivers are said to be rather hazardous, indeed disclose a higher risk of drinking drivers (to be precise and fair, the estimates base on the number of two-car crashes in the respective canton and not on the registration of the car (license plate)). Drinking drivers are most dangerous in the cantons St. Gallen and, if one believes in prejudices, not surprisingly in the canton Wallis. However, these results should be taken with some caution since the number of drinking-drinking and drinking-sober crashes are relatively small.

4.1.1. Externalities of Drinking Drivers

Our results suggest that the drivers with a blood-alcohol content between 0.5‰ and 0.99‰ are not more hazardous than sober drivers (i.e., BAC < 0.5‰). We thus concluded that the data would not provide arguments for a tendency towards a zero tolerance policy.

However, if drinking driving causes huge externalities and a decrease in the legally tolerated blood-alcohol content causes different risk groups to drive more carefully, a further decrease in the tolerated alcohol limit could even be welfare improving.[15] Even though the reduction in drinking drivers in the range 0.5‰ to 0.79‰ does not help in terms of the number of accidents avoided. Lower BAC-levels are obviously effective not because drinking drivers under the new law (i.e., by January 1, 2005) pose a lower risk but because additional measures, such as increased fines, had a general effect on road safety. In this subsection, we try to make some extrapolations about the magnitude of the externality associated with drinking driving.

To be able to make inferences about the externalities caused by drunk drivers, we include all accidents due to drunk driving involving at least one motorized vehicle. In contrast to our analyses regarding the relative risk of drinking drivers, we thus also include one-car crashes. And, we focus on deaths as well as on seriously injured persons. That is, we include all occupants of a vehicle, driver as well as passengers, and pedestrians killed or seriously injured in the accident. Following Levitt and Porter (2001a), we take into account direct costs of accidents only (i.e., material damage as reported by the police as well as estimates for the

15 We thank an anonymous reviewer who pointed out this fact which made us write this subsection.

value of life and hospital costs) but do not internalize any other costs. Note that our cost estimates mark a lower boundary since we base our estimations on medical costs and on a value of life which can be considered rather conservative.

To be able to make any inferences about the externality of drinking driving, we make two assumptions. First, the value of statistical life (VSL) is on average 5 million Swiss francs. This figure is a moderate average, considering that normally different VSL are calculated for different occupations and different groups of workers (e.g., VISCUSI, 2004). Second, since we have no indication about how long seriously injured persons had to be treated in hospital, we use averages for costs of hospital treatment as well as days spent in hospital. The average number of hospital days for the period 2001–2004 was 12.5 days and 11.7 days for 2005, respectively. The average costs of one day in hospital were 1,209.50 Swiss Francs (2001–04) and 1,329.80 Swiss Francs in 2005 (BUNDESAMT FÜR STATISTIK, 2007). Table 5 reports the respective figures. Drinking driving caused costs of about 1.1 billion Swiss Francs in the period 2001–2004 and about 284 million Swiss Francs in 2005. Despite the reduction in the legally tolerated BAC-level for 2005, annual costs attributed to drunk drivers could obviously not be reduced compared to earlier years.

The deaths and seriously injured persons due to road accidents steadily decrease since the mid 1980s (deaths: 2001: 544, 2002: 513, 2003: 546, 2004: 510, 2005: 409; seriously injured: 2001: 6,194, 2002: 5,931, 2003: 5,862, 2004: 5,528, 2005: 5,059). However, as Table 5 clearly shows, there are – despite the legislative step to reduce the legal BAC to 0.5‰ – no less deaths and seriously injured persons due to drinking drivers in 2005 than, on average, for the period 2001–2004 (on average about 50 deaths and about 488 seriously injured persons per year). And, as can be seen, most casualties are claimed by drivers with a BAC of 1‰ and above. There has been no change in this pattern for the year 2005.

Drivers with a BAC between 0.5‰ and 0.79‰ cause little costs, compared to the overall costs of drinking driving. This is in accordance with our finding, that these drivers are not more hazardous than sober drivers with a BAC below 0.5‰. However, at least for the two-car crashes, there seems to have been a reduction in lives claimed and seriously injured persons in 2005 compared with the average numbers for the period 2001–2004. However, if the magnitude of the direct externality associated with drinking driving is to be reduced, the legislator should focus on the group of drivers with a BAC of at least 1‰. They are responsible for about 87% (2001–2004) and, respectively, 88% (2005) of all costs.

According to LEVITT and PORTER (2001a, S. 1228), $(\theta - 1)/(\theta + 1)$ gives the percentage of casualties in two-car crashes which could have been avoided had the driver not been drinking. The relative risk of drinking drivers (i.e., a BAC of

Table 5: Casualties, Medical Costs, and Material Damage of Accidents Due to Drinking Drivers

2001–2004

Type	BAC	Deaths	Costs[a]	Injured	Costs[b]	Damage[c]
	≥0.8	201	1,005	1,954	29.55	62.60
all	≥1.0	175	875	1,694	25.61	53.80
	0.5–0.79	22	110	164	2.48	6.11
	≥0.8	18	90	254	3.84	31.90
2-car	≥1.0	16	80	221	3.34	27.20
	0.5–0.79	1	5	33	0.50	3.11

2005

Type	BAC	Deaths	Costs[a]	Injured	Costs[b]	Damage[c]
	≥0.5	53	265	421	6.55	12.70
all	≥1.0	47	235	345	5.37	9.42
	0.5–0.79	2	10	35	0.55	1.85
	≥0.5	2	10	52	0.81	6.20
2-car	≥1.0	2	10	42	0.65	4.51
	0.5–0.79	0	0	2	0.03	0.93

Notes: The top three rows report figures for all accidents involving at least one motorized vehicle. The bottom three rows report the respective figures for the subsample of two-car crashes only. BAC (blood-alcohol content) in per mil, where the legal BAC-levels for 2001–2004 was 0.8‰ and for 2005 0.5‰. Figures in the second and third (fifth and sixth row) thus refer to a subsample of the first (fourth) row.

a Estimates of the costs of lives claimed due to drinking drivers. All costs in million Swiss Francs. Estimates are based on a value of statistical life of 5 million Swiss Francs.

b Estimates of the costs of hospital treatment due to drinking drivers. All costs in million Swiss Francs. Estimates are based on the average number of hospital days and the average costs per day in hospital. The respective figures (Bundesamt für Statistik, 2007) are 12.5 days (2001–04) and 11.7 days (2005), respectively, and 1,209.50 Swiss Francs per day (2001–04) and 1,329.80 Swiss Francs per day (2005).

c Total material damage in million Swiss Francs as the sum of the material damage reported for the respective accidents in the data at hand.

0.8‰ and higher) for the period 2001–2004 was $\hat{\theta} = 3.8406$. For the year 2005 (i.e., a BAC of 0.5‰ and higher), the relative risk was $\hat{\theta} = 3.9219$. Therefore, in the period 2001–2004, 58.68% of all casualties and costs can directly be attributed to drinking driving. For the year 2005, 59.37% of all costs and casualties in two-car crashes was due to drinking drivers.

4.2. Relative Risk of Other Groups

The model is not restricted to estimating the risk of drinking drivers. On principle, the method is suitable to determine the relative risk and share on the road of arbitrary groups as long as they can be discriminated on a binary characteristic. This subsection will present results for four groups which are often said to have an increased risk of causing an accident.

The referendum on a simpler naturalization of non-native persons born in Switzerland (with a poll defeat for the advocates of the referendum on September 26, 2004) lead to an partly exaggerated discussion in the run-up to the poll on alien residents in Switzerland. Especially young people with a citizenship from Eastern Europe or the Balcan stood in the center of the discussion. Due to a number of fatal crashes involving drivers with an Eastern European nationality, right-wing parties generally accused (young) foreigners of speeding. Different Swiss media (SFDRS, Facts, Blick, NZZ) were willingly or unwillingly involved in creating the foe image of the *Balkan Raser*.[16]

The data at hand do not allow for a separate analysis of different nationalities. However, we can estimate the relative risk of foreigners with a Swiss place of residence to drivers with a Swiss nationality. Table 6 reports results for this comparison and for further analyses regarding yet other groups. Since we have no indication that assumption 4 is violated (an equal mixing of Swiss and foreigners must be assumed), the resulting $R = 1.49 < 4$ suggests that the group of alien residents does not pose a higher risk than Swiss drivers. The share of the former group on the total of road users thus is proportional to their involvement in two-car crashes.

A further group which is often accused of being potentially hazardous are drivers not yet turned 21 years. This group is likewise accused of speeding.[17] Whether

16 Even though the decision has been revoked now, the Swiss insurance company Mobiliar did then no longer take out insurance policies with drivers with an Eastern Europe or Balcan nationality.

17 “Kein Wochenende ohne schwere Verkehrsunfälle: Junge Männer rasen von Beiz zu Beiz. Ein Freizeitvergnügen mit hohem Risiko.” (Facts 49, 2001), or, “Raser-Rennen auf Stadtgebiet. Zwei junge Autolenker haben sich in der Nacht auf Freitag in der Stadt Zürich ein Autorennen geliefert.” (NZZ, 24.01.2005).

Table 6: Relative Risk of Selected Groups of Drivers 2001–2005

Characteristic	Time	# of Crashes†	R	θ	$se(\theta)$	$A/(1+A)$
Foreigners	0:00–23:59	6,171/22,422/54,730	1.49	~ 1	–	$A \propto U_{FF} / U_{SS}$
Young Persons	0:00–23:59	578/11,414/66,763	3.39	~ 1	–	$A \propto U_{YY} / U_{OO}$
Young Persons	20:00–5:00	243/2,584/8,255	3.33	~ 1	–	$A \propto U_{YY} / U_{OO}$
Old Persons	0:00–23:59	1,210/16,111/65,519	3.27	~ 1	–	$A \propto U_{OO} / U_{YY}$
Old Persons	20:00–5:00	25/1,231/10,688	5.67	3.3779	0.1297	0.0263
Men	0:00–23:59	39,630/34,227/8,590	3.44	~ 1	–	$A \propto U_{MM} / U_{WW}$

Note: Only those foreigners with a Swiss place of resident are taken into account. Persons are considered young (old) if they are between 18 and 21 years old (64 years or older).

† Absolute number of crashes between specific mixing of driver types: two bearer of the characteristic/bearer and non-bearer of the characteristic/two non-bearer of the characteristic.

a possibly increased risk of young drivers is subject to speeding or simply due to lack of driving experience, cannot be answered. As Table 6 shows, however, young drivers are not more dodgy than older drivers, independently of the time of the day we focus on (whole day or nights only). Only for the year 2001, we find an increased relative risk of young drivers ($\hat{\theta} = 1.9963$, $se(\hat{\theta}) = 0.0917$) with a share of 9.17% on the total of road users (results not reported in Table 6). There is no exogenous variable which would explain why exactly in 2001 young drives posed a higher risk. Our results would thus yield no justification for the temporal driver's license for young drivers, recently introduced by the Swiss legislator.

If the time of observation embraces the whole day, we further find no indication that older people (i.e., age 64 and older) are more hazardous than persons not yet turned 64 years. Likewise, men pose no higher risk than women, even though Levitt und Porter (2001b) report a higher risk for US men. Table 6 reports the respective figures. Since there is no indication that assumption 4 of equal mixing is violated for these groups either, the results can be considered reliable. During night time, however, older people do pose a higher risk. Their risk to cause an accident is about 3.5 times higher than the risk of drivers younger than 64 years. Even though the share of older people on the road during nights is considerably small (viz., about 2.6%). The most likely reason for the increased relative risk is the reduced sense of sight of older people in the dark, rather than a general inability to drive. Therefore, the demand that older drivers should periodically re-do their driving test lacks a statistical basis. However, the current practise of regular medical examinations of elder drivers is useful. Reports on senile drivers, such as the story of a 75 year old man who made a U-turn on the highway (General-Anzeiger Bonn, January 28, 2003) rather serve the entertainment of the reader than that they are representative for the group of older drivers.

5. Restrictions and Conclusions

The causal relationship between an increased blood-alcohol concentration and the ability to react is often taken as evidence that drinking drivers pose a high risk to themselves and other road users. Even though there is lack of empirical evidence for this inference. The relative risk of drinking to sober drivers on the road, however, cannot be determined without knowledge of their respective shares on the road. Attempts to determine these fractions are inevitably subject to distortion. For instance, the Swiss police never carried out breath tests on all drivers stopped in occasional roadblocks. Due to selectivity and irregularity, police controls cannot deliver a representative impression of road users.

However, LEVITT and PORTER (2001a) have demonstrated that by use of a suitable econometric procedure, it is possible to measure the risk posed by drinking drivers (more precisely, the relative risk of drinking to sober drivers) without knowing the fraction of drivers on the road who were driving intoxicated. This paper uses LEVITT and PORTER's approach to estimate the risk of drinking drivers as well as other potential "high risk"-groups for Switzerland. We have data on all accidents including at least one motorized vehicle which occurred in 2001 through 2005. Our analyses, however, are based on two-car crashes only. The results indeed show an increased risk for drinking drivers but, generally, not for other potentially hazardous groups (viz., foreigners, young drivers, old drivers or men).

LEVITT and PORTER's (2001a) model rests on five crucial assumption which may seem restrictive on the first sight. It is thus useful to discuss possible relaxations and/or generalizations of these assumptions. The most general case of the model, as presented in this paper, is restricted to two-car crashes only. However, as soon as the relative share of drinking drivers on the road, A, is identified, one-car crashes can be implemented into the model quite easily. Or, the relative risk in one- and two-car crashes is identified via a simultaneous system of equations and a joint likelihood function. Generally, the additional insight from considering one-car crashes is not very comprehensive and the solution for θ, the relative risk of drinking drivers, is not affected.

More insights could be gained by relaxing assumption 1, that only two types of drivers exist (e.g., drinking and sober drivers). As we have already mentioned, in case of suitable data, the model can easily be extended to embrace more than two types, for instance, drinking young and older drivers and sober young and older drivers. Considering the data available to us, however, defining more than two driver types would result in subgroups with too little accidents to identify the model parameters. Since the limitation to two driver types has no influence on a possible distortion of the parameters, assumption 1 is definitely not crucial. Essential, on contrary, is assumption 2 about equal mixing of driver types on the road. It is more than likely that especially in the case of drinking and sober drivers, assumption 2 is violated geographically and temporally. It is reasonable to assume that drinking drivers are more common during night hours. Geographically, they are mostly en route between larger cities. The assumption of a temporally and geographically equal distribution is thus hard to justify unless one restricts analyses to car crashes which occurred during a specific time period and/or within a geographically restricted area. Since assumption 2 is theoretically required, such an empirical restriction is the only possible solution. We have chosen this approach in our analyses (viz., restriction to crashes between 20:00 and 5:00) when no clear arguments for equal mixing could be found.

This temporal restraint of two-car crashes only partially solves the problem of equal mixing unless one considers an extremely restricted sample of accidents (e.g., one road for one hour). Roads close to bars are populated by drinking drivers above average and the number of drinking drivers increases after closing time of bars. Theoretically, unequal mixing on the road should result in more crashes between two drinking drivers or two sober drivers and in less interactions between a drinking and a sober driver. Consequently, this results in a negative bias on θ, the relative risk of drinking drivers, and in overestimating A, the relative share of drinking to sober drivers on the road.[18]

Assumption 3, that a crash results from the error of one driver only, can be weakened if the following consideration is introduced into the model (Levitt and Porter, 2001a). We still assume that one driver makes an error which under "normal" circumstances results in a crash. However, we now introduce the possibility that the second driver can avoid the crash by acting accordingly. Denote the inability of drinking drivers to avoid the crash by $\mu_B \geq 1$ and the respective inability of sober types by $\mu_N \geq 1$. The risk drinking drivers pose thus is $\theta_B \mu_B$ and the risk of sober drivers is now given by $\theta_N \mu_N$. Consequently we have

18 This can easily be seen since unequal mixing reduces R (viz., the left-hand side of eq. (10)) which consequently results in a negative bias on θ (see eq. (12)). And, a negatively biased θ increases, due to eq. (6), the estimates for A.

that $\theta(\mu_N/\mu_B) = \theta_B/\theta_N$. The simple scenario of our analyses therefore assumed $\mu_B = \mu_N = 1$. If we assume that drinking drivers are less able to avoid crashes, that is $\theta/\mu_B = \theta_B/\theta_N$, eq. (11) yields the solution that $R = 2 + (\theta/\mu_B) + (\mu_B/\theta)$ and the denominator of eq. (12) will then be $2/\mu_B$ instead of just 2. All estimates for θ we reported in this paper are therefore lower limits for the risk drinking drivers pose.[19]

Finally, assumption 4 on the independence of driver types in accidents is unlikely to theoretically and empirically cause any problems. Even if assumption 4 was violated, no biases in the estimates are to be expected. Assumption 5, that drinking drivers have an increased risk relative to sober drivers to cause an accident, is theoretically sensible and empirically corroborated.

Given the above said, the reported risk for drinking drivers (and other groups) can be seen as conservative estimates of their true risk. LEVITT and PORTER's (2001a) approach is the only one which results, given sufficient data, in reliable estimates of drivers' risk and should thus be favorite to statistics which are based on occasional police controls and roadblocks. The estimates we presented in this paper are not only of interest retrospectively. In the long run, further estimates could form the basis for policy decisions. Our analyses have, for instance, shown that the reduction of the just tolerated BAC from 0.79‰ to 0.49‰ can impossibly be justified simply on the argument of an increased risk of drivers with a BAC between 0.5‰ and 0.79‰ relative to sober drivers. We have shown that drivers with a BAC between 0.5‰ and 0.99‰ pose no higher risk than sober drivers.

However, there have been less killed and injured persons on Swiss roads in 2005 compared to 2004. According to the Swiss Federal Statistics Office, in about 13.5% of all accidents with killed or seriously injured persons in 2005, the police reported alcohol being involved. Our data reveal a figure of 10.3%. The respective figures for the years 2001 through 2004 lie between 8.5% and 11.9%. We thus have about the same fraction of severe accidents involving drinking drivers before and after January 1, 2005. The composition of driver types in fatal crashes thus has not changed. The reduction in the absolute number of fatal crashes is thus most likely due all drivers driving more carefully (for fear of significantly increased fines). In sum, our analyses cannot provide arguments and figures for even more restrictive policy measures or a complete zero tolerance policy

19 For example, assume that drinking drivers are 25% less effective in avoiding crashes, $\mu_B = 1.25$. A re-examination of the relative risk of drinking drivers with a BAC of at least 0.8‰ during nights (Table 1) yields the following estimates: $\hat{\theta} = 4.8007$ with a standard error of 0.1541 – instead of $\hat{\theta} = 3.8406$.

with regard to drinking and driving. What our analyses have shown, however, is the fact that drivers with a BAC of 1‰ and higher are extremely dangerous and cause almost nine tenth of all costs attributable to drunk driving.

Even though one does not wish for more accidents, more data would make it possible to conduct more fine-grained analyses (e.g., more than two driver types, less wide BAC-ranges). Fortunately, more data does not necessary mean more accidents per year but simply data from a longer time period than just five years.

However, one last result of our analyses is beyond all doubt. Five years of two-car crashes are sufficient to invalidate the claim which is often found in newspapers or heard in discussions among persons with an esoteric touch: a full moon causes more accidents than happen in other nights. We have 62 nights of full moon in our data and clearly these nights pose no higher risk – in terms of severity of accidents – to drivers ($\chi^2(3) = 1.8070$, $p = 0.613$).

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SUMMARY

On January 1, 2005, Switzerland reduced the legal level of blood-alcohol concentration while driving from 0.8‰ to 0.5‰. This happend on basis of the assumption that more restrictive per mil levels increase road safety. The benefit of lower blood-alcohol levels, however, depends on whether drinking drivers indeed pose a risk for themselves and other road users. Analyses using official data of all 84,437 two-car crashes during 2001–2005 indeed show a higher relative risk of drinking to sober drivers. And, we also find evidence that prejudices against drivers with an Eastern European citizenship, contrary to recent newspaper articles, are groundless.