Do Stricter Drink-Driving Limits Improve Road Safety? Evidence from Scotland's BAC Reform

Melina Jafari*[1], Anupriya[2], and Daniel J. Graham[3]

[1]PhD Candidate, Transport Strategy Centre, Imperial College London, UK
[3]Postdoctoral Research Associate, Transport Strategy Centre, Imperial College London, UK
[3]Professor of Statistical Modelling, Transport Strategy Centre, Imperial College London, UK

Short summary

This study evaluates the impact of Scotland's 2014 reduction in the legal blood alcohol concentration limit from 0.08 to 0.05 g/dL on road traffic accidents. Using yearly data aggregated at the Middle-layer Super Output Area (MSOA) level for Engalnd and Wales and Intermediate Zone (IZ) level for Scotland, a balanced panel dataset of 7,940 spatial units across Great Britain from 2008 to 2019 is constructed. The analysis employs the Synthetic Difference-in-Differences (SDID) method to estimate a credible counterfactual. The results indicate a significant reduction in crash rates following the policy, with an estimated decline of 12.00% in total crashes. Stronger effects are observed during periods associated with higher alcohol-related risk, with reductions of 31.63% in night-time crashes and 25.28% in weekend crashes. Robustness checks, including placebo tests, confirm the statistical significance of these findings.
Keywords: Blood Alcohol Concentration (BAC), Road Traffic Accidents, Synthetic Difference-in-Differences, Causal Inference, Drink-Driving

1 Introduction

Road traffic accidents represent one of the most serious and persistent global public health concerns. According to the World Health Organization (WHO), approximately 1.19 million people die each year as a result of road traffic accidents, while an additional 20–50 million people suffer non-fatal injuries, many of which lead to long-term disability (WHO, 2023).

Among the behavioral factors contributing to road traffic injuries, driving under the influence of alcohol or drugs remains one of the most significant causes. Alcohol consumption impairs judgment, coordination, and reaction time, while increasing risk-taking behavior and reducing alertness. The level of alcohol in the body can be measured using blood, urine, or breath samples, commonly expressed as blood alcohol concentration (BAC) (WHO, 2022).

A substantial body of evidence demonstrates a strong relationship between BAC levels and accident risk. Studies by Blomberg et al. (2005) found that drivers with a BAC of 0.05 g/dL were 38 % more likely to be involved in an accident than sober drivers, and at 0.07 g/dL the risk more than doubled. They estimated accident risk using a matched case-control design, where accident-involved drivers were compared to non-accident drivers from roadside surveys, and logistic regression was applied to compute odds ratios representing relative accident risk across BAC levels. Levitt & Porter (1999) estimated that legally intoxicated drivers were 15 times more likely to be involved in a fatal crash. In this study, accident risk was estimated using a quasi-induced exposure approach, where non-responsible drivers in two-vehicle fatal crashes were treated as a random sample of the driving population, and relative accident risk was inferred by comparing alcohol involvement between responsible and non-responsible drivers using a likelihood-based framework. Zador et al. (2000) estimated accident risk using a case-control framework by combining fatal crash data with roadside survey data to approximate driver exposure. Relative risk was computed by comparing the distribution of BAC among crash-involved drivers and the general driving population, ranked by age and gender. Their findings indicated that even at BACs between 0.02–0.04 g/dL, crash risk was two to five times higher than for sober drivers, depending upon age and gender.

Lowering the legal BAC limit is therefore one of the most widely adopted policy interventions to reduce drink-driving. Numerous studies provide evidence supporting its effectiveness, although the magnitude of impacts varies across contexts and enforcement regimes. In the United States, Voas et al. (2000) used regression approach and Dee (2001) used Difference-in-Differences approach

found that introducing a 0.08 g/dL limit reduced fatal crash rates by 8% and 7.2%, respectively, while Tippetts et al. (2005) estimated reductions of up to 15% in alcohol-related fatal crashes by employing a meta-analysis approach. Strong evidence also emerges from Australia, where Homel (1994) employed an interrupted time-series method and reported a 13% reduction in fatal Saturday crashes following the introduction of a 0.05 g/dL limit, and Henstridge et al. (1995) employed an interrupted time-series approach with a comparison group, using a quasi-experimental design and found significant reductions in alcohol-related crashes when combined with Random Breath Testing (RBT).

Similar patterns have been observed in Europe and Asia, including France (Mercier-Guyon, 1998), where a before–after time-series analysis was used, Japan (Nagata et al., 2008; Desapriya et al., 2006), where studies employed interrupted time-series analysis and before–after approaches, respectively, and across European countries (Albalate, 2008), where a fixed-effects panel data regression framework was applied. These studies consistently report reductions in alcohol-related crashes and fatalities, with particularly strong effects among high-risk groups such as young and male drivers. However, the findings are not universally consistent. Bernhoft & Behrensdorff (2003) in Denmark, Francesconi & James (2021) in Great Britain and Foss et al. (2001) in North Carolina, U.S. reported negligible or null effects, likely reflecting weak enforcement or short post-policy evaluation periods. Overall, meta-analyses by Ferguson (2012) and Fell & Scherer (2017) conclude that reducing BAC limits generally yields a 5–11 % reduction in alcohol-related crashes, especially when combined with strong enforcement visibility. However, these studies also highlight that estimates of policy effectiveness are highly sensitive to methodological choices and underlying assumptions. For example, Fell & Scherer (2017) relies on simulation-based projections based on previously estimated effects, meaning their results depend on how well findings from other contexts apply to the study setting, as well as assumptions about the baseline data. Similarly, Ferguson (2012) emphasizes that findings vary between study designs, data quality, and enforcement contexts, with more rigorous causal methods generally producing more reliable estimates.

These findings have contributed to the widespread adoption of a lower BAC limit across many countries. In December 2014, Scotland reduced the legal BAC limit for drivers from 0.08 to 0.05 g/dL of blood, while England and Wales continue to maintain a higher limit of 0.08 g/dL. However, reducing this threshold has been the subject of ongoing policy discussions. In this context, evidence from Scotland, where the lower limit was implemented in 2014, provides a valuable opportunity to inform future policy decisions. This research, therefore, aims to determine whether the observed changes in accident outcomes can be causally attributed to the implementation of this policy, after accounting for confounding factors and underlying trends.

Two prominent studies have examined this reform. Haghpanahan et al. (2019), using a comparative interrupted time-series design with weekly country-level data, find no evidence of a reduction in road traffic accidents following the policy change. Similarly, Francesconi & James (2021), using monthly data at the local authority level, report no significant impact and attribute this to weak enforcement and limited behavioral responses.

However, reassessing the Scottish reform remains important for several reasons. Much of the existing evidence on BAC reductions is based on policies implemented decades ago, often under different traffic conditions, and with more limited data and analytical tools. In contrast, the Scottish intervention represents a relatively recent policy change in a transport context, characterized by improved data availability and more advanced evaluation methods. As such, it provides a valuable opportunity to re-examine the effectiveness of BAC reductions using more advanced data and methodologies, and to generate evidence that is directly relevant for current policy discussions in countries considering similar reforms.

This study addresses key limitations in the existing literature by overcoming issues related to spatial aggregation, short post-treatment periods, and the focus on average treatment effects. Using a disaggregated panel dataset at the Middle-layer Super Output Area (MSOA) level for England and Wales and Intermediate Zone (IZ) level for Scotland over an extended time horizon, it applies Synthetic Difference-in-Differences (SDID) method to improve causal inference and provide a more robust evaluation of Scotland's BAC reduction policy. The SDID framework improves upon traditional Difference-in-Differences (DiD) by constructing a weighted control group that closely matches pre-treatment trends, thereby enhancing the credibility of causal inference.

2 Methodology

Data

This study used a comprehensive longitudinal dataset covering all police-reported road traffic collisions in Great Britain between 2008 and 2019. The core data were obtained from the *UK Department for Transport's (DfT) STATS19 system.* All collisions were spatially aggregated based on 2011 MSOA and IZ administrative boundaries. Population data were obtained from the Office for National Statistics (ONS) for each MSOA area and from the National Records of Scotland (NRS) for each IZ area on an annual basis. Rather than using raw crash counts, the analysis employed log-transformed crash rates, with a small constant ($\epsilon = 1$) added to account for zero values. The final dataset comprised approximately 7,940 spatial units observed over 12 years, forming a balanced panel suitable for causal analysis.

Treatment and Outcome Definition

The treatment corresponds to the reduction of the legal BAC limit in Scotland from 0.08 to 0.05 g/dL, implemented in December 2014. Spatial units located in Scotland are defined as the treated group, while units in England and Wales serve as the control group, where no change in BAC legislation occurred.
A binary treatment indicator is defined such that it takes the value of 1 for treated units in the post-policy period (2015 on-wards) and 0 otherwise. The pre-treatment period spans from 2008 to 2014.
The main outcomes of interest are the logarithm of total crash rates, night-time crash rates, and weekend crash rates. Night-time (22:00-4:00) and weekend crashes (22:00-4:00 on Friday and 22:00-4:00 on Saturday) are included as they are more likely to be associated with alcohol-related driving behavior and therefore provide additional insight into policy effectiveness in high-risk contexts.

Synthetic Difference-in-Differences (SDID)

To estimate the causal impact of the policy, this study employs the SDID method proposed by Arkhangelsky et al. (2021). SDID combines features of DiD and Synthetic Control methods by constructing a weighted control group that closely matches the treated units in the pre-treatment period.
Let Y_{it} denote the outcome for unit i at time t, where $i = 1, \ldots, N$ and $t = 1, \ldots, T$. Suppose that the first N_1 units are treated after period T_0, and the remaining N_0 units serve as controls.
The SDID estimator is defined as:

$$\hat{\tau}^{SDID} = \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{\omega}_i \hat{\lambda}_t D_{it} Y_{it} \tag{1}$$

where $\hat{\omega}_i$ are unit weights, $\hat{\lambda}_t$ are time weights, and D_{it} is a treatment indicator equal to 1 for treated units in the post-treatment period and 0 otherwise.
The weights are chosen to minimize discrepancies between treated and control units in the pre-treatment period. This involves solving an optimization problem that balances pre-treatment outcomes while applying regularization to avoid overfitting:

$$\min_{\omega,\lambda} \sum_{i \in \mathcal{C}} \sum_{t \leq T_0} \left(Y_{it} - \sum_{j \in \mathcal{T}} \omega_j Y_{jt} \right)^2 + \zeta \|\omega\|^2 + \gamma \|\lambda\|^2 \tag{2}$$

where $\mathcal{T}$ and $\mathcal{C}$ denote treated and control units, and ζ and γ are regularization parameters.
Intuitively, SDID constructs a synthetic control group that closely reproduces the pre-treatment trajectory of the treated units while also allowing for flexible time weighting. This improves the credibility of the counterfactual by relaxing the strict parallel trends assumption required in standard DiD. As discussed in Arkhangelsky et al. (2021), the use of both unit and time weights enhances robustness by balancing latent factors across units and time periods, thereby reducing bias in causal estimation.
Model performance is evaluated using pre-treatment fit, particularly the Root Mean Squared Prediction Error (RMSPE). A lower pre-treatment RMSPE indicates a better match between treated and synthetic control units and therefore a more reliable estimate of the treatment effect. In

addition, the Post/Pre RMSPE ratio is used as a diagnostic measure, defined as the ratio of post-treatment RMSPE to pre-treatment RMSPE. A large ratio suggests that the divergence between treated and synthetic control units increases substantially after the intervention, providing evidence of a potential treatment effect, whereas a ratio close to one indicates little change beyond pre-treatment discrepancies.

To assess statistical significance, placebo tests are conducted by iteratively assigning the treatment to control units and re-estimating the SDID model. This generates a distribution of placebo treatment effects under the null hypothesis of no effect. The placebo p-value is calculated as the proportion of placebo estimates that are as large as or larger than the observed treatment effect in absolute value. A small p-value indicates that the estimated effect is unlikely to have occurred by chance.

Furthermore, placebo-based confidence intervals are constructed using the distribution of these placebo estimates. The lower and upper bounds represent the range within which the treatment effect would fall under the null distribution. These intervals provide a non-parametric measure of uncertainty that is robust to model misspecification and serial correlation, which are common concerns in panel data settings.

Overall, these diagnostic and inference tools are essential for validating the credibility of the SDID estimates, ensuring that observed effects are not driven by poor pre-treatment fit or spurious patterns in the data.

3 Results and Discussion

Table 1 presents the estimated effects of Scotland's BAC reduction policy using the SDID approach across three outcome measures: log total crash rate, log night-time crash rate, and log weekend crash rate.

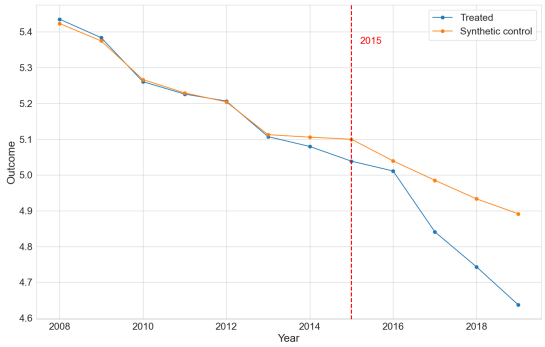
The results indicate a consistent and statistically meaningful reduction in crash rates following the policy implementation. For total crashes, the policy led to a moderate decline in overall crash rates across treated areas. Stronger effects are observed for night-time and weekend crashes. These findings are consistent with expectations, as drink-driving behavior is more prevalent during night-time and weekends, indicating that the policy was particularly effective in targeting high-risk periods.

The pre-treatment RMSPE values are relatively low across all outcomes, indicating a strong pre-treatment fit between treated and synthetic control units. This suggests that the SDID model successfully constructed a credible counterfactual for the treated units prior to the intervention. The Post/Pre RMSPE ratios further support the presence of a treatment effect. For total crashes, the ratio is 13.37, while substantially higher values are observed for night-time and weekend crashes. These large ratios indicate a significant divergence between treated and synthetic control units after the policy implementation, reinforcing the interpretation that the observed reductions are attributable to the BAC reform rather than pre-existing trends.

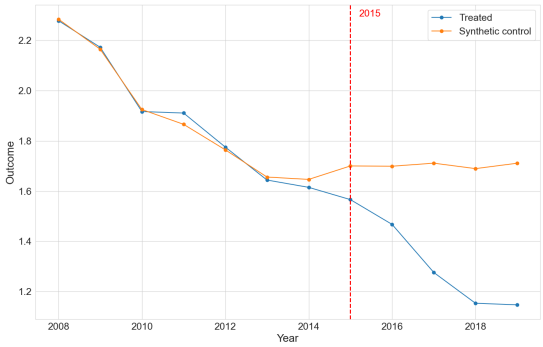
Table 1: SDID Results

Outcome	$\hat{\tau}^{SDID}$	**Pre-RMSPE**	**Post/Pre RMSPE Ratio**	**Policy Percent Effect**
Log Total Crash Rate	-0.1278	0.0119	13.3692	-12.00 %
Log Night Crash Rate	-0.3803	0.0222	18.7626	-31.63 %
Log Weekend Crash Rate	-0.2914	0.0140	21.9653	-25.28 %

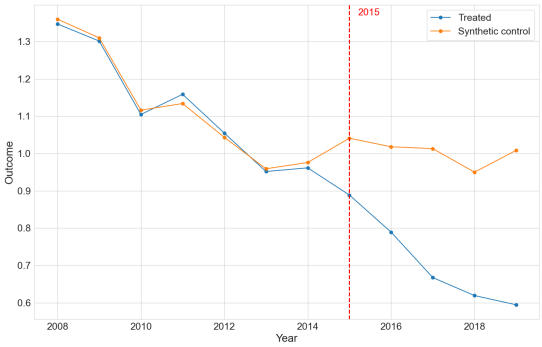
Figure 1 provides a visual comparison between treated units and their synthetic counterparts over time. The close alignment between the two series in the pre-treatment period indicates a strong pre-treatment fit, supporting the validity of the SDID approach. Following the policy implementation in 2015, a clear divergence emerges, with treated units exhibiting a sharper decline in crash rates compared to the synthetic control.



(a) Log Total Crash Rate



(b) Log Night Crash Rate



(c) Log Weekend Crash Rate

Figure 1: Trends in Treated and Synthetic Control Groups Before and After BAC Policy Implementation.

The placebo test results shown in table 2, provide strong evidence supporting the statistical significance and robustness of the estimated treatment effects. The placebo standard errors are relatively small across all outcomes, indicating stable estimates under repeated random assignments. The 95% confidence intervals, constructed using the standard deviation of placebo estimates as an approximation for standard errors, lie entirely below zero for all outcomes. This indicates that the estimated SDID effects are statistically significant and unlikely to be driven by random variation. Reporting confidence intervals is particularly important for interpreting time-varying estimates, as they provide a measure of uncertainty around the estimated effects across periods. Most importantly, the placebo p-values are consistently low for all outcomes, indicating that fewer than 1% of placebo estimates are as extreme as the observed treatment effects. This provides strong evidence against the null hypothesis and confirms that the reductions in total, night-time, and weekend crash rates are statistically significant and attributable to the BAC policy rather than spurious correlations or model artifacts.

Table 2: Placebo Test Results

Outcome	**Placebo Standard Deviation**	**Confidence Interval (95%) for $\hat{\tau}^{SDID}$**	**Placebo p-value**
Log Total Crash Rate	0.0089	[-0.1452 , -0.1104]	0.0099
Log Night Crash Rate	0.0293	[-0.4377 , -0.3229]	0.0099
Log Weekend Crash Rate	0.0296	[-0.3494 , -0.2334]	0.0099

Overall, the results provide strong evidence that lowering the BAC limit in Scotland had a mean-

ingful impact on reducing road traffic collisions, particularly in contexts associated with higher likelihoods of alcohol-impaired driving. The larger effects observed for night-time and weekend crashes highlight the importance of considering temporal heterogeneity when evaluating road safety policies.

4 Conclusions

This study examined the impact of Scotland's reduction in the legal BAC limit from 0.08 to 0.05 g/dL using a Synthetic Difference-in-Differences approach and a disaggregated panel dataset. The findings indicate that the policy led to a meaningful reduction in road traffic accidents, with particularly strong effects during periods associated with higher alcohol-related risk, such as night-time and weekends. These results suggest that lowering BAC limits can be an effective policy tool for improving road safety.

By leveraging granular spatial data and a robust causal inference approach, this study provides new evidence that contrasts with previous findings of negligible effects. The results highlight the importance of methodological choice, temporal context, and disaggregation in evaluating policy impacts.

Future research could extend this analysis by examining heterogeneous treatment effects across different types of areas. In particular, clustering spatial units based on similar characteristics and re-estimating the SDID model within each cluster would allow for a more nuanced understanding of how policy impacts vary across contexts. Such an approach could provide valuable insights for designing more targeted and effective road safety interventions.

References

Albalate, D. (2008). Lowering blood alcohol content levels to save lives: The european experience: Lowering blood alcohol content levels to save lives. *Journal of policy analysis and management*, *27*(1), 20-39. doi: 10.1002/pam.20305

Arkhangelsky, D., Athey, S., Hirshberg, D. A., Imbens, G. W., & Wager, S. (2021). Synthetic difference-in-differences. *American Economic Review*, *111*(12), 4088–4118. doi: 10.1257/aer.20190159

Bernhoft, I., & Behrensdorff, I. (2003). Effect of lowering the alcohol limit in denmark. *Accident Analysis amp; Prevention*, *35*(4), 515–525. doi: 10.1016/s0001-4575(02)00029-5

Blomberg, R. D., Peck, R. C., Moskowitz, H., Burns, M., & Fiorentino, D. (2005). *Crash risk of alcohol involved driving: A case-control study.* Stanford, CT: Dunlap Associates, Inc.

Dee, T. S. (2001). Does setting limits save lives? the case of 0.08 bac laws. *Journal of Policy Analysis and Management*, *20*(1), 111–128. doi: 10.1002/1520-6688(200124)20:1<111::aid-pam1006>3.0.co;2-#

Desapriya, E. B. R., Shimizu, S., Pike, I., & Smith, D. (2006). Impact of lowering the legal bac limit to .03 on teenage drinking and driving related crashes in japan. *Japanese journal of alcohol studies drug dependence*, *41*(6), 513-527.

Fell, J. C., & Scherer, M. (2017). Estimation of the potential effectiveness of lowering the blood alcohol concentration limit for driving from 0.08 to 0.05 grams per deciliter in the united states. *Alcoholism: Clinical and Experimental Research*, *41*(12), 2128–2139. doi: 10.1111/acer.13501

Ferguson, S. A. (2012). Alcohol-impaired driving in the united states: Contributors to the problem and effective countermeasures. *Traffic Injury Prevention*, *13*(5), 427–441. doi: 10.1080/15389588.2012.656858

Foss, R. D., Stewart, J., & Reinfurt, D. W. (2001). Evaluation of the effects of north carolina's 0.08% bac law. *Accident Analysis Prevention*, *33*(4), 507–517. doi: 10.1016/s0001-4575(00)00064-6

Francesconi, M., & James, J. (2021). None for the road? stricter drink driving laws and road accidents. *Journal of Health Economics*, *79*, 102487. doi: 10.1016/j.jhealeco.2021.102487

Haghpanahan, H., Lewsey, J., Mackay, D. F., McIntosh, E., Pell, J., Jones, A., ... Robinson, M. (2019). An evaluation of the effects of lowering blood alcohol concentration limits for drivers on the rates of road traffic accidents and alcohol consumption: A natural experiment. *The Lancet*, *393*(10169), 321–329. doi: 10.1016/s0140-6736(18)32850-2

Henstridge, J., Homel, R., & Mackay, P. (1995). The long-term effects of random breath testing in adelaide. In *Proceedings of the 13th international conference on alcohol, drugs and traffic safety (t'95).* Adelaide, Australia.

Homel, R. (1994). Drink-driving law enforcement and the legal blood alcohol limit in new south wales. *Accident Analysis Prevention*, *26*(2), 147–155. doi: 10.1016/0001-4575(94)90084-1

Levitt, S., & Porter, J. (1999). Estimating the effect of alcohol on driver risk using only fatal accident statistics. *SSRN Electronic Journal*. doi: 10.2139/ssrn.149729

Mercier-Guyon, C. (1998). Lowering the bac limit to 0.05: Results of the french experience. In *Proceedings of the transportation research board 77th annual meeting.* Washington, DC, USA.

Nagata, T., Setoguchi, S., Hemenway, D., & Perry, M. J. (2008). Effectiveness of a law to reduce alcohol-impaired driving in japan. *Injury Prevention*, *14*(1), 19–23. doi: 10.1136/ip.2007.015719

Tippetts, A. S., Voas, R. B., Fell, J. C., & Nichols, J. L. (2005). A meta-analysis of 0.08 bac laws in 19 jurisdictions in the united states. *Accident Analysis amp; Prevention*, *37*(1), 149–161. doi: 10.1016/j.aap.2004.02.006

Voas, R. B., Tippetts, A., & Fell, J. (2000). The relationship of alcohol safety laws to drinking drivers in fatal crashes. *Accident Analysis Prevention*, *32*, 483–492. doi: 10.1016/s0001-4575(99)00063-9

WHO. (2022). *Drink-driving a road safety manual for decision-makers and practitioners.* International Federation of Red Cross and Red Crescent Societies.

WHO. (2023). *Global status report on road safety.* World Health Organization.

Zador, P. L., Krawchuk, S. A., & Voas, R. B. (2000). Alcohol-related relative risk of driver fatalities and driver involvement in fatal crashes in relation to driver age and gender: An update using 1996 data. *Journal of Studies on Alcohol*, *61*(3), 387–395. doi: 10.15288/jsa.2000.61.387