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ABSTRACT

An Extra Hour Wasted? Bar Closing Hours and Traffic Accidents in Norway*

Driving under the influence of alcohol is a major cause of fatalities worldwide. There have been a range of legislative and policy interventions that aim to address this. Bar closing hours is one policy with clear implications for drink driving. Existing evidence, largely drawn from one-off policy changes in urban settings, reports mixed evidence that is difficult to generalise. We return to this issue using a setting, Norway, that is advantageous due to large temporal and regional variation in closing times, frequent changes in closing hours, and a lack of other confounding policy changes. We demonstrate an average zero effect of closing hours on traffic accidents that masks large variations in effects, especially in terms of population density, accident severity, and direction of change in closing hours. Our results suggest that estimates from single policy changes may be difficult to generalise, while demonstrating that closing hours have the potential to generate large effects on traffic accidents.

JEL Classification: I18, R41
Keywords: closing hours, alcohol policy, traffic accidents

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1 Introduction

Driving under the influence of alcohol remains a leading cause of fatalities and serious injuries worldwide. According to the World Health Organization (2007), approximately 20 percent of fatally injured drivers in high-income countries have a blood alcohol concentration above the legal limit. Furthermore, over half of fatal accidents in the US happen at night-time, where 54 percent of accidents are alcohol-related (Forbes, 2009). As a consequence, policies aiming to prevent drink-driving and reduce the risk of accidents remain a central part of the debate on appropriate alcohol policies.

The forefront of attempts to reduce these fatalities have been interventions aimed at reducing drink-driving, mainly through lowering the blood alcohol level permissible while driving and attaching large penalties to breaches of these restrictions. Along these lines, the past decades have seen a general move to more stringent drink driving laws and these have been shown to be effective in reducing traffic accidents and injuries. At the same time, a broader range of legislation on alcohol consumption has the potential to substantially impact upon drink-driving and associated societal harms. One such area is on-premise licensing laws. Where and when individuals can purchase and consume alcohol, such as at a bar, restaurant or hotel, has natural links with drink-driving. Moreover, at the same time that drink-driving laws have become stricter, there has been a move towards more liberal closing hours of licensed premises in many jurisdictions. As an example, several US states (California, Michigan, Ohio and Wisconsin) have bills currently in the legislative process aimed at extending closing hours.

In practice, the relationship between closing hours, drink-driving, and traffic injuries is complicated by several factors. Longer opening hours are linked to greater alcohol consumption with the associated heightened drink-driving risk. Yet, early closing times are often thought to result in so-called drinking 'against the clock'. This has the potential to lead to increased inebriation at closing time and heightened risk of traffic accidents. More generally, unified and early closing hours increase risks related to multiple drinkers driving at the same time (Levitt & Porter, 2001). Stringent closing hours may also make multiple-vehicle accidents more likely due to the higher underlying traffic flows present earlier at night. Yet, later hours may limit alternative modes of transport (public transport) and/or make it more expensive (taxis). Together this means that the direction of effect between closing hours and traffic accidents is unclear and the existing evidence perhaps reflects this point.

A body of research has developed that seeks to provide causal estimates of closing hours on traffic accidents and fatalities. These papers typically have examined individual events of licensing changes. For example, Vingilis et al. (2005) investigate the effect on road safety of an extension in on-premise alcohol sales from 1 to 2am in Ontario, Canada. They find no impact on traffic fatalities with positive blood alcohol concentration after the extension. In a second paper, Vingilis et al. (2006) study accidents in Windsor, Canada following a harmonisation in closing hours with bordering, later-closing, Detroit. This extension lead to an increase in accidents in the Windsor region. Yet, accidents in Detroit were reduced, likely reflecting reductions in Canadian patrons crossing the border to take advantage of the longer on-premise closing hours. Bouffard, Bergeron, and Bouffard (2007) examine the effect of extended closing hours in Minnesota on DUIs. While they demonstrate a significant increase in the number of police stops for DUI following this legislative change, further analyses suggested that this increase may largely reflect the increased policing that accompanied the policy change. Green, Heywood, and Navarro (2014) explore the effects of a large liberalisation in bar closing hours, from 11pm up to 5am that occurred simultaneously across all of England and Wales.[1] They demonstrate marked reductions in traffic accidents and injuries. At the same time, Biderman, De Mello, and Schneider (2010) examine the effect of a restriction of bar closing hours in the São Paulo Metropolitan Area, and demonstrate a reduction in fatal traffic accidents. Together, this highlights the mixed evidence of the effect of closing hours on traffic accidents. Related research shows that on-premise availability increases accidents accidents in settings likely to encourage driving to and from venues. For instance, Cotti and Walker (2010) demonstrates that casino openings lead to marked increases in drink related traffic fatalities within US counties. While both Cotti and Walker (2010) and Burton (2020) show that non-uniform smoking bans, increase drink driving traffic accidents, likely through increased distance individuals drive to consume alcohol in combination with smoking.

We return to this issue focusing on Norway. This provides an advantageous focal point for a variety of reasons. First, on-premise closing hours are set at a highly disaggregated municipal level and vary considerably over time. This provides substantial variation in closing hours with changes in different directions and at different margins. Second, many other potential policy changes likely to confound estimates of the effect of on-premise hour do not vary at the municipal level. This is in contrast to many other settings, where drink-driving penalties,

[1] In practice most venues increased opening times by 1-2 hours.

drink-driving limits, and off-premise alcohol laws may be changed at the same time, or as a result of, on-premise law changes. This makes it difficult to disentangle the effect of changes in closing hours from other changes in alcohol related policies. In Norway, these types of policies are set nationally and simply do not vary within our period of analysis. Third, policing decisions in Norway are taken at a different, higher level, than bar closing hours and are unlikely to be varied with closing hour changes. Together, we argue that this provides a clean setting to isolate the effect of on-premise closing hours on individual behaviour. On top of this, there is marked regional variation in population density with commensurate differences in the density of off-premise venues and availability of public transport. We utilise these differences to understand likely mechanisms generating our results, which is important when discussing the implications of our results for other jurisdictions.

Municipalities in Norway are free to choose closing hours within a broad nationally set limit of midnight to 3am. Moreover, local political candidates frequently include changes in bar hours as part of their political platforms. This leads to substantial variation both across municipality and time. Our main approach utilises this within municipal across time variation to estimate the effect of different closing hours on a range of accident types and injury outcomes. We use panel data on closing hours covering 2009 to 2018 for 424 municipalities in Norway, and combine it with detailed data on all reported night-time traffic accidents. We demonstrate an average zero effect that hides marked variation across jurisdictions. Longer hours in highly populated urban areas are associated with pronounced lower accident and injury rates. In contrast, longer hours increase accidents in less populated areas. These results are robust to a range of likely confounding influences, and remain in alternative data sources such as police DUI reports.

Combining detailed data on accident outcomes with the marked regional variation allows us to further investigate heterogeneous effects of closing hours. We demonstrate that the effect is concentrated in the urban areas of a municipality, and has particularly large effects on the rate of multiple-car accidents. This has implications both for policing decisions, while also being relevant for policymakers as two-car accidents involve higher average societal costs than single-car accidents. Furthermore, we utilise the advantage of having both extensions and restrictions of closing hours in our sample to show that these have asymmetric effects. Restrictions appear to have no effect on accidents, while liberalisations decrease accidents in populous, urban settings. Finally, we demonstrate important trade-off effects for less populated municipalities, where extending closing hours will increase more common, but less serious accidents, and decrease

costly and infrequent accidents that involves serious injuries or fatalities. These effects suggest an important role for context in which closing hours are chosen and changed. As existing literature shows very mixed results of bar closing hours on traffic accidents, we demonstrate how closing hours can have dramatically different effects in one setting.

In what follows, we describe the institutional framework and outline our data. This is followed by a description of our empirical methodology, our main results, robustness checks and examination of heterogeneity in treatment effects. We then provide a conclusion.

2 Institutional framework and the data

According to Norwegian law on-premise alcohol sales are permitted between 8am to 3am for beverages with an alcohol content up to 22 percent, such as beer and wine. Spirits containing between 23 and 60 percent alcohol can be served between 1pm and 3am.[2] Municipalities are free to decide serving regulations within these hours, and serving hours can differ between beer and wine, and hard liquor, in the same municipality. Serving hours can also differ between weekdays and weekends. Our main approach, unless stated otherwise, is to use weekend closing hours for hard liquor. We stress, however, that our results are unchanged if we, instead, use the beer and wine serving hours.

Unlike on-premise laws, Norway has a national alcohol policy with respect to off-premise alcohol sales. Beer (up to 4.7 percent alcohol content) cannot be purchased off-premise after 8pm on weekdays, 6pm on Saturdays and not at all on Sundays. Other stronger alcohol can only be purchased from the government run monopoly which exists in few locations (for example, Trondheim with 200,000 inhabitants has eight of these shops) and with very limited opening hours (weekdays til 6pm, 10am-3pm on Saturdays and closed on Sundays). These off-premise laws remain unchanged across our period of analysis.

Changes to on-premise closing hours in Norwegian municipalities are frequent and are often subject to political debate and media attention (Rossow & Baklien, 2014). These changes often, but not exclusively, take place shortly after a new council has been elected, suggesting that alcohol policy often is part of local election campaigns. In general, the reasons behind the decision to alter closing hours are multi-factorial, and the public debate is often divided between public health and industry interests. Proponents of liberal closing hours argue that

[2]Patrons can stay up to 30 minutes after alcohol sales time in order to finish their drinks.

it contributes to the liveliness of cities and increases revenue for hotels, restaurants and bars. Opponents argue that earlier closing hours decrease street violence and a range of other social externalities including drink-driving. Support for both of these arguments can be found in the small, associative, literature that exists for Norway. For instance, Melberg and Schøyen (2012) find that a reduction in alcohol serving time by one hour is associated with higher revenue of between 9 and 12 percent. On the other hand, Rossow and Norström (2012) find that a one hour extension in closing hours is associated with an increase in assaults by 13 percent.

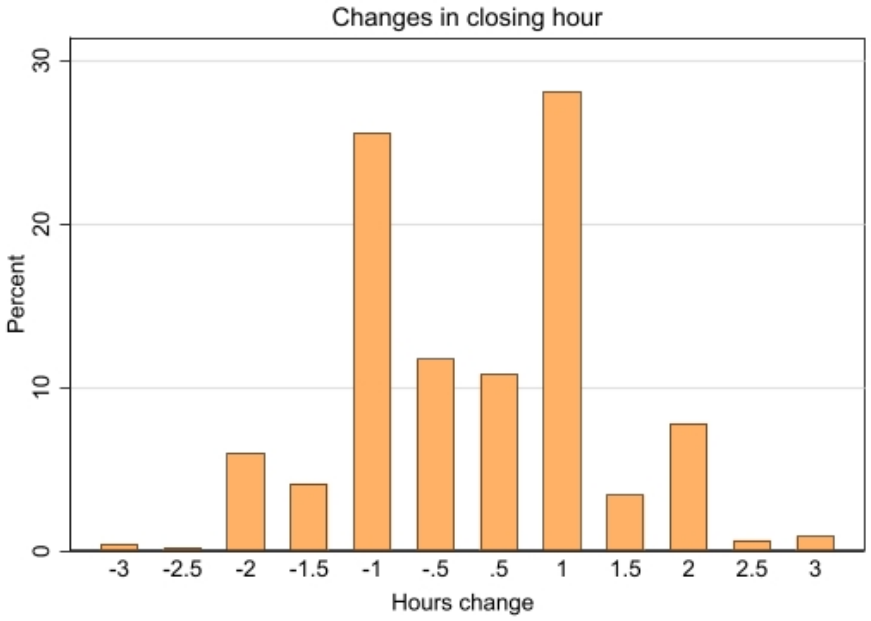

Figure 1: An overview of the direction of closing hours change in the period between 2009 and 2018. *Source: Norwegian Institute of Public Health.*

Data on closing hours comes from local council responses to the Alcohol Act survey, conducted by the Norwegian Institute of Public Health. The questionnaire is sent to all Norwegian municipalities every year, with a very high response rate of between 93 to 99 percent. We use the information on closing hours from 2009, the earliest year for which information on municipal closing hour is available, to 2018. During this period there were 434 individual municipal changes in on-premise serving hours. This is equivalent to each municipality changing their closing hours, on average, one time over the ten year period.

Figure 1 shows the distribution of changes in closing hours in terms of size and direction. The changes are quite evenly split between reductions and extensions. Around 55 percent of changes involve increases or decreases of on-premise sales by one hour, 22 percent are 30 minute

changes, and there is a non-trivial amount of changes of more than one hour in terms of both extensions and restrictions. This allows us to examine the effects of a range of changes (size, direction) on the effect of closing hours on traffic accidents.

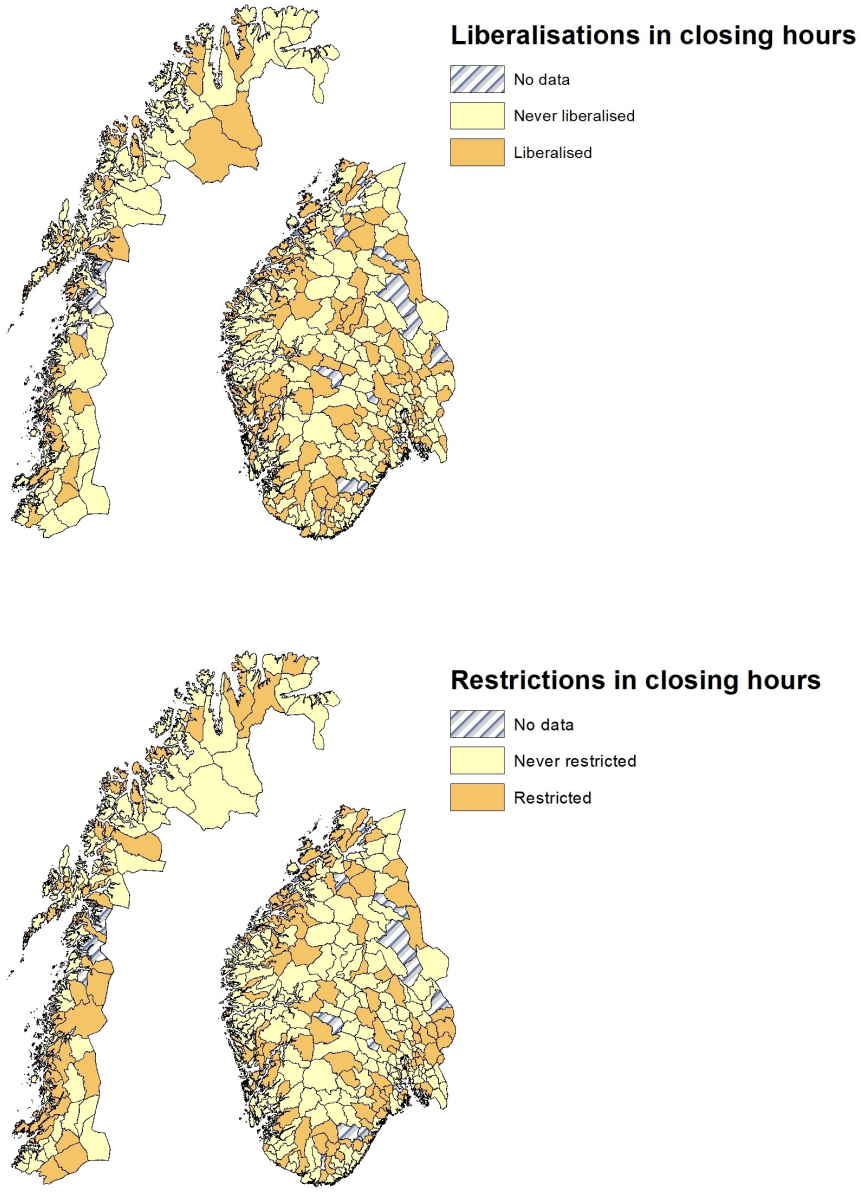

Figure 2: Geographical distribution of municipalities that ever liberalised and restricted their closing hours. *Source: Norwegian Institute of Public Health.*

Figure 2 provides geographic information on these changes where for presentation purposes we separate northern and southern Norway. The upper panel displays municipalities that at some point during the sample period extended on-premise serving hours.[3] In the lower panel we plot municipalities that have restricted their closing hours. Two points can be made from

[3]The municipal structure in Norway has changed somewhat during the last decade. Municipalities that have merged are challenging to map, and are therefore marked as missing.

these maps. First, municipalities that liberalised or restricted hours are spread across the country. This reduces concerns that changes are geographically clustered in some manner, for instance around major cities, in areas with strong religious preferences, or in areas with a strong brewing industry. Second, and although more difficult to see graphically, a non-trivial number of municipalities have both extended and restricted closing hours during the period (158 municipalities).

Our road accident data comes from The Norwegian Public Roads Administration (NPRA) and contain all motor vehicle accidents reported to the police from 2009 to 2018 for all 429 municipalities. We have information on the date and time of accident, severity, road speed limit and accident location. This data allows us to match accident location to the corresponding municipality's closing hours. We match the accidents and closing hour data to population level data from Statistics Norway, and data on the number of individuals between the age of 18 and 25 to construct a variable of the share of young adults in the municipality. This reflects the fact that young drivers are both much more likely to be involved in a traffic accident than other sober drivers, and also may be more affected by changes in on-premise closing hours.

Table 1: Descriptive statistics by closing hours status (2009-2018)

	(1)	(2)	(3)
Variable	**All**	**Unchanged**	**Changed**
Municipalities	423	204	219
Accidents	0.82	0.96	0.68
	(2.60)	(3.37)	(1.58)
Closing hour (beer/wine)	2.02	2.05	1.98
	(0.60)	(0.57)	(0.63)
Closing hour (spirits)	1.73	1.78	1.67
	(0.82)	(0.79)	(0.86)
Population	11,943	14,553	9,508
	(36,561)	(48,031)	(20,495)
Young adults	1,247	1,540	972
	(4,056)	(5,287)	(2,362)

Note: The variable *Accidents* is the number of traffic accidents occurring weekends between 10pm and 5am in a municipality over the course of one year. Standard deviations in parentheses.

Systematic differences between those municipalities that did and did not change closing hours can bias estimates. Table 1 displays summary statistics of the variables included in our analysis, divided by whether or not municipalities have changed their closing hours. Approximately half of the municipalities have not altered closing hours during the sample period. No

change municipalities have slightly more accidents and have somewhat more liberal closing hours. It is worth noting that population size, is on average, larger for municipalities that do not change closing hours. Controlling for population and including municipality fixed-effects should account for related confounding factors that might bias the estimates of the effects of closing hour.

Population-size variation within Norway is worthy of further discussion, as Norwegian municipalities vary greatly in size and population. For example, the least populated municipality has 200 inhabitants, whereas 658,000 people live in the most populated municipality. In fact, the smallest half of Norwegian municipalities account for approximately 10 percent of the entire population.

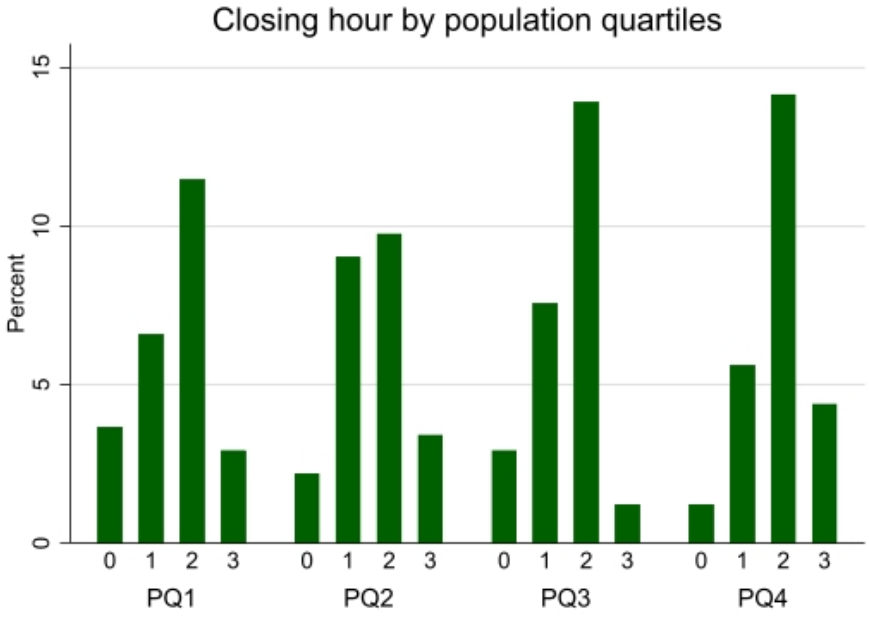

Figure 3: An overview of closing hours according to population size quartiles.

Figure 3 presents an overview of closing hours according to different municipal population quartiles in the middle year of the sample, 2014.[4] There is no evidence that, for example, only populous municipalities close at the latest permissible hour (3am). Although municipalities belonging to different population quartiles have similar variation in closing hours, there are other differences related to population size that are germane to our analysis. For instance, in smaller to mid-sized municipalities, there are no buses, trains or trams to take bar patrons home

[4]The first quartile includes municipalities with less than 2,170 inhabitants. The municipalities belonging to the second and third quartiles have between 2,171 and 4,500 inhabitants and 4,501 and 10,000 inhabitants, respectively. The last quartile include municipalities with more than 10,001 inhabitants.

after the bar closes. With approximately 20,000 inhabitants, Grimstad is to our knowledge the smallest town (and municipality) that provides night-time public transport. Consequently, taxis may be the only viable public transport alternative. If there is a night-time taxi service available, which is not always the case, there is likely to be queuing around closing time. Moreover, people often live scattered within the least populous municipalities, meaning that taxi costs can be prohibitive especially when coupled with average taxi driver wages in Norway. For example, a weekend night-time taxi ride of 6.3 kilometres (4 miles) with a duration of 15 minutes is estimated to cost 400 NOK (45,7 USD). A 30 minutes ride that covers approximately 20 kilometres (12.4 miles) costs 1,145 NOK (131 USD). In summary, night-time public transport is often not a realistic alternative in sparsely populated municipalities. This might translate to heterogeneous effects of changes in closing hour on night-time traffic accidents between rural and urban areas, which will be important to account for in our analysis.

3 Methodology

Our main approach is to estimate variants of:

$$Acc_{it} = \alpha_i + \beta_1 ClosingHour_{it} + \gamma X_{it} + \delta T_t + \varepsilon_{it} \tag{1}$$

where Acc_{it} is the number of weekend accidents happening between 10pm and 5am in municipality i in year t. $ClosingHour$ is the maximum allowed on-premise alcohol serving hour during weekends in municipality i in year t, ranging from midnight to 3am. Vector X includes the population level and the number of young adults (aged 18 to 25) in municipality i in year t. α_i captures municipal fixed effects, T_t is a set of year dummies, and ε_{it} is random idiosyncratic error. Hence, our estimate of interest β_1 is identified by within municipality variation in closing hours holding constant nationwide annual patterns in accidents.

Our choice of municipal fixed effects approach is motivated by a range of concerns regarding cross municipal variation in time-invariant factors influencing alcohol consumption, bar closing hours, and underlying risk of traffic accidents. For instance, there is variation across Norway in the strength of religious attitudes, which simultaneously influences drinking culture, closing hours, and night time activities. Some of these municipalities are in locations where the difficulty of driving, and the risk of accident, is higher. This leads to a concern that OLS

estimation will overstate the effect of bar closing hours on traffic accidents. Alternatively, some municipalities in rural areas might have a strong drinking culture with liberal bar closing hours, but also a higher accident prevalence because of lesser provision of night-time public transport services. Again this may lead to OLS estimates being upwardly biased.

A further concern, not mitigated by this approach, is the potential for time-varying factors correlated with both closing hours and traffic accidents. For example, nation-wide shocks, caused by government awareness campaigns or increased taxation on alcohol, could reduce closing hours and the number of traffic accidents in several municipalities within the same year. We include year fixed effects to capture such influences that are common for all municipalities. Municipal specific time varying factors are more difficult to address, and it is unclear in what direction these may bias our results. For example, restrictions of hours and the election of municipal governments that favour restrictions may gain more traction in instances where there have been increases in underlying problems related to alcohol consumption in the local area. At the same time, increases in local economic activity may increase the number of licensed venues, and increase pressure on municipal governments to extend hours. We adopt a number of approaches aimed at assessing the sensitivity of our main estimates to these types of factors. These range from including municipal specific time trends to estimating disaggregated models for liberalisations and restrictions. While these tests do not directly address time-varying unobservables, they provide some gauge of the sensitivity of our main estimates.

Finally, we suspect that any effect of bar closing hours is heavily dependent on municipal population size for the reasons we described earlier. These include the fact that more populous municipalities are likely to have higher concentrations of bars, but also have substantially greater public transport availability at closing times attenuating any effect on drink driving. In rural, less populated, areas, typically there will be no public transport provision and distances from bars to home may be substantially greater, both increasing the risk of accident and the cost of taxis (even when available). In practice, there does not exist an obvious way to model and capture these differences. Our initial approach is to include an interaction term of bar closing hours and population in our main model, with the aim of examining if there is any evidence of heterogeneous effects of closing hours by population.

4 Results

Column (1) in Table 2 provides initial estimates of the relationship between closing hours and night-time traffic accidents. This and all regressions henceforth are estimated with municipal fixed-effects, year dummies and standard errors are clustered at the municipal level. The result suggest a negative, however small and not statistically significant, relationship between longer opening hours and accidents. This estimate provides the linear effect of increasing closing hours by one and may hide marked non-linearities across actual closing time. To examine this, we additionally estimated an analogue of (1) where we replaced closing hours with a series of dummy variables to indicate closing hour, where midnight is the omitted category. These estimates are plotted in Figure 4, which depicts a coefficient plot with confidence intervals at the 95 percent level. They suggest no difference between closing times of midnight, 1am or 2am, but some suggestion of lower accidents at the latest closing time. However, none of these coefficients are statistically significant at standard levels, and the estimate for 3am closing is particularly imprecise.

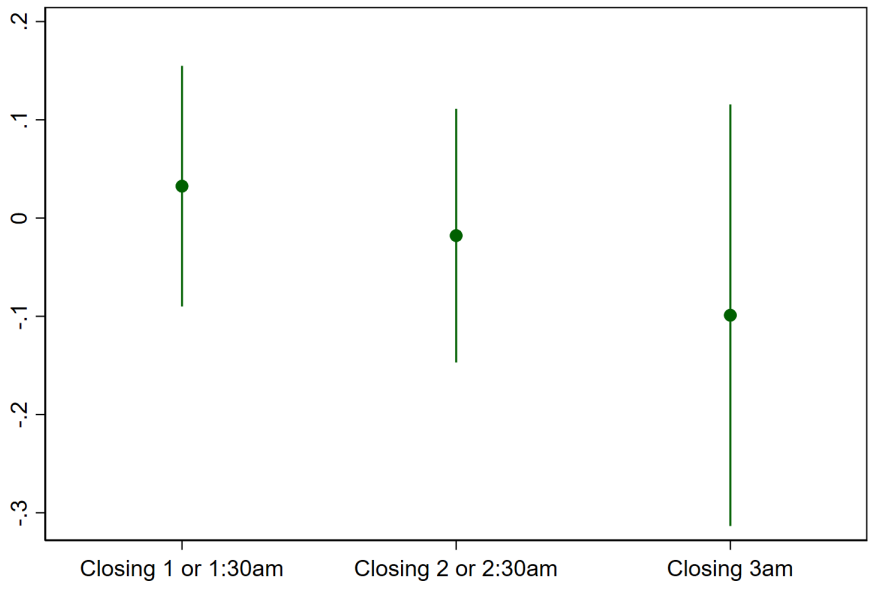

Figure 4: Estimated impact of different closing hours on traffic accidents.

As discussed earlier, it is likely that any relationship between closing hours and accidents may vary according to population levels and the number of young adults in a given municipality. As a first step to investigating this, we allow the effect of closing hours to vary by the population size of the municipality. In column (2), we present the results where we include an interaction between municipal population and bar closing hours. This dramatically changes the

Table 2: The influence of bar closing hours on traffic accidents between Friday and Sunday (2009-2018)

	Hard liquor			Beer and wine
	(1)	(2)	(3)	(4)
	FE	FE	FE	FE
	Accidents	Accidents	Accidents	Accidents
Closing hour	-0.004	0.382***	0.137***	0.128***
	(0.033)	(0.071)	(0.046)	(0.043)
Closing hour×		-0.536***	-0.187***	-0.236***
population		(0.091)	(0.064)	(0.052)
Population			-3.496***	-3.397***
(/10,000)			(0.510)	(0.439)
Number of young adults			13.195*	13.552**
(/10,000)			(7.150)	(6.872)
Constant	1.123***	1.795***	3.890***	3.878***
	(0.090)	(0.177)	(0.361)	(0.393)
Year dummies	Yes	Yes	Yes	Yes
R^2	0.019	0.116	0.167	0.169
Observations	4039	4039	4039	4039
Municipalities	423	423	423	423

Note: The dependent variable is the number of traffic accidents occurring weekends between 10pm and 5am. ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

estimate of interest. The initial effect of liberalising bar closing hours is positive and statistically significant at the one percent level, implying an increase in 0.4 accidents when extending bar closing hours by one hour. The interaction term between bar closing hours and population is negative, statistically significant, and also sizeable. This positive effect of bar closing hours decreases as population size increases, with the effect on average being zero in municipalities with approximately 7,100 inhabitants and turning negative in more populous municipalities. This provides an initial suggestion of marked differences in the effect of closing hours by municipal setting. For example, for the most populous municipality in Norway (Oslo), the results suggest approximately 37 accidents less per year after liberalisation, or three night-time accidents less per month.[5] At the same time, there are 230 municipalities in Norway with less than 5,000 inhabitants. Extending closing hours would increase accidents by 30 percent for these municipalities, adding up to 24 accidents for all municipalities. We next add population level and the number of young adults to the model, in our municipal fixed effects strategy these seek to capture potential confounding influences of demographic change on the number of night-time

[5]Oslo has approximately 674,000 inhabitants as of 1^{st} of January, 2018.

traffic accidents. The result is presented in column (3), which is equivalent to equation 1. The magnitude of both closing hours and the interaction term is reduced, but both direction and statistical significance are unaltered.

Municipalities have the ability to differentiate between serving hours for spirits, and for beer and wine, allowing beverages with lower alcohol levels to be sold later than hard liquor.[6] For simplicity we have used hard liquor closing hours up to this point. In column (4), we present estimates where we use the applicable serving hours for beverages with a lower alcohol content. The key estimates of interest are essentially unchanged by this. As a result, we focus solely on the hard liquor hours from this point on but stress that all following estimates are essentially unchanged if we use these alternative hours.

5 Robustness

5.1 Alternative specifications

Table 3: Alternative specifications of the effect of closing hours on traffic accidents

	Logs	Weighted	County cluster	Municipal trends	Fixed population at 2009
	(1)	(2)	(3)	(4)	(5)
Closing hour	1.92**	0.722***	0.137***	0.101**	0.162***
	(0.889)	(0.186)	(0.045)	(0.040)	(0.050)
Closing hour×	-0.225**	-0.469***	-0.187**	-0.178***	-0.231***
population	(0.110)	(0.107)	(0.075)	(0.053)	(0.075)
Weighted	No	Yes	No	No	No
County cluster	No	No	Yes	No	No
Municipal trends	No	No	No	Yes	No
R^2	0.029	0.424	0.167	0.324	0.168
Observations	4039	4039	4032	4039	4039
Municipalities	423	423	423	423	423

Note: All regressions are estimated using fixed effects and include controls. ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

We next test the sensitivity of these results to alternative specifications of the main model. In column (1) in Table 3, we modify all variables, with the exception of closing hours, to be expressed in natural logarithms.[7] The result supports the findings from the main model,

[6]The correlation between the two closing hours is 73 percent.

[7]We replace the zeros in the dependent variable with 0.001.

suggesting that an increase in closing hours increases the number of traffic accidents, but that the magnitude of this effect changes with population size with a turning point that is similar to that for the main estimates. Next, we re-estimate our main model using population levels as weights.[8] Comparing unweighted and weighted regressions is a useful diagnostic for model misspecification, as suggested by Solon, Haider, and Wooldridge (2015). The coefficients of interest in column (2) increase somewhat compared to the main model, but the sign and significance of the coefficients persist.

In column (3), we allow standard errors to be correlated within counties and cluster at that level. The standard errors are near to unaltered, suggesting that within-county correlation between clusters is not a major cause for concern in the main estimates. Next, there might be some unobserved trending factors that affect both closing hours and the number of traffic accidents, such as attitudes towards alcohol or local economic factors. Failing to control for these may lead to biased and inconsistent estimates of the effect of closing hours on traffic accidents. To examine this, we estimate our main model including municipal time trends. The coefficients presented in column (4) are marginally smaller in magnitude compared to the main result, yet both estimates are quite precisely estimated and the patterns of effects remain essentially the same. This makes it less likely that our results are driven by, for instance, policy responses to trends in drink driving within municipalities.

A further test is related to our interaction of closing hour and population. As both variables vary over time it may be that some of the effect of the interaction term derives from variation in population levels instead of changes in closing hour. We explore this by fixing population levels in the interaction term at the first year of observation, so that only closing hour changes over time. The results of this approach, displayed in column (5), replicates the coefficients in the main results both in terms of magnitude and statistical significance.

5.2 Threats to identification

This section provides further checks aimed at examining threats to our identification strategy. One concern is that people living in rural areas may be more affected by closing hours in nearby cities than in their own municipality. This generates potential measurement error likely to bias our estimates of closing hours effects towards zero. At the same time, an alteration in closing

[8] We use population levels from the first year in the sample in order not to place more weight on the latter years because of population growth.

hours that increases patronage from neighbouring municipalities might lead to more accidents in the neighbouring city. If this is the case, the estimate of the interaction term between closing hours and population could be biased upwards. To explore this we aggregate the data to the economic regions level and assign the closing hours of the biggest city to all municipalities in the region.[9] The result of this exercise is presented in column (1). Neither the coefficient of the initial effect nor the interaction term is statistically significant. This suggests that local municipality closing hours are the relevant focus.

Table 4: Examination of threats to identification

	Economic regions	Rush hour accidents	DUI	DUI
	(1)	(2)	(3)	(4)
Closing hour	0.151	0.164	0.605***	1.944***
	(0.258)	(0.137)	(0.190)	(0.462)
Closing hour×	-0.061	-0.290	-0.915***	-1.322***
population	(0.057)	(0.215)	(0.263)	(0.232)
Weighted	No	No	No	Yes
R^2	0.206	0.263	0.084	0.320
Observations	890	4040	4036	4036
Municipalities	89	423	424	424

Note: All regressions are estimated using fixed effects and include controls. ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

Additionally we examine placebo tests where we estimate our main model only on accidents during rush hours between Monday and Thursday.[10] Accidents in these times should unaffected by local closing hours and weekend on-premise alcohol serving hours should have no explanatory power with respect to accidents taking place on weekdays. The result of this placebo exercise is presented in column (2). Neither the estimated coefficient for closing hours nor the interaction between closing hours and population are significantly different from zero. This provides supportive evidence again that on-premise closing hours have a causal effect on night-time traffic accidents.

A feature of the accidents data is that we do not observe whether the driver was impaired and whether or not their blood alcohol concentration level was above the legal limit.[11] This

[9]The classification of economic regions follows the structure of proposed by Statistics Norway, which is based on labour and commodity market flows, and population levels.

[10]We do not include Fridays due to its proximity to the weekend. Changes in weekend closing hours could lead to changes in travel patterns during rush hour on Fridays, such as leaving work at a different time than the rest of the week.

[11]The legal blood alcohol concentration level is 0.02 in Norway.

means that the effect of closing hours on the number of accidents may reflect drinking behaviour, or potentially other factors such as driver fatigue. To explore this further, we utilise police report data regarding motorists driving under the influence.[12] There are two issues with this data. First, some charges are dropped if later testing (typically at a hospital) clears the driver of wrong doing, yet these reports will remain in our data. Second, we cannot determine whether the driver was under the influence of alcohol or drugs, or both. Nonetheless, using this data provides additional information on the likely channels of the effect that we observe of closing hours on traffic accidents. We re-estimate our main models with our dependent variable being the number of night-time DUI reports. Column (3) in Table 4 presents these estimates. The estimated relationship between closing hours and DUI reports follows that for accidents. Longer hours lead to more DUI reports, but this effect decreases and becomes negative in more populous municipalities. The turning point of this relationship, approximately 6,600 inhabitants, is very similar to that for our main models. This further suggests that there is substantial heterogeneity between the effect of closing hours in large urban municipalities, and smaller rural municipalities. At the extreme, these results imply a decrease of 61 police reports per year in Oslo when closing hours are extended by one hour.

A further concern is the potential for scale effects in the detection of DUI across municipalities of differing sizes. For example, a roadside breath-test on 50 motorists in a less populated municipality, compared to a large one, will lead to a oversampling of drivers in the small municipality. We follow the approach suggested by Solon et al. (2015) and estimate a weighted regression with robust standard errors in order to obtain consistent coefficients. The results are presented in column (4). Once again, the direction of the estimates are the same as the results obtained in the main model. The coefficients are larger and statistically significant at the one percent level. These results suggest that driving under the influence is the likely transmission channel between closing hours and night-time traffic accidents.

Finally, for our estimates to reflect changes in closing hours, a requirement is the existence of licensed premises in the municipality. This is not a given in very small municipalities. We examine this by re-estimating our main models split according to the number of liquor licenses

[12] An incident can be reported to the police in three different circumstances. First, if a traffic accident happens, police will report the driver if they suspect that they were under the influence at the time of the accident. Second, police may stop and report a driver if the car is observed driving in a suspicious way. Third, a motorist is reported if an alcohol blood level concentration above the legal limit is revealed after roadside breath-testing.

Table 5: Estimating the effect of changes in on-premise alcohol sales on the number of traffic accidents by the number of serving licences in the municipality

	Less than 6	Between 6 and 12	More than 12
	(1)	(2)	(3)
Closing hour	0.046	0.010	0.397***
	(0.06)	(0.077)	(0.134)
Closing hour×	0.006	-0.034	-0.296***
population	(0.2)	(0.16)	(0.077)
R^2	0.019	0.019	0.256
Observations	1429	1639	1437
Municipalities	156	170	145

Note: The dependent variable is the number of traffic accidents occurring weekends between 10pm and 5am. ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

in each municipality. These estimates hold population levels constant, so can be viewed as controlling for the relative level of night-life activities across municipalities.[13] We use license tertiles and the results are presented in Table 5 show that there is no effect of closing hours in municipalities with only few liquor licenses (up to 12). In those where the number of licences exceeds twelve, the effect of liberalising closing hours has a substantial impact on accidents and again follows the patterns of the main results. This provide further confidence that changes in accidents we estimate reflect the impact of closing hours changes.

6 Heterogeneity

6.1 Heterogeneous treatment effects

An advantage of our setting is that we observe both liberalisation and restriction of closing hours. This has two implications. First, it reduces the risk of unobserved variables confounding the interpretation of our estimates of closing hours. Second, it allows us to split the sample between municipalities that have liberalised and municipalities that have restricted their bar closing hours, providing the basis of a symmetry testing exercise. From a policy perspective, it is interesting to uncover whether an alteration in closing hour of a particular direction maximises the reduction in the number of traffic accidents. There is one challenge regarding splitting up

[13]We estimated all equations in the main model controlling for the number of licensed places in each municipality. The variable did not contribute to explain the variation in the number of traffic accidents, which is likely due to limited variation in licenses over time.

the sample in this manner. During the ten-year period in our sample, many municipalities changed closing hours in both directions, as pointed out in Section 2. Municipalities that only liberalised or only restricted closing hours constitute around 28 and 25 percent of the sample, respectively. Our approach is to estimate our main model where we split the sample into municipalities that either only extended or only restricted bar closing hours.

Table 6: Estimated effect of on-premise alcohol sales on the number of traffic accidents, separated by whether hours were extended or restricted, separately (2009-2018)

	Only Liberalised	Only Restricted
	(1)	(2)
Closing hour	0.531***	-0.104
	(0.176)	(0.131)
Closing hour×	-0.501*	0.080
population	(0.253)	(0.271)
R^2	0.083	0.120
Observations	472	389
Municipalities	52	40

Note: The dependent variable is the number of traffic accidents occurring weekends between 10pm and 5am. ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

The estimates are presented in Table 7. Column (1) reveals that the effects found in the baseline estimates are also found in municipalities that have liberalised closing hours. The coefficients of interest are larger relative to the main model, and statistically significant. Turning to column (2) reveals smaller and not statistically significant effects of closing hour restrictions on traffic accidents. These results suggest asymmetric effects of closing hours changes on traffic accidents. Reductions in opening hours have no effect on traffic accidents, but liberalisation increase the number of accidents in smaller municipalities and decreases those in more populous municipalities.

Our data records information on the location and speed limit of the road where the accident happened. We exploit this information in columns (1) and (2) in Table 7, and differentiate between accidents occurring on urban roads where the maximum speed limit is up to, and over, 50 kilometres per hour, respectively. The results indicate that extending closing hours increases the number of accidents on urban roads for municipalities of a smaller size. On the other hand, the average municipality experiences a reduced number of accidents in urban areas

Table 7: Differences in treatment effect of changes in on-premise alcohol serving hours

	Urban roads		Persons		Injuries	
	Up to 50 km/h (1)	Over 50 km/h (2)	One (3)	Two or more (4)	No or minor (5)	Serious or fatal (6)
Closing hour	0.102***	0.035	0.071**	0.066***	0.117***	0.020
	(0.039)	(0.027)	(0.034)	(0.021)	(0.039)	(0.016)
Closing hour×	-0.124**	-0.064*	-0.095**	-0.093***	-0.155***	-0.033**
population	(0.059)	(0.036)	(0.045)	(0.030)	(0.056)	(0.016)
Mean	0.35	0.47	0.54	0.28	0.64	0.18
R^2	0.200	0.041	0.043	0.224	0.197	0.014
Observations	4035	4035	4035	4035	4035	4035
Municipalities	423	423	423	423	423	423

Note: The dependent variable is the number of traffic accidents occurring weekends between 10pm and 5am. ***, **, * indicate statistical significance at 1%, 5% and 10%, respectively.

when closing hours are extended. The effects of closing hours is notably weaker for accidents on higher-speed roads.

An additional and related question is how many cars or people are involved in an accident. This is motivated by the findings of Levitt and Porter (2001) that drivers with alcohol in their blood are seven times more likely to be involved in a fatal car crash. One-car accidents have societal costs, yet, two-car accidents involve an additional externality where drinking drivers may injure others. In our data, we are able to separate between single-car accidents and accidents involving one car colliding with another car, a cyclist or a pedestrian.[14] The results are presented in columns (3) and (4), and suggest that changing closing hours have the same effect on one and several people accidents. In terms of percentage point effects, the magnitude on both the initial effect and the interaction term are essentially the same. However, if one considers the large differences in the underlying frequency of these two events, this implies much larger effects of closing hours on several people accidents. Provided that changes in closing hour mostly affect accidents on urban roads where road user density is higher, which is the result obtained in the first two columns, it is likely that the reduction in accidents is stronger for accidents involving several people. It also suggests that extended closing hours allows patrons to disperse at more diverse times. This reduces the number of people leaving bars simultaneously with a resultant decline in accidents.

An important remaining question is how altering bar closing hours affects the severity of

[14]The last category will hereby be referred to as accidents involving several people.

traffic accidents. More specifically, changing closing hours may affect the number of serious traffic accidents, which are subject to higher social costs than accidents where no one is hurt. Consequently, the treatment effect on accident severity may be of greater policy interest. Additionally, there is likely less measurement error of more serious accidents. Columns (5) and (6) in Table 7 presents the results when we split the number of accidents by the degree of severity.[15] The effect of extending closing hours on no and minor injury accidents reflects the evidence found in the main results. Moving on to column (6), once again direction of the coefficients mimics the results seen throughout the paper. Nevertheless, the initial effect of closing hours is not statistically significant. This result suggests that extending closing hours will lead to fewer accidents with serious or fatal injuries, irrespective of city size. Yet, the negative effect is growing with population size. On the basis of the mean number of accidents and the sample mean population size, liberalising closing hours will reduce the number of accidents with minor injuries by 12 percent, whereas the number of serious or fatal injuries will fall by 25 percent. Consequently, the findings in the two latter columns imply a trade-off for the smallest municipalities, in that increasing closing hours will increase accidents with no and minor injuries, whereas it may decrease serious and fatal accidents. The magnitude of the increase in less serious accidents is smaller, and the social cost of traffic accidents of a more serious manner is larger. In contrast, less serious accidents are more common, making it a question of assigning priorities for policy-makers.

The monetary consequences associated with altering bar closing hours and the effect it has on traffic accidents can be estimated from the value of avoiding traffic accidents. This value encompasses both direct costs such as production loss, medical and material expenses, and indirect costs including pain, grief, reduced health or reduced years of life (The Norwegian Public Roads Administration, 2018). The value of a statistical life in Norway has been calculated at $3,408,239 (in 2019 US Dollars), while the value of avoiding an accident involving a serious injury is $1,263,983. The value of preventing accidents involving a minor injury or material damages is $82,384 and $4,288, respectively. Our results indicate that extending closing hours for an averagely populated municipality will save $2,990 worth of damages for accidents involving a minor injury or material damages. For serious and fatal accidents, the effects of extending closing hours will avoid accidents corresponding to a value of $93,444. In summary, a one hour

[15] In our data, minor injuries are scratches and fractures. Serious injuries include injuries that require hospital admissions, with the potential of being permanently injured.

extension aggregates to $96,434 in avoided costs per year for a municipality with the average of 12,000 inhabitants. Assuming that this effect is applicable for all Norwegian municipalities, the value of avoided accidents is $40.8 million per year.

Due to the variations by population size we have demonstrated, these monetary effects will also be heterogeneous. For example, for municipalities with 5,000 inhabitants, liberalising closing hours will lead to an increase in less serious accidents corresponding to a cost of $1,733 per year. On the other hand, liberalisation will decrease serious and fatal accidents by a value of $46,722 per year. To sum up, the value of avoiding traffic accidents for less populated municipalities by changing bar closing hours appear to speak in favour for liberalisation. At the same time, there are a number of other costs related to increased bar closing hours that is not included in this rough calculation, such as increased policing and possibly increased associated societal harms, which may alter the net welfare benefit of extended closing hours.

7 Conclusion

There is ongoing debate regarding the regulation of alcohol availability, where bar closing hours is a focus. This debate reflects a range of issues and interest groups, including perceived trade-offs between costs associated with health and public disorder, and benefits from greater individual liberty and economic activity.

A particular focus is the link between bar closing hours and traffic safety. Existing evidence in this area, which primarily comes from one-off extensions or restrictions, paints a mixed picture. We return to this issue focusing on Norway where municipalities are free to choose closing hours within quite large margins set nationally. Moreover, they exercise this choice, and frequently change these hours. This provides a setting where we observe many changes, both extensions and liberalisations, across a variety of time margins. Critically, this occurs in a setting where other relevant policy decisions are set nationally, and do not vary in our time of analysis.

We demonstrate average zero effects of closing hours on traffic accidents that mask large and consequential variations. A key source of variation relates to population. Later closing hours increase accidents in smaller, less populated, municipalities, while substantially decreasing accidents in average and more populated municipalities. This likely reflects factors such as differential access to public transport, and differences in underlying traffic flows. Moreover,

we also show large variations in terms of the effect of closing hours on accident severity, and the direction of the change in closing hours. Our results suggest that estimates from single policy changes may be difficult to generalise, while demonstrating that closing hours have the potential to generate large effects on traffic accidents.

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