The relative risk of motor vehicle collision on cannabis celebration day in Great Britain

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ABSTRACT

Cannabis celebration day, also known as "420 day", takes place at 4:20pm on April 20 every year. The objective of this paper is to study whether there is an increase in road traffic collisions in Great Britain on that day. We used daily car crash data resulting in death or injury from all 51 local police forces covering Great Britain over the period 2011–2015. We compared crashes from 4:20pm onwards on April 20 to control days on the same day of the week in the preceding and succeeding two weeks, using panel data econometric models. On the average cannabis celebration day in Britain, there were an additional 23 police-reported collisions compared to control days, corresponding to a 17.9% increase in the relative risk of collision.

1. Background

1.2 million people lose their lives in car crashes (also known as traffic crashes or motor vehicle collisions) globally each year, which constitute the leading cause of death for those aged 15–29 (World Health Organization, 2015). In Great Britain, over 1600 people are killed in car crashes every year, and about 180,000 are injured (Department for Transport, 2016).

Some major collision risk factors include sleep deprivation, fatigue, stress and distraction (see for example Horne and Reyner, 1995; Beanland et al., 2013; Lagarde et al., 2004; Dula et al., 2010; Philip et al., 2001; Vandoros et al., 2018).

Alcohol consumption also constitutes a major collision risk factor (Beanland et al., 2013; Philip et al., 2001; Richter et al., 1986). Especially with regards to young drivers, previous studies have shown that lowering the minimum legal drinking age can often lead to a reduction in car crashes (Lovenheim and Slemrod, 2010; Dee and Evans, 2001). Young drivers are in general more likely to be involved in a collision (Turner and McClure, 2003; Department for Transport, 2015). This is often a result of differences in risk perception (Rhodes and Pivik, 2011) and risk-taking (Machin and Sankey, 2008; Jelalian et al., 2000).

Studies using driving simulators have provided evidence on how cannabis can affect driving (Lenné et al., 2010; Hartman et al., 2016; Downey et al., 2013; Richer and Bergeron, 2009). Evidence from actual traffic collisions often confirm the findings of simulated driving (Romano et al., 2017; Laumon et al., 2005; Blows et al., 2005;

Macdonald et al., 2004; Asbridge et al., 2014; Asbridge et al., 2012). The Highway Loss Data Institute (2017) reported a relative increase in car crashes in U.S. States that had legalised cannabis use, compared to control States. Other studies found no effect of legalising marijuana on cannabis-positive driving in general (Sevigny, 2018), or fatality rates (Aydelotte et al., 2017). This might be due to a possible substitution of alcohol with cannabis (Santaella-Tenorio et al., 2017). Evidence on the impact of legalising cannabis on alcohol consumption is often conflicting (Cameron and Williams, 2001; Williams and Mahmoudi, 2004; Guttmannova et al., 2016; Reiman, 2009). However, cross-state studies often rely on the Fatality Analysis Reporting System (FARS). Although this is an excellent source of data, the National Highway Traffic Safety Administration has warned that the data in the FARS are insufficient to allow comparisons and do not allow us to make "inferences about impairment, crash causation, or comparisons to alcohol" (Berning and Smither, 2014). Importantly, unlike experimental studies, epidemiological studies have shown contradictory results (Brubacher et al., 2018; Asbridge et al., 2014; Sewell et al., 2009; Jones et al., 2005; Movig et al., 2004; Mura et al., 2003).

Cannabis celebration day, also known as "420 day", takes place from 4:20pm onwards on April 20 every year, when some people celebrate using cannabis. In light of the literature on the various collision risk factors, we might expect a higher relative risk on 420 day for a number of possible reasons: Consumption of cannabis and alcohol; the presence of more young or inexperienced drivers; or the presence of people who might demonstrate risk-taking behaviours that may extend

to driving. A recent study by Staples and Redelmeier (2018) that used this celebration as a natural experiment in the US, found an increased number of drivers involved in fatal car crashes after 4:20pm on that day compared to control days. However, there is no evidence on collisions on 420 day in other countries.

Our objective was to assess changes in crash risk on "420" days compared to control days using data on motor vehicle collisions in Great Britain, in a similar way as Staples and Redelmeier (2018). Possible differences between the US and the UK in driving patterns and behaviour, driving laws, minimum driving age and cannabis legislation make this research question worth examining in Britain.

2. Data and methods

2.1. Data sources

We used publicly available data on motor vehicle collisions in Great Britain over the period 2011–2015, obtained from the Road Safety Database, which is published by the Department for Transport. This database includes data on crashes resulting in injury or death in England, Scotland and Wales. Our focus was on the number of collisions from 4:20pm onwards each day, by police force jurisdiction (there are 51 police forces in Britain that cover different geographic areas). In addition, we collected data on the regional unemployment rate in each of Britain's 11 regions (obtained from the Office for National Statistics) and weekly unleaded petrol prices per litre measured in pence (provided by the Department for Business, Energy and Industrial Strategy).

According to the Department for Transport, "every personal injury road traffic collision that is reported to the police is recorded in the administrative system" called STATS19 (Department for Transport, 2013). The police officer attending the collision fills in a standard form that includes details of the collision. A concern could be whether police put an extra effort to record all crashes on the 420 days. Nevertheless, police are obliged to record all collisions resulting in death or injury that are reported to them regardless of the date of time. According to the data provider, "police forces have internal checking processes designed to ensure that police officers complete this form" and "there are a number of layers in the validation process" (Department for Transport, 2013). In addition, the data are also checked and validated by the local highway authority, and often additionally by the Department for Transport (for England), the Scottish Government (for Scotland), or the Welsh Government (for Wales).

2.2. Cannabis celebration day

The 420 cannabis celebration day started becoming popular in the US following an article published in *High Times* in 1991 (Time Magazine, 2017). However, such annual events may take time to gain popularity both nationally and internationally. Cannabis is considered a "Class B" drug in the United Kingdom, and producing, possessing or selling it is illegal and may lead to a fine and/or imprisonment (Home Office, 2018). Nevertheless, there are reports of people gathering in public places to celebrate 420 day across Britain (Evening Standard, 2017; Manchester Evening News, 2014; Bristol Live, 2018).

In order for our analysis to be meaningful, we would need to consider a period during which this event was popular in Britain. We used Google Trends to observe its popularity, according to which 420 cannabis celebration day Google searches started demonstrating large spikes every April in the United Kingdom from 2011 onwards and reached a plateau from 2012 onwards.

2.3. Econometric approach

Traffic crashes are seasonal, and also vary significantly by day of week, so any control group would need to involve the same day of the week as the treatment group, within a narrow timeframe. We thus compared the number of collisions from 4:20pm onwards on April 20 to the same day of the week in the preceding and succeeding two weeks (also from 4:20pm onwards). Considering a larger time frame would expose the analysis to potential seasonality problems. Overall, the baseline model considered the total number of crashes resulting in injury or death from 4:20pm onwards, on April 6, April 13, April 20, April 27 and May 4 in each of the 51 police force areas.

We followed a panel data econometric approach. There may be differences across police forces in the intensity of traffic prevention measures or illegal substance use enforcement, or even resources and equipment. Therefore, the observations for each police force area may not be independent. Using panel data analysis would allow us to take into account changes over time at the local police force level and to control for any unobserved heterogeneity across individual areas. The Hausman test suggested that it was safe to use random effects ($\chi^2 = 0.09$), which is a more efficient estimator than fixed effects. The model specification is provided in Appendix A.

The dependent variable was the number of collisions per police force resulting in injury or death on a single day from 4:20pm onwards. The main explanatory variable was a dummy variable, taking the value of 1 from 4:20pm on April 20, and zero on other days. We controlled for the day of the week using dummy variables. The unemployment rate and petrol prices are confounders and are included in the model, as they may affect the number of collisions. Unemployment may play a role because fewer people commuting to work means fewer cars on the streets. In addition, unemployment may trigger affordability issues, meaning that people may go out less, and it can also affect drinking patterns (Ruhm and Black, 2002). Oil prices, that are directly linked to petrol prices, can often be volatile, and can change significantly over even just a few weeks, thus affecting the affordability of using a car, and, consequently, traffic volume. The expected effect of these two factors is ambiguous: Lower traffic volume means fewer cars that are at risk of collision – but also a greater opportunity to speed due to less congestion. Therefore, the regional monthly unemployment rate and the weekly petrol prices also entered the model as control variables (although we additionally tested specifications excluding them in sensitivity analyses).

The panel identifier in the panel data models was the local police force area, which accounts for differences in the intensity of traffic enforcement and cannabis use enforcement demonstrated by local police forces (Evening Standard, 2017; Manchester Evening News, 2014), each area's population, cannabis use rates, and any other unobserved area and population characteristics. In all models we clustered standard errors at the police force level. Summary statistics are available in Table A1 in Appendix A.

3. Results

Our sample includes 1275 observations, and there were 2.60 crashes on average resulting in injury or death per local police force from 4:20pm onwards on the days included in the study: 2.97 on April 20 and 2.51 on control days. Results of the baseline random effects model are presented in Table 1. From 4:20pm onwards on April 20 there were on average 0.45 more crashes in each police force area resulting in death or injury compared to control days (an increase of 17.9% compared to the average of 2.51 on control days), as the coefficient of the main explanatory variable capturing April 20 is positive and statistically significant at the $\alpha = 1\%$ level [coef: 0.45; 95% CI: 0.20–0.70]. The coefficients of the unemployment rate and petrol prices are statistically insignificant. (Results of an ordinary least squares and fixed effects model were similar and are available upon request).

We conducted a falsification test considering April 18 and April 22, as in the paper by Staples and Redelmeier (2018). The coefficient of the April 18 dummy in the random effects model (column 1 in Table 2) is statistically insignificant, indicating that the number of collisions on this placebo day is not higher than control days on the same day of the

Table 1
Baseline random effects model. Collisions on April 20 compared to four control days, Great Britain 2011–2015.

Dependent variable: Number of crashes resulting in death or injury per police force area from 4:20pm onwards, 2011–2015	
April 20	0.448***
	[0.196–0.701]
unemployment rate	0.235
	[−0.138–0.608]
petrol price	0.050
	[−0.073–0.173]
Constant term	−6.020
	[−22.628–10.587]
Observations	1275
Chi-squared	50.83

Robust CI in brackets. Standard errors clustered at police force area level. Models adjust for day of week using dummy variables. *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 2
Falsification test: Relative risk of collision on placebo days (18 or 22 April) compared to control days. Great Britain, 2011–2015. Random effects model.

Dependent variable: Number of crashes resulting in death or injury from 4:20pm onwards, 2011–2015		
	(1)	(2)
	April 18	April 22
Placebo day	0.142	−0.187
	[−0.055–0.338]	[-0.448–0.074]
unemployment	−0.076	0.281
	[−0.312–0.159]	[−0.138–0.700]
petrol price	−0.143**	−0.241***
	[−0.256 to −0.030]	[−0.365 to −0.117]
Constant term	23.554***	33.836***
	[7.681–39.428]	[17.324–50.348]
Observations	1275	1275

Robust ci in brackets. Standard errors clustered at police force area level. Models adjust for day of the week using dummy variables.
*** p < 0.01, ** p < 0.05, * p < 0.1.

week in the preceding and succeeding two weeks [coef: 0.14; 95% CI: −0.06–0.34]. The coefficient of the other placebo day, April 22 (column 2 in Table 2), is also statistically insignificant [coef: −0.19; 95% CI: −0.045–0.07].

We conducted a dose-response test considering years 2006–2010, before 420 day gained popularity in Britain (according to Google Trends), to see whether there was any effect on crashes when there was less interest in or awareness of 420 day. There were 3.37 crashes on average per police force area after 4:20pm on April 20, compared to 3.21 on control days, which is statistically insignificant ($t = −0.58$; $p = 0.56$). In the random effects model, the coefficient of the *April 20* dummy variable is statistically insignificant (Table 3), suggesting that collisions after 4:20pm on April 20 were not higher than those on control days. These null results in the dose-response test suggest that the relative number of crashes on April 20 appears to have increased only after 420 celebration became more widespread.

We conducted the same analysis, but this time limiting the control days to the same day of the week only one week before and one week after April 20. The coefficient of the variable capturing the April 20 effect is again positive and statistically significant (Table A2 in Appendix A). In addition, in sensitivity analysis, estimating the same random effects model with stepwise exclusion of control variables led to similar results (available upon request).

We also performed a permutation test, by considering the relative risk of crashes from 4:20pm onwards on all 30 days in April over the five-year period, compared to the same day of the week in the two preceding and two succeeding weeks. Of all 30 days in April, cannabis celebration day on April 20 demonstrated the highest percentage

Table 3
Dose-response: Years 2006–2010, *before* 420 celebration day gained popularity in Great Britain.

Dependent variable: Number of crashes resulting in death or injury per police force area from 4:20pm onwards, 2006–2010	
	Random Effects
April 20	0.164
	[−0.121–0.450]
unemployment rate	−0.048
	[−0.295–0.199]
petrol price	0.116**
	[0.004–0.227]
Constant term	−9.853
	[−22.065–2.359]
Observations	1275

Robust CI in brackets. Clustered at police force area level. Models adjust for day of week using dummy variables. *** p < 0.01, ** p < 0.05, * p < 0.1.

increase compared to control days. April 20 also demonstrated on average a higher percentage increase than 96.16% of all 365 calendar days.

4. Discussion and conclusion

Using data on motor vehicle collisions in Great Britain, we studied whether there was an increase in collisions on "420" cannabis celebration day on April 20 compared to control days. We found that from 4:20pm onwards on cannabis celebration day, there was an increase in collisions resulting in injury or death by 0.45 per police force area, which translates to 23 additional crashes across Britain, or a 17.9% increase compared to control days. The relative increase in crashes compared to control days on April 20 was larger than that observed on any other calendar day that calendar month, and than 96.16% of all other 364 days in the calendar year. The 17.9% increase in relative risk of collision that we found is in line with Staples and Redelmeier (2018) who reported a 12% increase in the number of fatal crashes after 4:20pm on April 20 in the United States.

While our study shows that there is a rise in the relative risk of collisions on 420 day, it is impossible to assess what causes this increase. One possible explanation could be that cannabis use might contribute to this spike, but the data do not allow to conclude that this is necessarily the main cause. There are other possible reasons linked to the celebrations, such as a relatively large number of young or less experienced drivers (Turner and McClure, 2003; Department for Transport, 2015), many of whom might be risk taking (Machin and Sankey, 2008; Jelalian et al., 2000) as cannabis is illegal in the UK. Another reason might be related to alcohol consumption during the celebrations (Beanland et al., 2013; Philip et al., 2001; Richter et al., 1986; Lovenheim and Slemrod, 2010; Dee and Evans, 2001) or an increase in driving exposure, i.e. more driving taking place due to 420 day.

Unfortunately, due to the daily aggregate number of collisions used in the analysis we could not control for driver characteristics or particular conditions. Another limitation is that there are no statistics available on various behaviours on 420 day. While there are reports that people often gather in parks and public places (Evening Standard, 2017; Manchester Evening News, 2014; Bristol Live, 2018), it is impossible to know how many people may celebrate in private spaces, especially as cannabis is illegal in the UK. We do not have figures on how many people attend in various places, how many people arrive by car, the average time people spend at these celebrations, the amount of alcohol or other substances consumed, and whether people may gather before or after the celebration.

Overall, this study shows that there is an increased relative risk of collision during cannabis celebration day and adds to existing evidence from the US (Staples and Redelmeier, 2018). Further research may

study the reasons for this increase in order to help design relevant traffic control measures on high-risk days in Britain and elsewhere.

Declarations of interest

None.

Appendix A

Section A1. The econometric model

The Random Effects Panel Data model is presented in Eq. (A1).

$$collisions_{it} = \mu + \beta_1 cannabisday_{it} + \beta_2 unemployment_{it} + \beta_3 petrol_{it} + \sum_{k=4}^{10} \beta_k dayofweek_{it} + \gamma_i + \varepsilon_{it}$$

(A1)

where *collisions* represents the number of collisions per day from 4:20pm onwards in each police force area; *cannabisday* is a dummy variable that takes the value of 1 on 20 April and 0 otherwise; *unemployment* denotes the unemployment rate; and *petrol* denotes the average petrol price. *dayofweek* is a set of 6 dummy variables that represent the day of the week (in such cases one day of week is always excluded from the model so that the dummies do not add up to 1, which would lead to a singular matrix). i denotes the police area, and t denotes time. μ is the intercept and individual effects γ_i are treated as random (Verbeek, 2004).

Table A1
Summary statistics.

Variable	Mean	Std. Dev.	Min	Max
Observations: $N = 1275$				
Number of Police Forces: 51				
Number of crashes involving injury or death	2.598	3.784	0	35
April 20 dummy variable	0.200	0.400	0	1
Unleaded price per litre (in pence)	130.942	9.828	112.37	142.17
Unemployment rate	7.081	1.554	4.3	10.7

Section A.2. Tables

Table A2
Regression analysis using only 13 and 27 April as control days (instead of four control days).

Dependent variable: Number of crashes involving death or injury per police force area from 4:20pm onwards, 2011-2015	
	Random Effects
April 20	0.318**
	[0.070 - 0.566]
unemployment rate	0.092
	[-0.200 - 0.384]
petrol price	0.384***
	[0.162 - 0.606]
Constant term	−47.968***
	[−76.101 to −19.836]
Observations	765
Chi-squared	44.32

Robust CI in brackets. Clustered at police force area level. Models adjust for day of week using dummy variables. *** p < 0.01, ** p < 0.05, * p < 0.1.

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