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Cannabis and road accidents: evidence from unintended liberalization in Italy

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Abstract

Very little is known about the effects of cannabis liberalization on road fatalities, road accidents and road traffic injuries in Europe. This paper studies the effects of the unintended liberalization of light cannabis, which took place in 2016 in Italy, on the number of road fatalities, road accidents and road traffic injuries. By matching a dataset on the quarterly road fatalities, road accidents and road traffic injuries and a dataset on the location of light cannabis retailers, a staggered difference-in-difference model is adopted. From these analyses can be concluded that the local market accessibility of light cannabis led to a mild, but not statistically significant, increase of road fatalities. However, the local market availability of light cannabis has led to a small, but not statistically significant, decrease of road accidents and road related injuries.

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1 Introduction

Cannabis, also known as marijuana, is the most widely cultivated drug worldwide. Besides, it is one of the longest-established drugs in Europe and is becoming more and more popular. With nearly 20% of people of age between 15-24 years, who reported that they have used cannabis in the last year, it is also the most commonly used illicit drug in Europe. It is a psychoactive drug which is used for medical and/or recreational use and a diversity of cannabis products are currently available. These products can range from medicinal products, which contain compounds from the cannabis plant, to raw cannabis preparations. In the last two years there has been an appearance of cannabis light products, which claim to have less than 0.2% tetrahydrocannabinol (THC). THC is the main psychoactive element in cannabis and is responsible for euphoric effects, besides THC, cannabis also contains cannabidiol (CBD), which is responsible for the relaxant effects (EMCDDA, 2019).

The cannabis market is booming (or a more appropriate appellation: blooming) and in more countries worldwide (light) cannabis is currently legalized in some form. Like, in Canada and the United States where recreational use of cannabis is already liberalized in states like California, Michigan and Oregon. In addition, in European countries like The Netherlands and Italy where the light version of cannabis has been legalized (Carrieri, Madio & Principe, 2019). These countries provoke a consideration about cannabis of the costs and benefits of different regulatory and control options. In Europe a considerable amount of police resources go into cannabis control: in 2017 over half of 1.2 million use or possession for personal use offences are related to cannabis (EMCDDA, 2019). Besides this unfavourable aspect of cannabis there are also other (beneficial as well as unfavourable) outcomes, which are associated with the legalization of cannabis. Other alleged unfavourable outcomes are the potential health risks associated with cannabis usage among young people and the involvement in the cannabis market as a driver for youth criminality (EMCDDA, 2019).

Moreover, commonly named economically beneficial outcomes are increased tax revenues, job growth and investment opportunities (Krishna, 2019). Other beneficial outcomes are the reduction of organized crime (Povoledo, 2018) and the forgone revenues for criminal organizations, which are estimated at least 90 million euros per year (Carrieri, Madio, & Principe, 2019b).

However, there is still a lot of opposition regarding the legalization. Commonly named possible externalities are the increase in road fatalities, road accidents and road traffic injuries caused by drivers who are under influence of cannabis.

A leading cause of mortality around the world are road accidents. More specifically: it is the leading cause of death for children and young adults aged 5-29 years old (World Health Organization, 2018). The World Health Organization (WHO) already reported that approximately 1.35 million people die every year as a result of road traffic crashes, that is nearly 3700 people dying on the world's roads every day. These are more deaths than the deaths that are caused by diseases like AIDS or tuberculosis (Bruzzone, Castriota, & Tonin, 2019). Besides, the WHO reported that 20 to 50 million more people suffer non-fatal injuries as a result of road traffic crashes. According to the "deaths ticker" of the WHO every 23 seconds a road user worldwide dies[1]. Therefore it can be acknowledged as a global phenomenon (Awal, 2013). Additionally, the WHO noted that road traffic injuries are currently estimated as the eighth leading cause of death across all age groups around the world and predicted that this will become the seventh leading cause of death by 2030 (World Health Organization, 2018, 2020).

There is a difference across countries: the death rates in low-income countries are three times higher than in high-income countries (World Health Organization, 2018) and the number of road traffic deaths of middle-income countries is two times higher than the number of deaths in high-income countries (Keum, 2016). Moreover, in both developed and developing countries the social costs of road accidents exceed 2.1% of the annual GDP (Wijnen & Stipdonk, 2016). Social costs are injury related and crash related (Bruzzone et al., 2019). The injury related costs consist, among other things, of medical costs, these are costs that are a result of the treatment of casualties (e.g. costs of hospital stay, medicine and rehabilitation) and production loss, this is a loss of production and income that resulted from the temporary or permanent disability of the injured and the complete loss of production of fatalities. Furthermore, the crash related costs consist of property damage (e.g. damage to vehicles and roads) and administrative costs (e.g. costs of police services, law courts and administrative costs of insurers) (Bruzzone et al., 2019; Wijnen & Stipdonk, 2016).

[1] https://extranet.who.int/roadsafety/death-on-the-roads/#ticker

The most important risk factors, according to the WHO, are unsafe road infrastructure or vehicles, speeding, driving under the influence of drugs or alcohol, driving distracted (e.g. use of smartphones) and failure to wear seat-belts or helmets (World Health Organization, 2018). Several studies have shown that cannabis is the most frequently detected non-alcoholic substance in traffic crashes and that drivers with THC in their blood are twice as likely to be responsible for a deadly crash or of being killed than drivers who didn't have THC in their blood (National Institute on Drug Abuse, 2019). Drummer (2008) made a selection of (psychomotor and cognitive) skills and attributes that are required for safe driving:

- Vigilance
- Divided attention skills, which means that someone can perform two or more functions simultaneously
- Attentiveness and concentration
- Visual fields and acuity
- Reaction time
- Tracking, which is the ability to maintain lane control
- Hand-eye and foot-eye coordination.

Cannabis affects psychomotor skills and cognitive skills that are important for driving (National Institute on Drug Abuse, 2019). Cognitive skills are related to the ability to make appropriate decisions and the psychomotor skills to time and distance perception, hand-eye coordination and reaction times (Drummer, 2008). So cannabis affects brain functions that adversely influence the ability to drive safely (Drummer, 2008) and therefore there is an increased risk of crashing (Drummer et al., 2004).

To get a perception of the current relationship between cannabis and (fatal) road accidents, the following statistics with data from the United States are given. These data are collected from the National Center for Health Statistics (NCHS) and the Insurance Information Institute (I.I.I.). These US data are used because, there is limited testing of alcohol and drug abuse after an accident in European countries (Sardi, 2011).

According to Figure 1, 33.883 residents died due to a road accident in 2009. This number rose to 36.560 residents in 2018. So in absolute values, more people died due to a road accident in 2018 compared to 2009. This supports the findings of the WHO that road accidents are getting a higher rank on the causes of death rankings. Also, from 2014 until 2016 this amount increased substantially with 5062 more deaths. However, from 2016 until 2018 the deaths provoked by road accidents in the US declined.

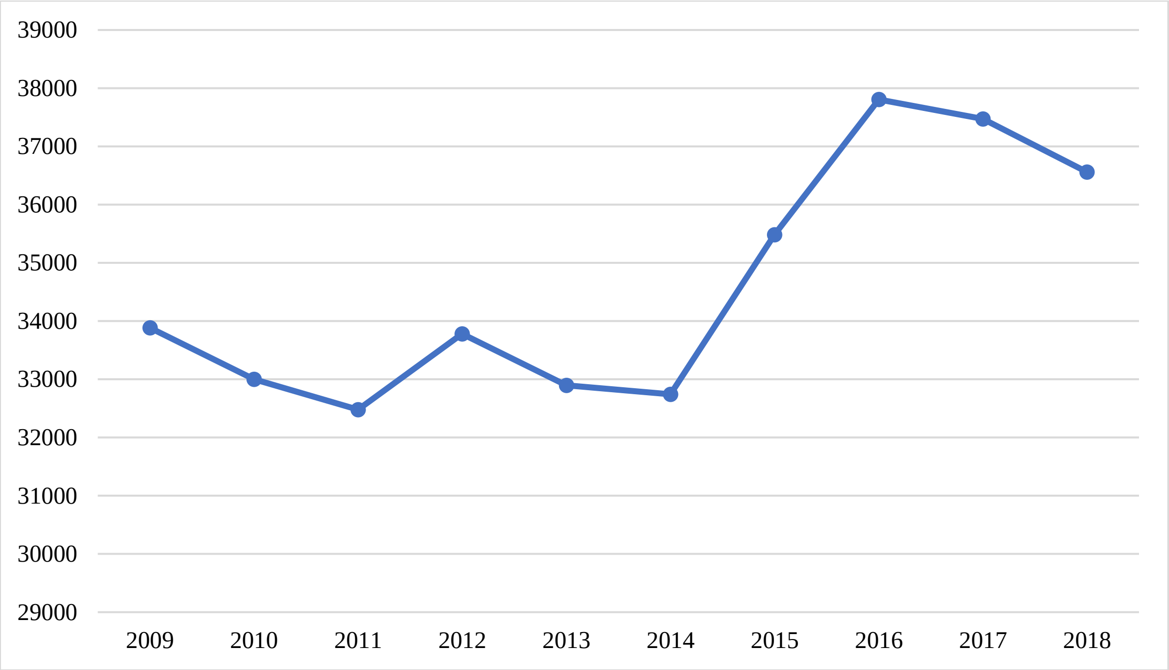

Figure 1: Total deaths provoked by road accidents per year in the United States (in absolute terms), 2009-2018

Additionally, a degree of the road fatalities depended on alcohol use. There were no data available of marijuana-use in traffic. Because alcohol can be seen as a substitute for marijuana (Miller & Seo, 2018), these data are used to get an idea of the impact of such a substance on road fatalities. Figure 2 shows the number of alcohol-impaired road fatalities of the total road fatalities. The number of the alcohol-impaired road fatalities (light blue bar) seems quite steady across time. Nevertheless, it can be noted that it decreased and increased following the total number of road fatalities. For example: when the number of road fatalities increased from 2015 to 2016, the number of alcohol-impaired road fatalities also increased.

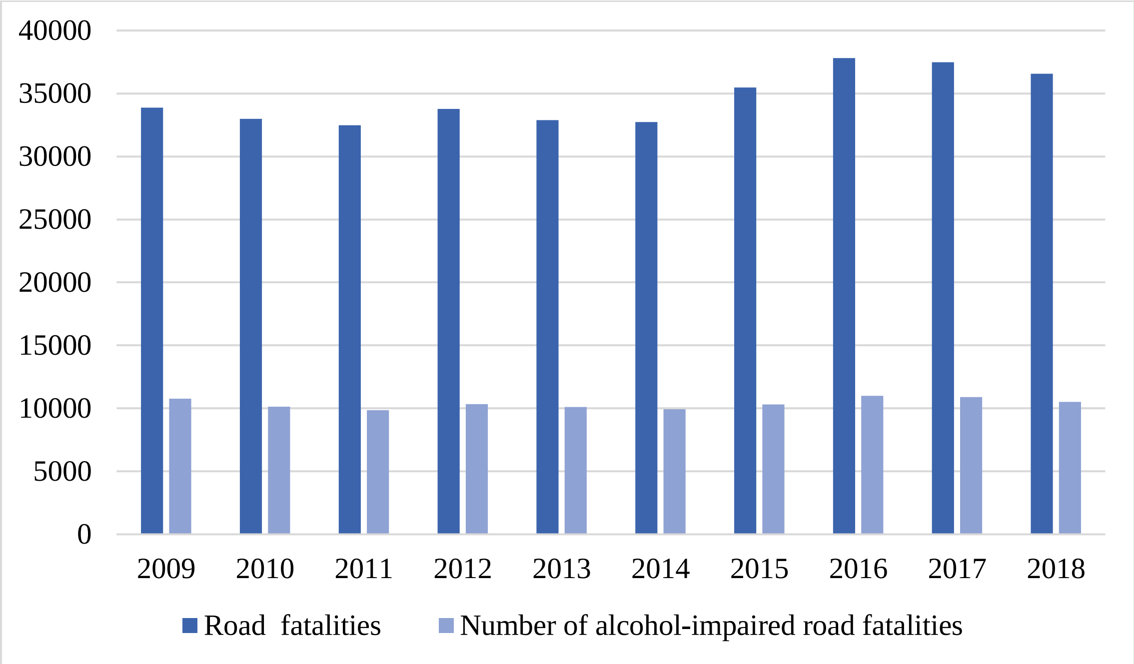

Figure 2: Road fatalities and number of alcohol-impaired road fatalities in the United States (in absolute values), 2009-2018

Figure 3 helps to give a clearer picture of how many deaths on the roads are caused by using alcohol. Figure 3 shows alcohol-impaired road fatalities as a percentage of all road fatalities, from which can be concluded that the percentage alcohol-impaired road fatalities decreased from 2009 (31.75%) compared to 2018 (28.75%). However, in 2018, still 28.75% of all road fatalities depended on alcohol, which is a substantial amount.

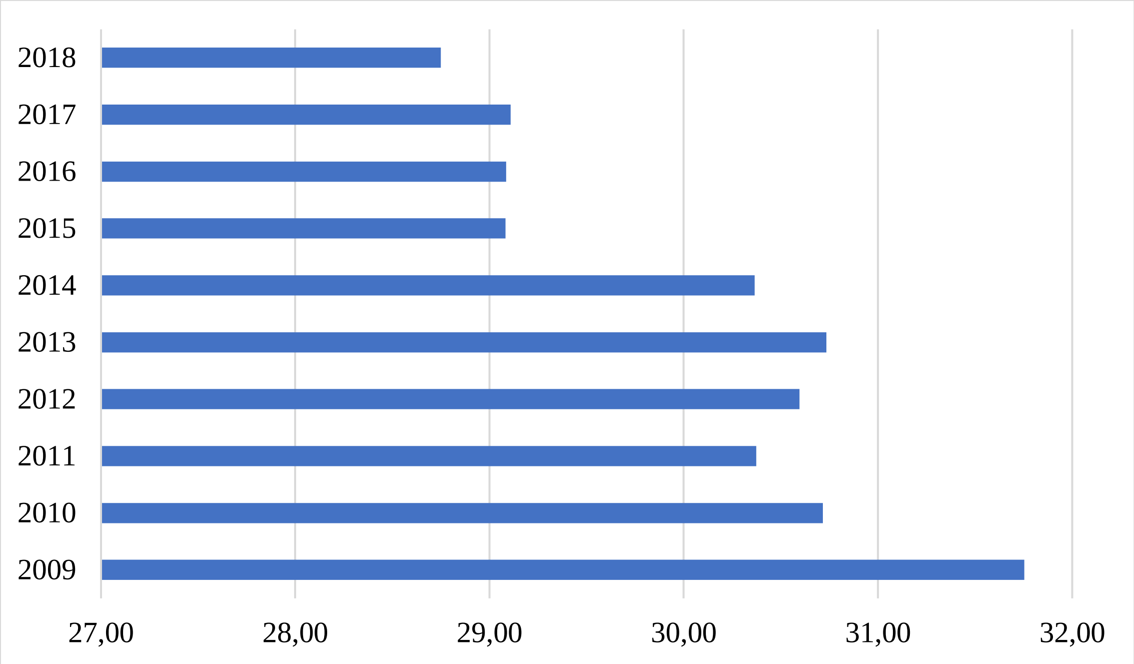

Figure 3: Alcohol-impaired road fatalities as a percentage of all road fatalities in the United States, 2009-2018

The figures show that a lot of deaths that are provoked by road accidents depend on alcohol. Because cannabis can be seen as a substitute for alcohol it is very likely that this is also the case for cannabis (Miller & Seo, 2018). Due to the legalization of cannabis, people can more easily get access to cannabis and the use of cannabis. Even though the percentage of alcohol-impaired road fatalities decreased in 2017 compared to 2018, it could be the case that cannabis-impaired road fatalities increased. As mentioned before, alcohol is a substitute for cannabis, therefore, due to legalization of cannabis, the number of people who are using cannabis could increase while the number of people who are using alcohol could decrease. Consequently, despite the seemingly decreasing percentage of alcohol-impaired road fatalities, the possible externality that road fatalities increase due to drivers who are under influence of cannabis is still very likely to occur.

Only a few recent papers have analysed the issue of cannabis legalization on road accidents, mainly in the geographical context of the United States. These studies, such as the study of Anderson et al. in 2013, find that legalization of cannabis is associated with a decrease in road fatalities, other American studies, such as the study of Hansen et al. in 2018, reported that there are no effects on road fatalities after legalization of cannabis.

However, despite the great relevance of this issue, there are few studies that examine the relationship between the legalization of cannabis and road fatalities in Europe. Nevertheless, these findings could have relevant implications for public policy. They can lead to more complete decision-making for policy makers with regards to the trade-off between economic benefits and drawbacks that arise from the legalization of cannabis. Furthermore, to get a completer assessment of the (health related) policy effects there will also be looked at more road accident related outcomes. These outcomes are the number of road accidents and number of injured people because of a road accident (hereafter: “road traffic injuries”).

The aim of this research is to determine the impact of cannabis legalization on road fatalities, road traffic injuries and road accidents in Italy and therefore to fill the gap in the research on cannabis legalization on road accidents resulting in deaths and injuries in Europe. Specifically, this research will be focused on the cannabis light liberalization in Italy. Therefore, the central question in this research is:

What is the impact of light cannabis legalization on road fatalities, road accidents and road traffic injuries in Italy?

The remainder of the thesis is structured as follows: chapter 2 provides background information on the developments in policy reform regarding cannabis which occurred in Italy, information about light cannabis and the trend of road accidents, road injuries and road fatalities (hereafter when talking about all outcomes: “road-related outcomes”) in Italy. Chapter 3 describes the used database and the applied methodology. Next, chapter 4 provides the main results and chapter 5 contains a discussion and concluding remarks.

2 Background

Cannabis light is cannabis which has a THC percentage below 0.2% (NOS, 2019), for comparison: in the Netherlands the amount of THC in cannabis is mostly between 15% and 25% (van der Ploeg, 2018). This means that the level of the psychoactive element, which makes people high, is a tiny fraction of what can typically be found in cultivated marijuana. On the other hand, cannabis light contains high levels of CBD. This combination of low levels of THC and high levels of CBD is associated with relaxing and antipsychotic effects (Cammarata, 2019). Furthermore, side effects of CBD in combination with THC, even with low levels of THC, are an increased heart rate and vertigo (Jellinek, 2019). Therefore, it can be concluded that cannabis light could also have a substantial impact on psychomotor skills and cognitive skills and thus also causes an increased risk of crashing. That cannabis results in driver impairment and that it is often found in traffic accidents is also confirmed by Ernest Difazio (1995).

This research will exploit a unique feature of the Italian case. In fact, the cultivation of cannabis for industrial use has a historical tradition in Italy (Carrieri et al., 2019). It has been said that Italy was the second-biggest producer of industrial cannabis (also called hemp) in the mid-20th century (Povoledo, 2018). However, after the government declared a war on drugs, the hemp cultivation collapsed in 1961 (van der Ploeg, 2018). In order to help revive this sector, in December 2016 a law (242/16), regulating hemp production, went into force. It was originally created to help distressed farmers who were suffering from structurally declining agricultural prices. Therefore, the demand for alternative agricultural products, such as hemp, increased. This hemp has commercial uses like food, fabrics and clothing. However, this new law did not regulate the use of cannabis flowers and due to this legislative void, an entire unannounced and unintended cannabis light economy emerged. At the start of May 2017, some start-ups began to start selling the cannabis flowers as a so-called “technical product”: it can be seen as a collector’s item and it is not meant to be smoked or consumed (Carrieri et al., 2019a). Additionally, light cannabis is very easily accessible in Italy: it can be bought from vending machines, herbalist shops and it is also possible to make use of delivery services without showing any form of identification (The Local, 2019; Kennedy, 2018). This consequently can result in more cannabis use.

There occurred a staggered entry into the market of light cannabis, which is presented by Figure 4. This means that the local availability of light cannabis did not arise simultaneously in all geographical areas. Mainly the areas that were previously served by so-called “grow shops” were affected in the first months after the unannounced liberalisation. These shops were already selling seeds and cannabis-related products and were primarily located in areas where industrial cannabis cultivation was more likely due to the geographical and morphological conditions in that territory (Carrieri et al., 2019a). According to Figure 4, of the 106 provinces, 22 had at least one cannabis light retailer in May 2017. After the introductory phase, the shops became a social phenomenon, which caused an expansion of the local coverage. Besides the grow shops, also tobacco and herbalist shops, para-pharmacists and vending machines began to sell the product (Carrieri et al., 2019a). As a result, by February 2018, 87 of the 106 provinces were selling the product and because of that the entire country was covered by retailers throughout 2018 (Carrieri et al., 2019a).

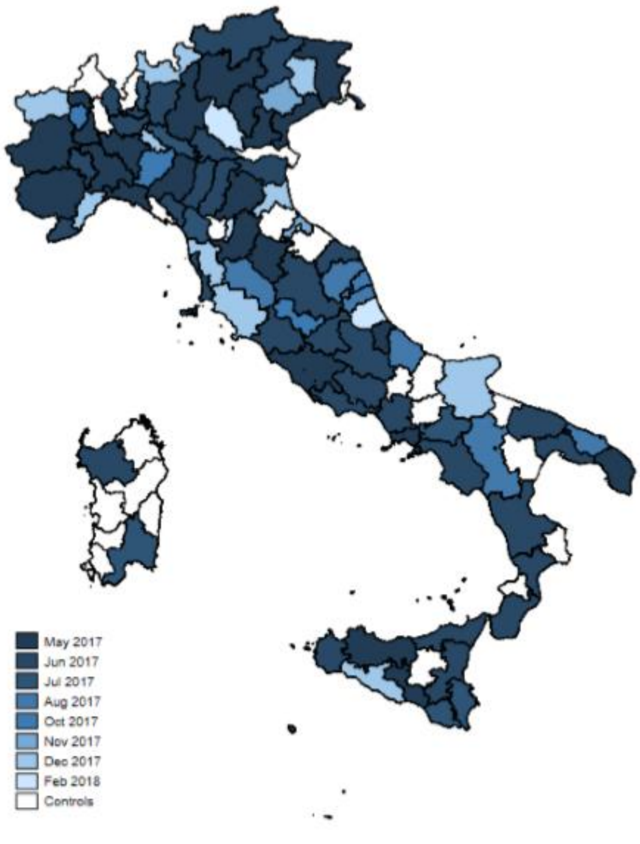

Figure 4: Timing of local availability of light cannabis (Carrieri et al., 2019a)[2]

[2] This figure is retrieved from the Carrieri et al., 2019a paper. They retrieved the corresponding data from the Internet Wayback Machine Archive. The map of Figure 4 shows the different timing of the local availability of light cannabis in the 106 Italian provinces which are considered starting from May 2017.

3 Data and empirical strategy

For this research, a unique longitudinal dataset that recorded the local market availability of retailers that are selling light cannabis is used. Data were collected using the Internet Archive Wayback Machine on the websites of the four main sellers of light cannabis in 2017, which are Easyjoint, Marymoonlight, Realhemp and XXXJoint. Data were collected on a monthly basis for all 106 Italian provinces over the period from January 2016 to February 2018[3].

These data will be matched with quarterly based data on road accidents resulting in death or injury that occurred in Italy between 2016 and 2017. These data are collected by the Italian Institute of Statistics (ISTAT). Because of the Italian rules, in case of an accident with injured or dead people, the police must intervene and fill in a detailed form, which is thereafter transferred into the electronic database of ISTAT. Each record provides a reflection of a road accident and yields information on time (hour), place (province) and nature of the accident and crash, the number and type of transport vehicles involved (e.g. whether it is a car or a motorbike), the weather, the age and gender of the drivers and passengers, the characteristics and type of the road (e.g. rural or urban, number of lanes, conditions, etc.), and the number of injured and dead (within the 30th day after the road accident) people. Information on the probable cause of the accidents (e.g. alcohol or drug use) is not available (Bruzzone et al., 2019)[4].

These datasets will be aggregated at the province level and will be at the quarterly level, as a result 848 (106 provinces*8 quarters) observations remain over the time period of 2016 and 2017.

Bruzzone et al. (2019) found that in Italy the number of accidents and people who died because of an accident are steadily declining over the last years. From the peak of 7096 people who died in 2001 because of a road accident to 3262 deaths in 2016, which corresponds to a decline of 54%. The number of accidents and injured people also declined over the years (Bruzzone et al., 2019). The declines in Italy are due to technological improvements and reforms to the road code over the years (Bruzzone et al., 2019). When comparing the total quantities of 2016 with 2017, the number of total road fatalities increased from 3262 in 2016 to 3340 in 2017. Additionally, the number of total road accidents decreased from 175.791 in 2016 to 174.933 in 2017.

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[3] This dataset is also used in the paper “Do-It-Yourself medicine? The impact of light cannabis liberalization on prescription drugs” of Carrieri et al., 2019. I have free access to this dataset, because Francesco Principe, one of the authors of the previous mentioned paper, is my thesis supervisor.

[4] I also have free access to this dataset because of Francesco Principe.

Moreover, the number of road traffic injuries also declined. In 2016, 245.687 people got injured as a result of a road accident while in 2017 243.639 road traffic injuries took place. Zooming in on the results per quarter per year (Figure 5), it can be concluded that most people die as a result of a road accident in the third quarter in both years. In both years most people got injured as a result of a road accident in the second quarter (Figure 6). Also, in both years, most road accidents happened in the second quarter (Figures 5 and 6).

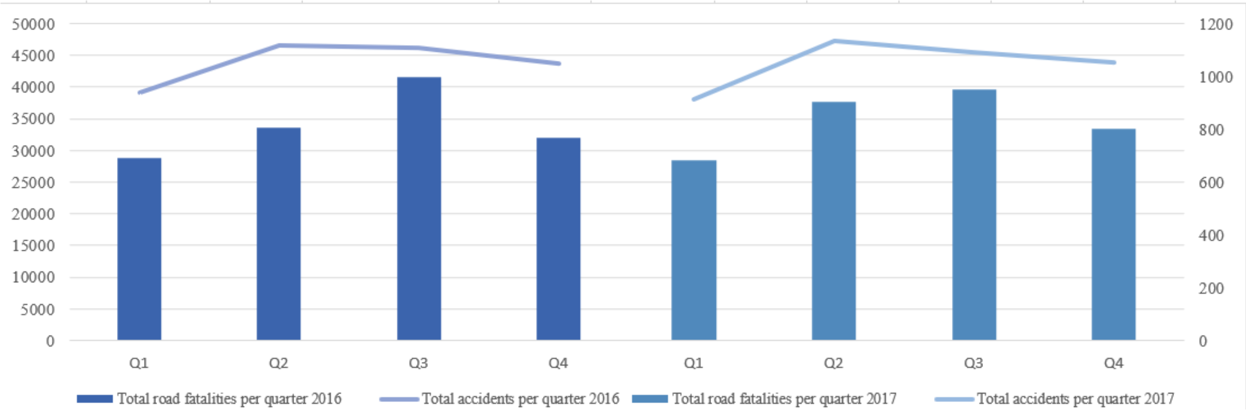

Figure 5: Quarterly road fatalities and accidents in Italy (2016 and 2017)

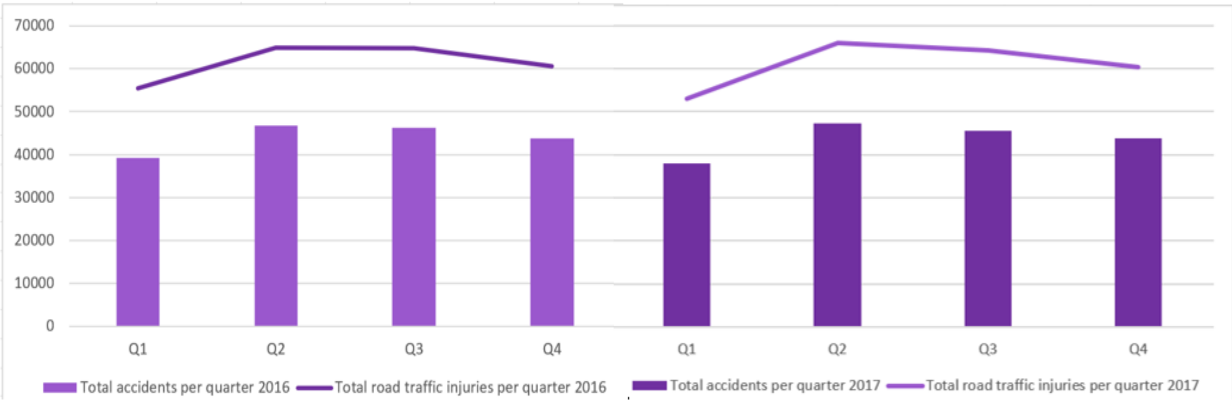

Figure 6: Quarterly road traffic injuries and accidents in Italy (2016 and 2017)

Table 1 reports the mean quarterly values of the variables of interest before and after the unintended legalization and the difference of these means. It can be concluded that the number of deaths, accidents and injured people increased after the unintended legalization of light cannabis. However, these are just summary statistics and only tell something about the values in the dataset and not about the effects.

Table 1: Summary statistics and difference in mean, before and after the unintended legalization

Variable	**Before unintended legalization**	**After unintended legalization**	**Difference in mean**
Deaths	816	879	63
Accidents	43371	44617	1246
Injured people	60782	62318	1536

Because the liberalization is the result of a legislative void a unique feature is that it was unannounced. Therefore, there was no intention to legalize the light cannabis consumption. This provides an exogenous variation in the policy setting which is not followed by changes in the institutional setting. Carrieri et al. used a staggered difference-in-difference model (DiD) to examine the impact of light cannabis liberalization on prescription drugs. They used the same data for the independent variable. Consequently, in order to identify the (causal) effect of light cannabis on road-related outcomes, also a staggered difference-in-difference model is used. A staggered difference-in-difference model will exploit the idiosyncratic entry of retailers of cannabis light in a given province. This approach will also exploit temporal and geographic variation of provinces. The identification will then rely on the staggered timing of the cannabis light availability and will also rely on the provinces without any cannabis light retailer as the control group.

When the locations of the cannabis shops are matched with the locations of the accidents it is possible to see if road-related outcomes have increased in the range of these cannabis shops. Therefore, the dependent variable will be respectively the number of road fatalities, road accidents and road traffic injuries and the independent variable will be local availability of light cannabis. For that reason, the following equation is estimated:

$$Rf_{it} = \alpha + \sum_{k} \beta_k \; Entry_{ik} + \delta X_{it} + \gamma_i + \mu_t + Summer + Weekend + OilP_t + \varepsilon_{it}$$

In which:

- α is the constant
- Rf_{it} is the number of road fatalities / road accidents / road traffic injuries at time t in province i
- $Entry$ is an indicator that takes value 1 if at least a cannabis retailer has entered in all periods k in province i
- γ_i and μ_t are province and time (quarter and year) fixed effects. The province fixed effects control for time invariant unobservable province characteristics, such as the age of the inhabitants of a certain province. Also, time fixed effects are included to control for unobservable variables that were constant across provinces but varied over time
- X_{it} is a vector of controls for province population size and density and a dummy for post-May period to take into account eventual changes which occurred at a national level after the unintended liberalization
- β_k is the coefficient of interest, which captures the quarterly change in road accidents to the local availability of light cannabis
- $Summer$ is a dummy variable which takes value 1 if it is in the Summer. Summer consists of the months: July, August and September, which are together the third quarter
- $Weekend$ is a variable which represents a share value of the number of weekends in a province given a certain period. The weekend consists of the days Saturday and Sunday
- $OilP_t$ is the price of oil per quarter. The oil prices are the Brent oil prices in 2017 constant Euro terms. It is calculated by taking the average of the oil prices per 3 months (so per quarter)[5]
- ε is the error term

The variables $Summer$, $Weekend$ and $OilP_t$, are included in the model because there is evidence that road fatalities are sensitive to seasonality and oil prices: They increase during the weekends, the summer and when fuel prices fall (Bruzzone et al., 2019). This could also be the case for road traffic injuries and road accidents (Best & Burke, 2018; National Safety Council, 2018; Nofal & Saeed, 1997).

[5] These data are retrieved from www.macrotrends.net.

When looking at the used data in this research, the following findings are made regarding the above-mentioned assumptions about the summer, the weekend and the oil price.

With regards to the summer it can be concluded from Figure 5, that the number of road fatalities are higher in the third quarter of both years, compared to the other quarters. The third quarter can be regarded as the summer. Nevertheless, it can be concluded from Figure 6 that most road accidents and road traffic injuries do occur in the second quarter and not in the summer.

Concerning the weekend, most deaths occur at Friday, Saturday and Sunday in 2016 and at Monday, Saturday and Sunday in 2017 (Figures 7 and 8). However, most road accidents and road traffic injuries occur in both years on Friday (Figures 10, 11, 13 and 14). When merging Saturdays and Sundays as the weekend and Monday up to and including Friday as no weekend, it can be noted from Figure 9 that indeed in the weekend more fatal accidents occur. Nevertheless, this is not the case for road accidents and road traffic injuries. For these two outcomes, more accidents and injuries are occurring when it is no weekend (Figures 12 and 15).

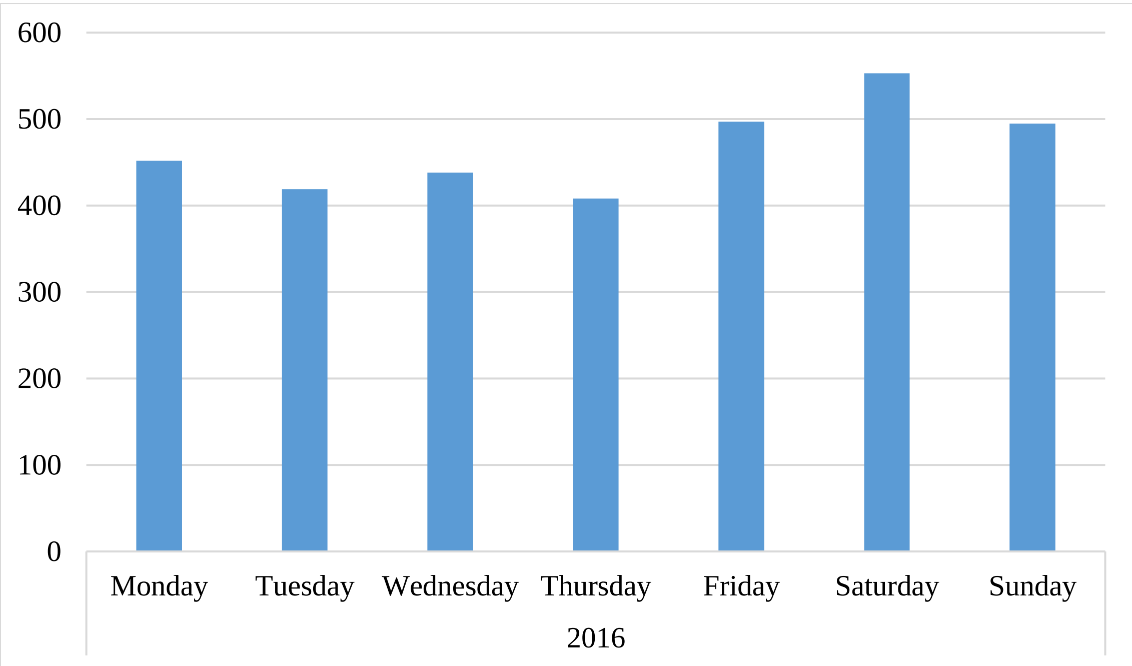

Figure 7: Road fatalities per day of the week (2016)

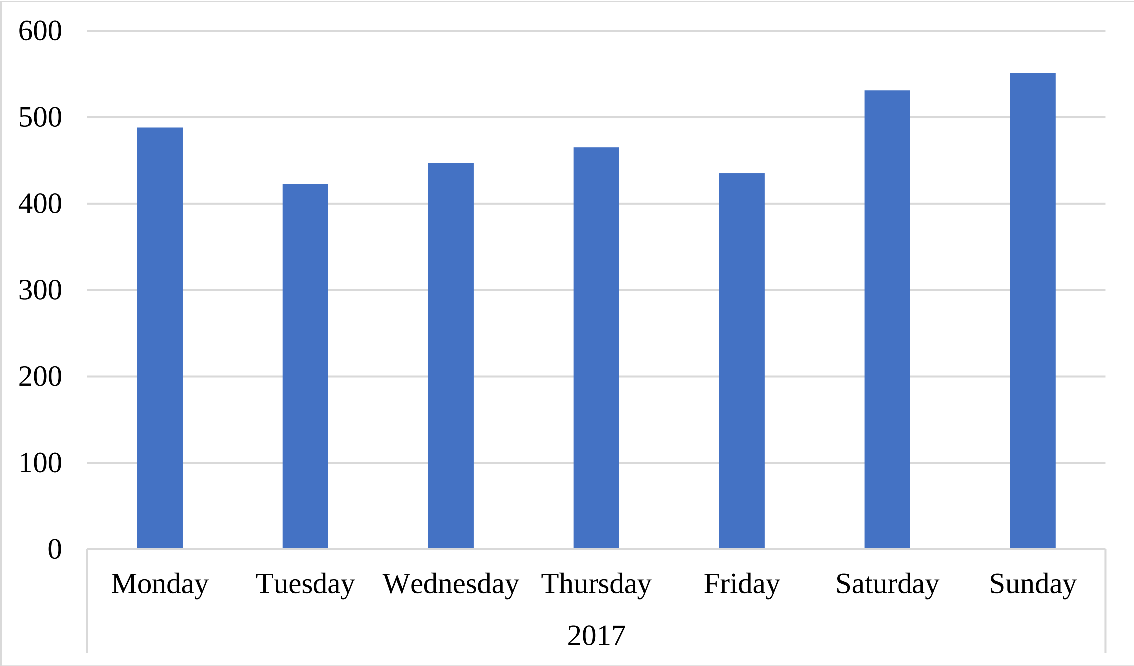

Figure 8: Road fatalities per day of the week (2017)

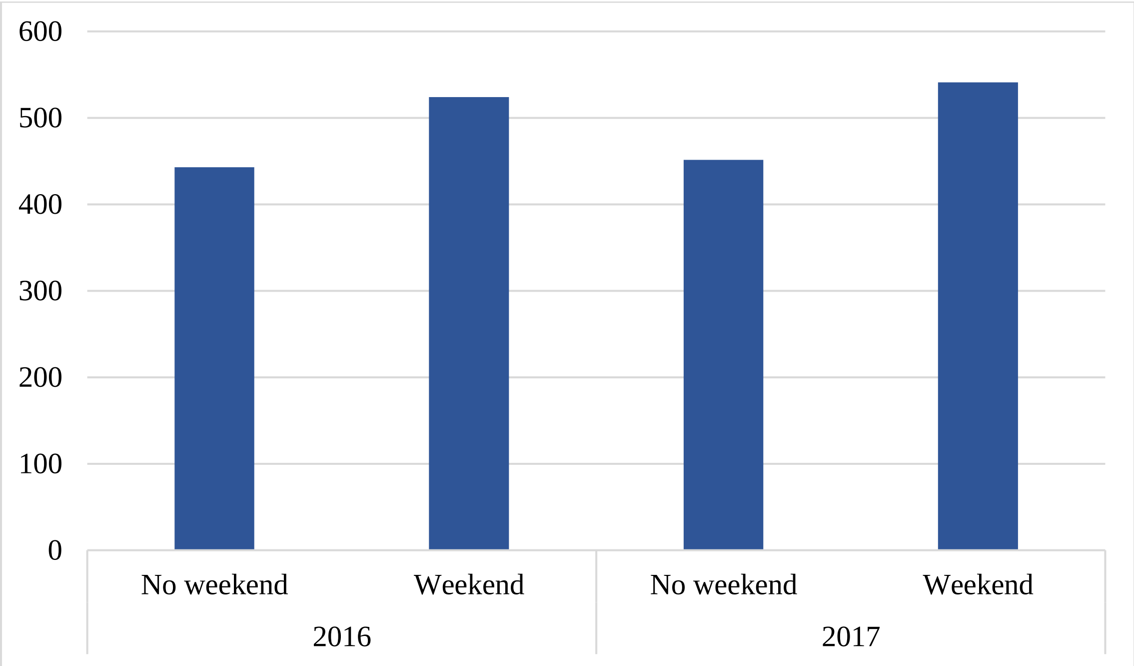

Figure 9: Road fatalities per (no) weekend (2016 and 2017)

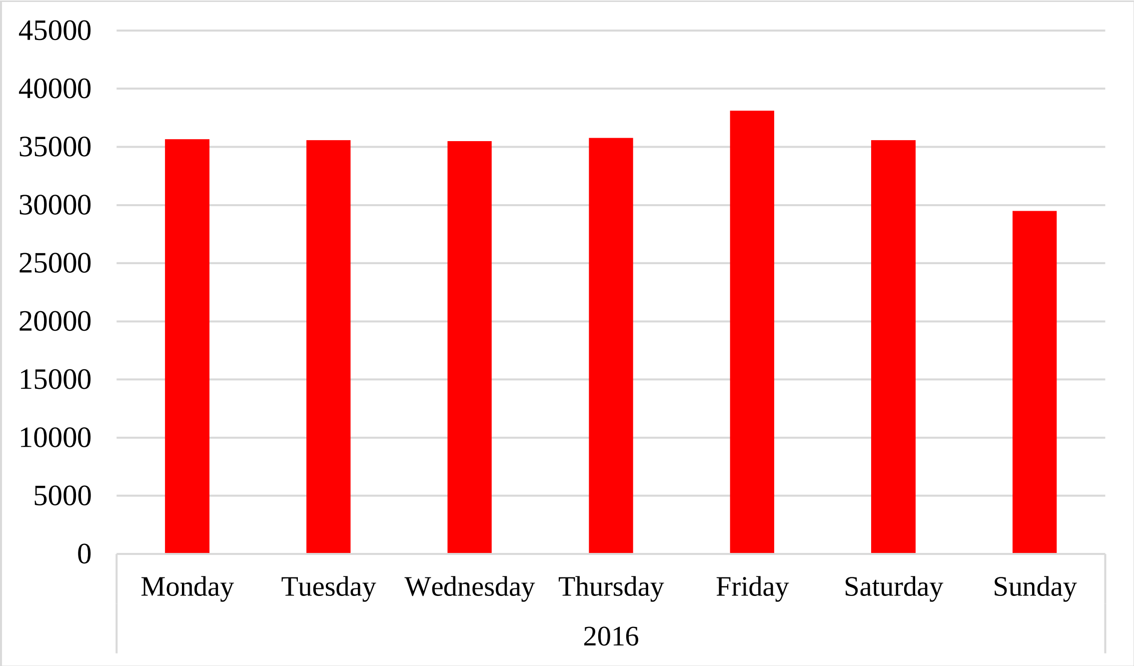

Figure 10: Road traffic injuries per day of the week (2016)

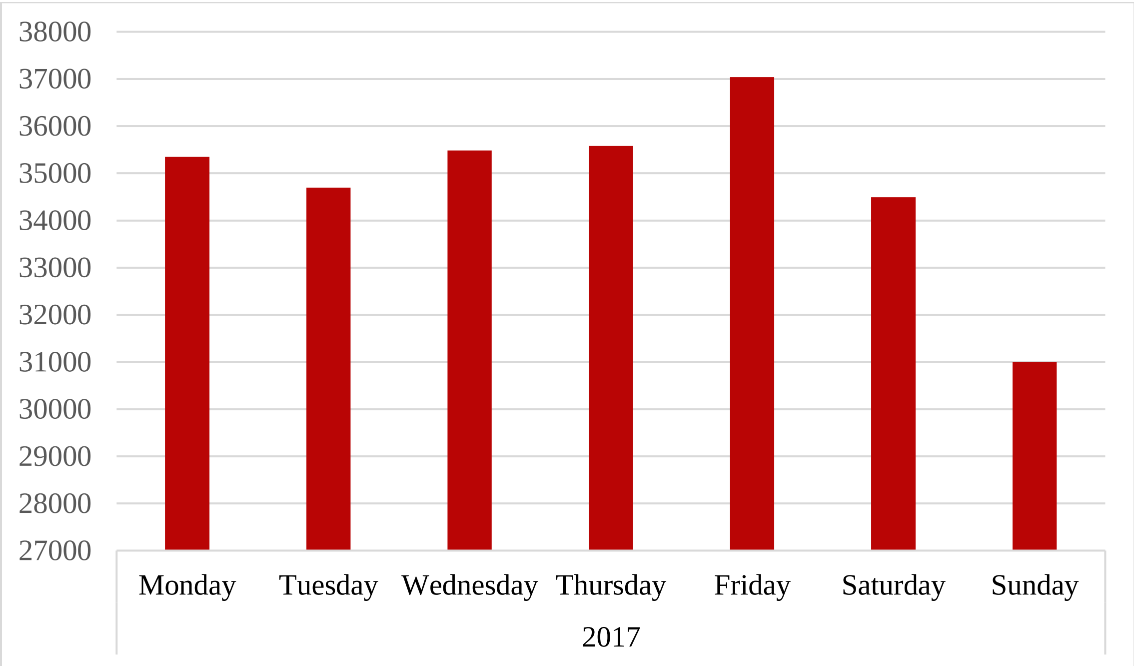

Figure 11: Road traffic injuries per day of the week (2017)

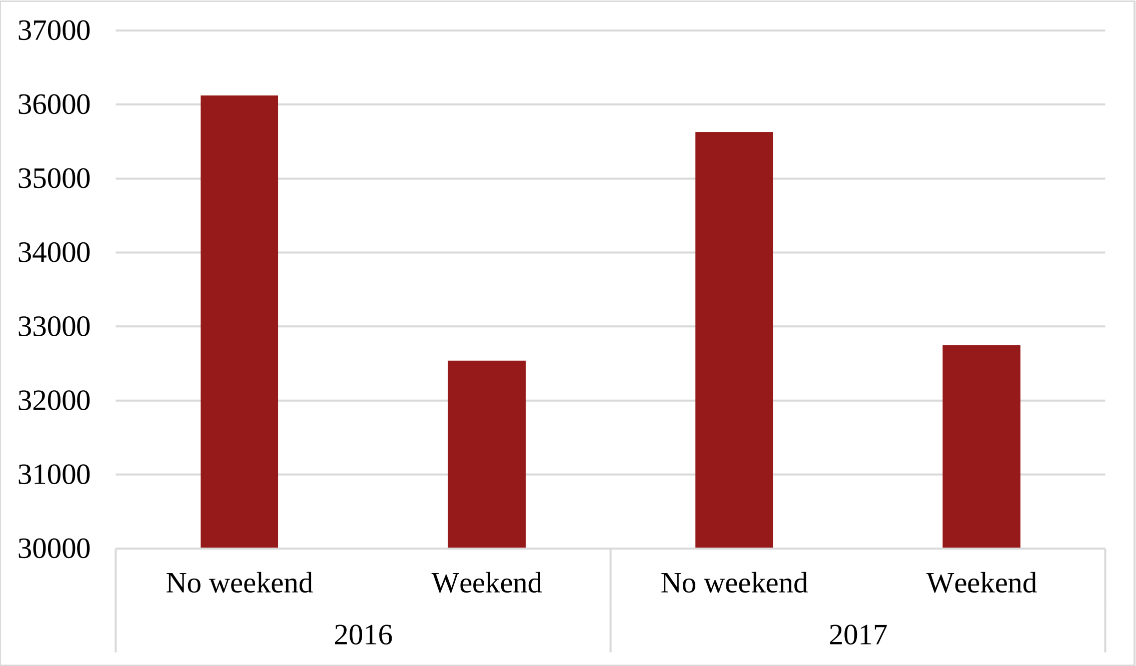

Figure 12: Road traffic injuries per (no) weekend (2016 and 2017)

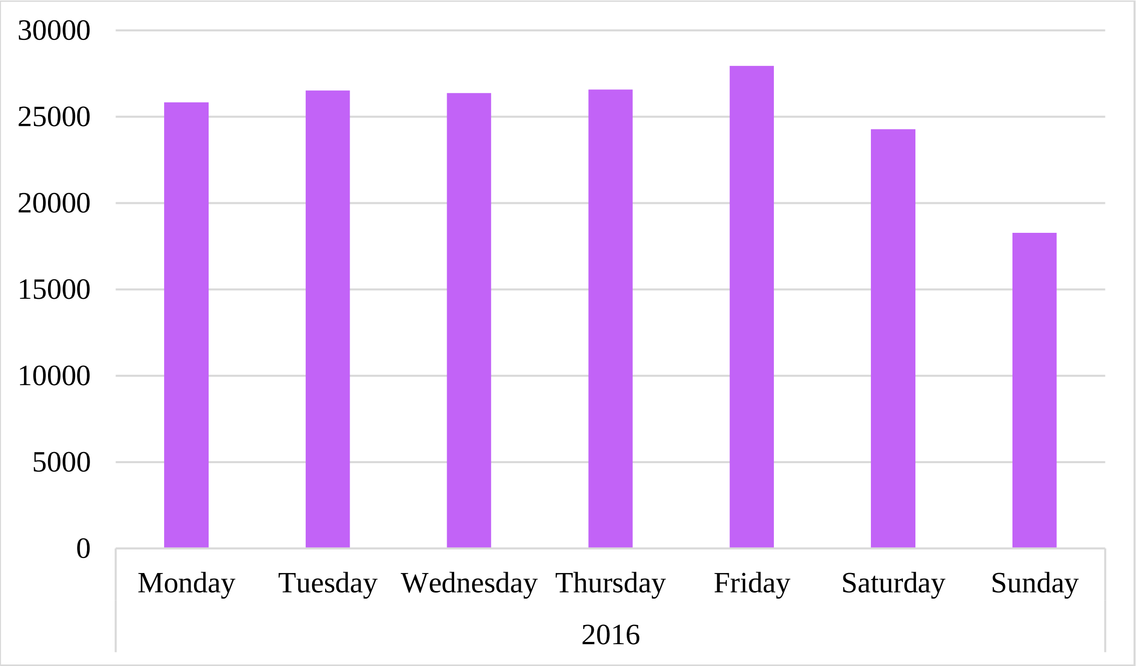

Figure 13: Road accidents per day of the week (2016)

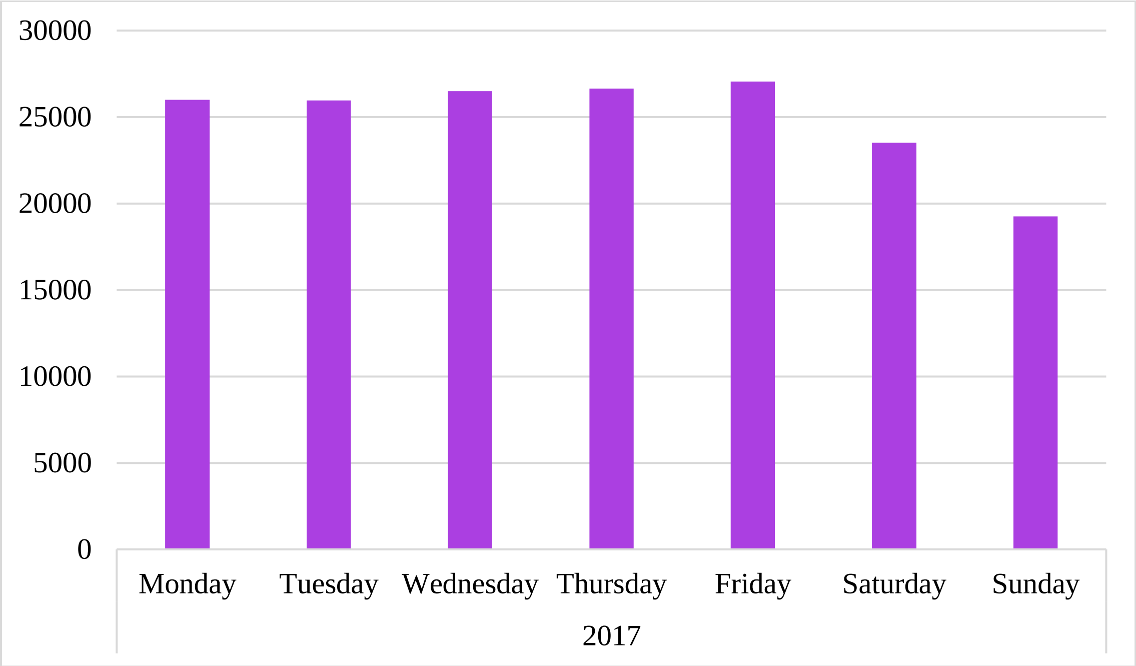

Figure 14: Road accidents per day of the week (2016)

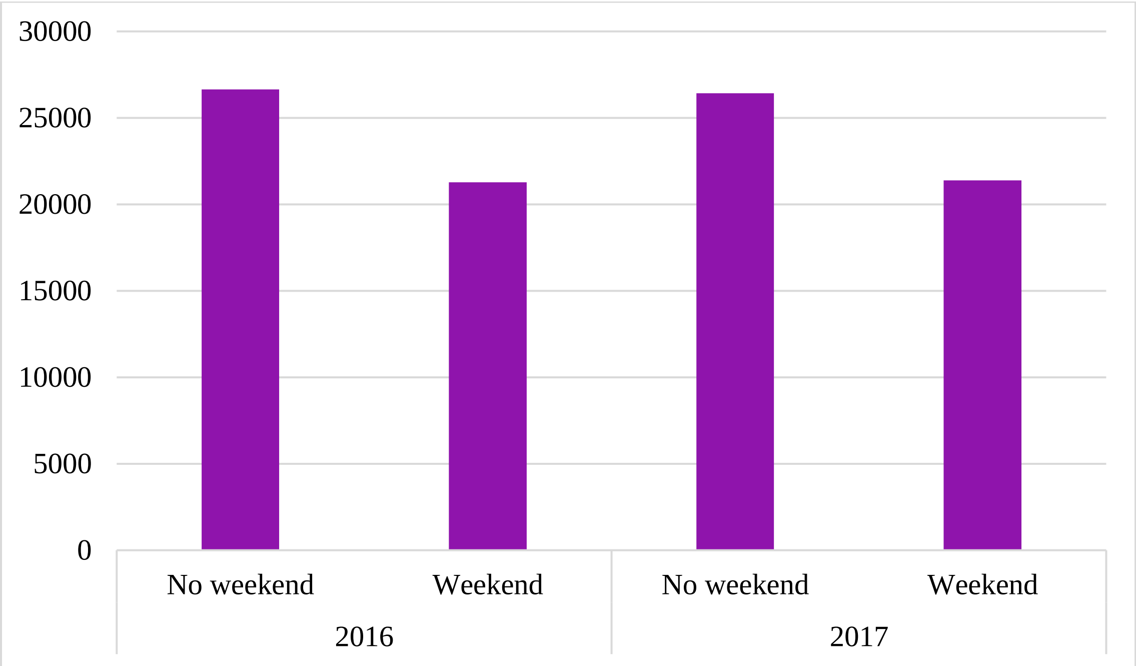

Figure 15: Road accidents per (no) weekend (2016 and 2017)

However, when looking at the data of oil prices, the assumption that higher oil prices are associated with a lower number of road fatalities, road accidents and road traffic injuries does not apply for every year and every quarter. In 2016 (Figures 16,17 and 18): a higher oil price, which means a higher fuel price, means a lower number of road-related outcomes in the fourth quarter of 2016. The price increased from the third quarter to the fourth quarter and this increase could have had an influence on the reduction of the total road-related outcomes. However, this cannot be found in the transition of the first quarter to the second quarter of 2016. Namely, a higher oil price was associated with more road-related outcomes.

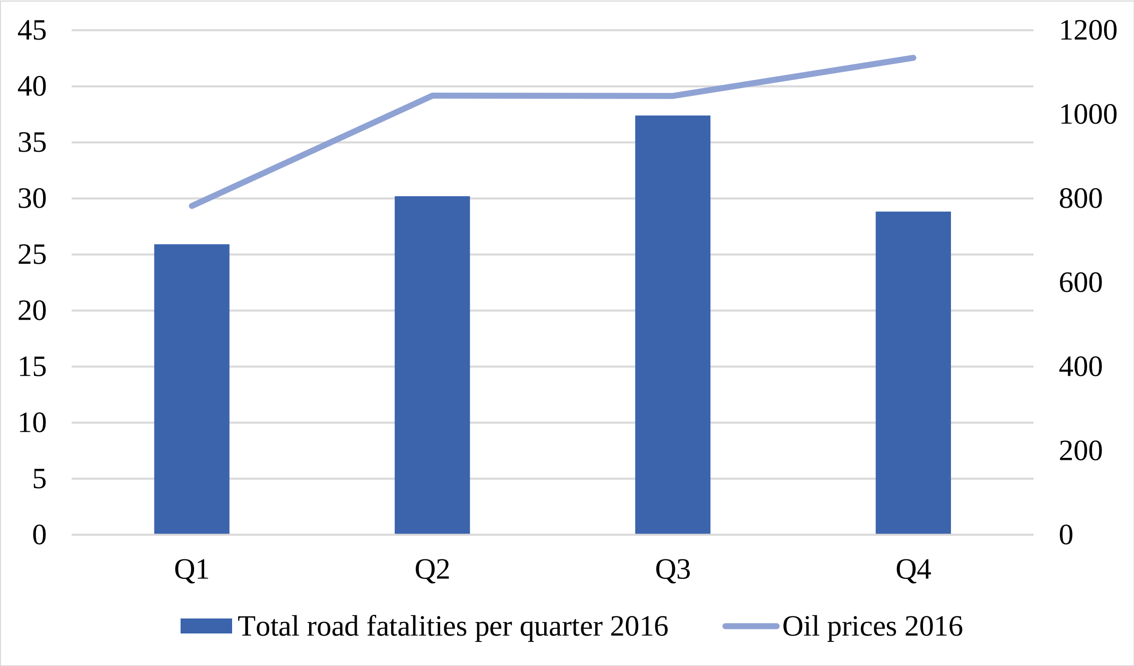

Figure 16: Total road fatalities per quarter and quarterly oil prices (2016)

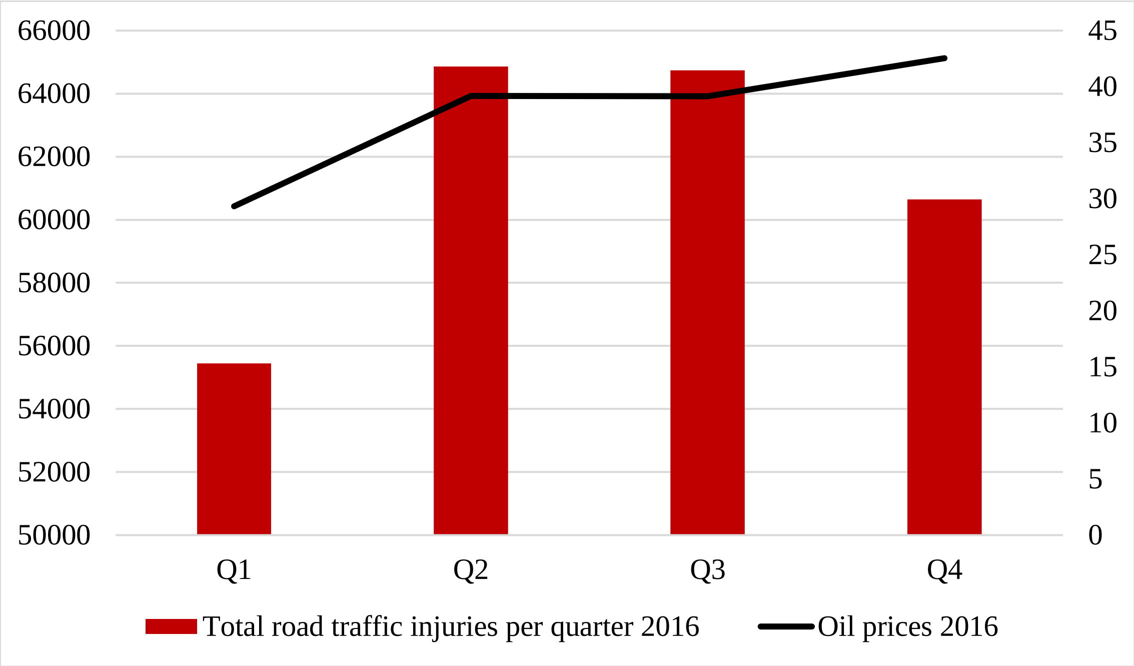

Figure 17: Total road traffic injuries per quarter and quarterly oil prices (2016)

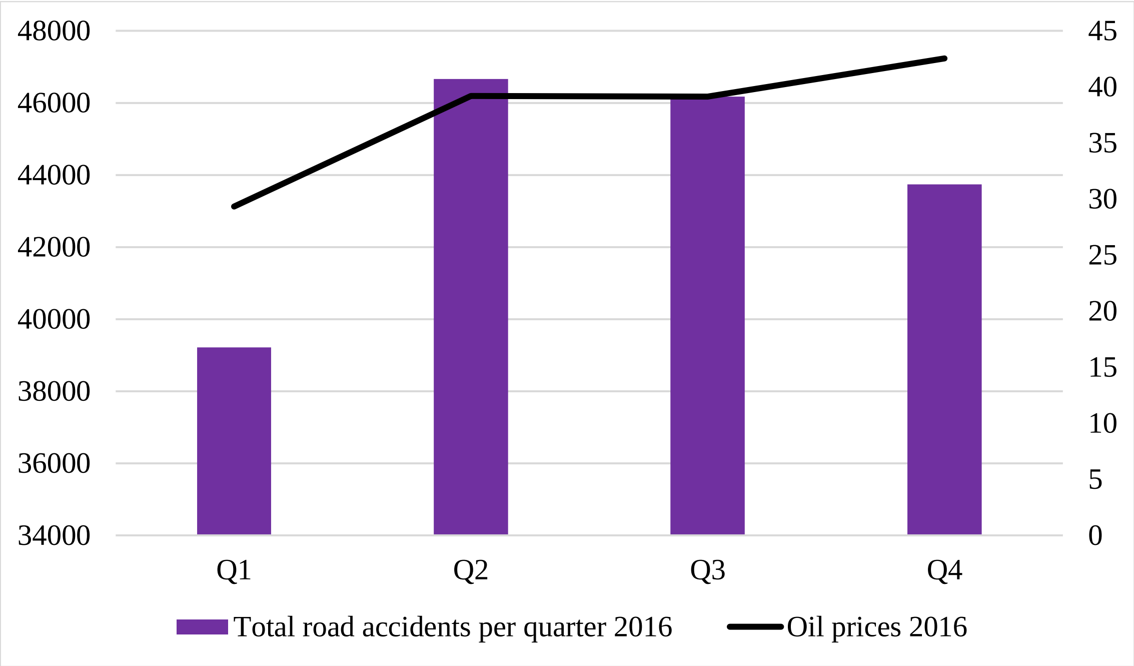

Figure 18: Total road accidents per quarter and quarterly oil prices (2016)

The assumption that lower oil prices are associated with a higher number of road fatalities is more visible in Figures 19, 20 and 21, which show respectively the total road fatalities, road traffic injuries and road accidents per quarter and quarterly oil prices of 2017. A lower oil price in the second quarter compared to the first quarter is associated with a higher number of road-related outcomes. The other way around: a higher oil price in the fourth quarter compared to the third quarter is associated with a lower number of road-related outcomes. From this short analysis can be concluded that the oil price has an ambiguous effect on the number of road-related outcomes.

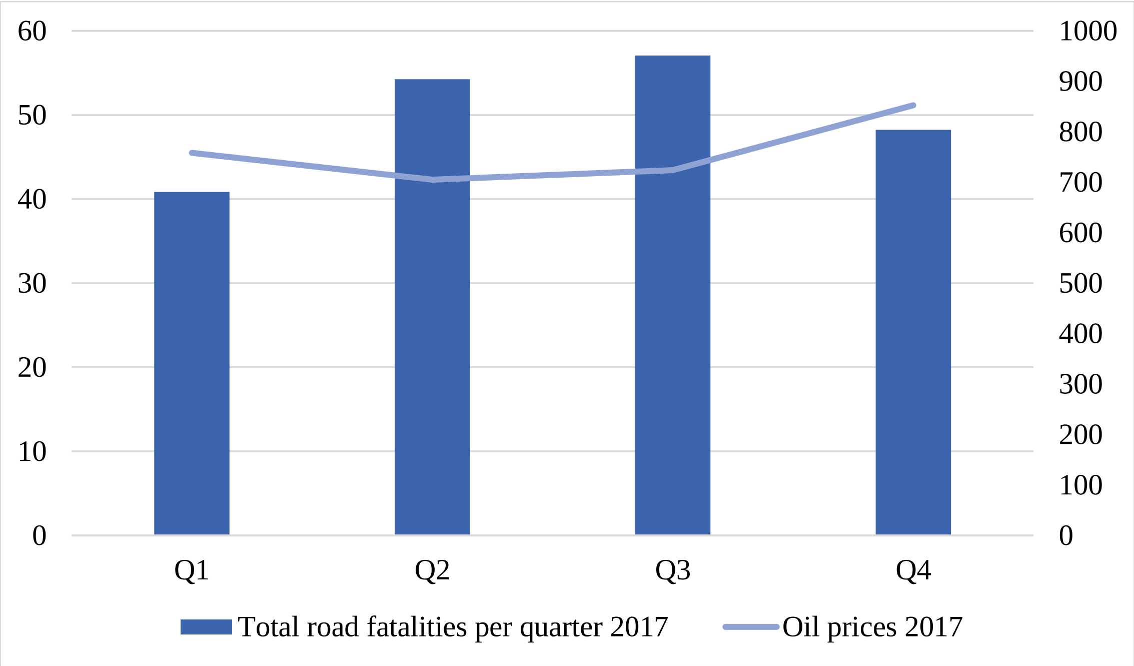

Figure 19: Total road fatalities per quarter and quarterly oil prices (2017)

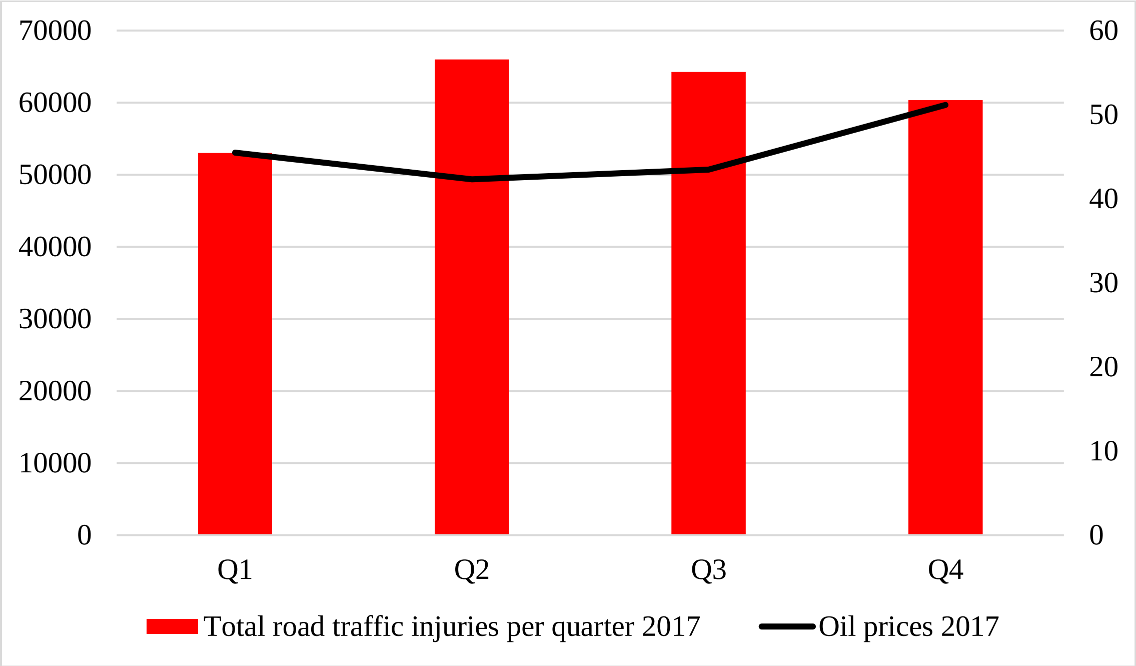

Figure 20: Total road traffic injuries per quarter and quarterly oil prices (2017)

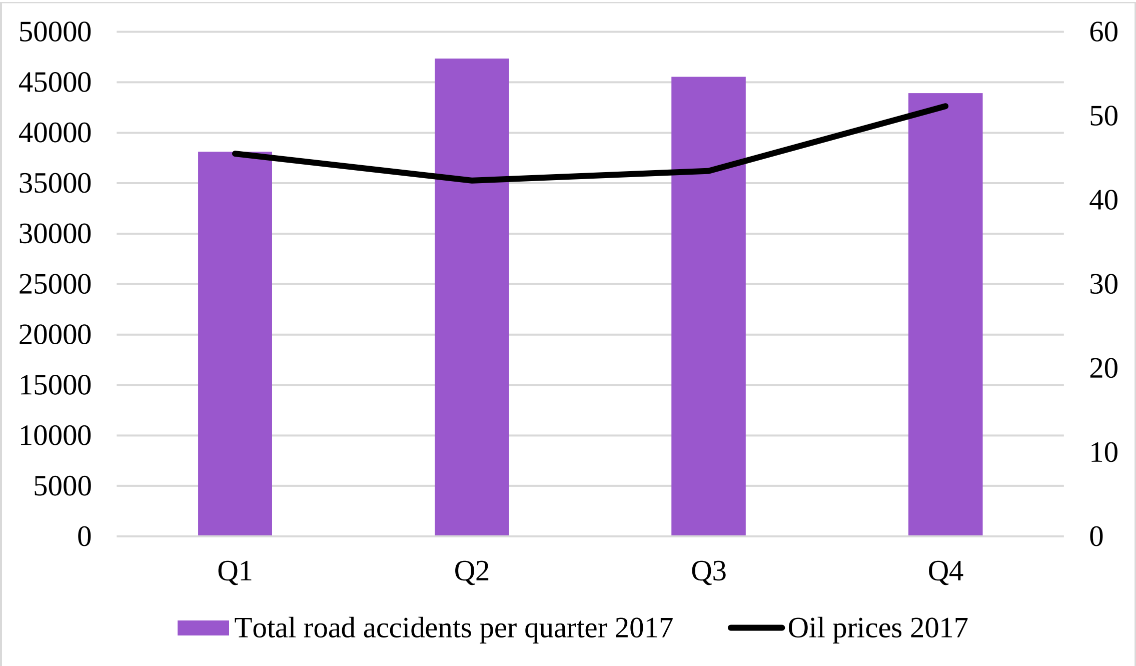

Figure 21: Total road accidents per quarter and quarterly oil prices (2017)

Nevertheless, these figures are not very specific, because it is quarterly based data and road-related outcomes are also determined by other factors, like the safety of cars, road code, weather conditions etc. Therefore, it is just a way to show that the mentioned variables could have an impact on road-related outcomes and should therefore be included in the model.

Additionally, the number of road-related outcomes per province differ in a high extent from each other. In 2016, the province Aosta has the lowest number of road fatalities, which was 3. However, this is not the case anymore in 2017, in which the provinces Gorizia and Biella do have the lowest number of road fatalities, which is in both provinces 4. In 2016 and 2017 the lowest number of road traffic injuries occurred in the province Isernia, with 249 road traffic injuries in 2016 and 221 road traffic injuries in 2017. With regards to the number of road accidents in 2016 the lowest number took place in the province Enna with 147 accidents and in 2017 this was the Isernia with 138 accidents. If examining the total road fatalities of both years bundled, the province Crotone has the lowest number of road fatalities, which is respectively 10 deaths in 2016 and 2017. This is Isernia in the case of road traffic injuries, with 470 injured people, and road accidents with 287 accidents.

The number of road fatalities, road traffic injuries and road accidents in the above-mentioned provinces are just a fraction of the number of road fatalities, road traffic injuries and road accidents which took place in the province Rome. Rome has the highest number of road fatalities, road traffic injuries and road accidents in both years separately as well as both years bundled. In 2016, 234 deaths occurred and one year later these were 216 deaths, which means 450 deaths when bundling both years. 22.195 people got injured in 2016, while in 2017 21.457 people got injured. Additionally, 16.608 accidents took place in 2016 and 16.208 in 2017. In the period from the beginning of 2016 and the end of 2017, 43.652 people got injured as a result of a road accident and 32.816 road accidents occurred. See Figure 22 for locations of these provinces.

When looking at different macro regions (Figure 23), on average most deaths took place in the North-East and Centre region of Italy, as well in both years bundled, as in both years separately. However, most road traffic injuries and road accidents happened the North-West and Centre region of Italy as well in both years bundled, as in both years separately. The least road fatalities, road traffic injuries and road accidents occurred in the Insular region.

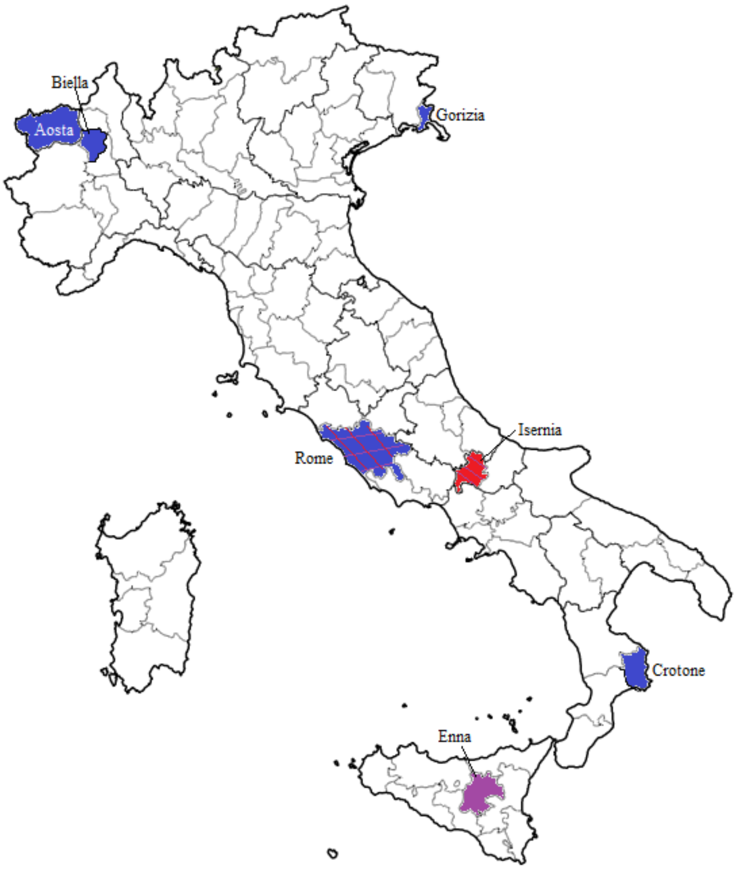

Figure 22: Provinces with most and least road fatalities (blue), road traffic injuries (red) and road accidents (purple) in 2016 and 2017

Figure 23: Macro-regions in Italy[6]

The difference-in-difference model will compare the average change over time in the number of road-related outcomes for the provinces where light cannabis is locally available (treatment group) and the average change over time for the provinces where light cannabis has never been locally available, so the provinces that are not affected by the unintended legalization (control group). So, the event is the unintended legalization of the cannabis which is determined by the opening of cannabis stores. The main identifying assumption to estimate causal effects is that both groups should have observed the same trends in road-related outcomes before the legalization of cannabis, the so-called parallel trend assumption, which makes the used method reliable. If there is a pre-policy trend, it means that this may have driven the main results in some extent. First, a graphical inspection of the trends for provinces in which a shop has opened in all periods and for provinces in which no shops has opened in all periods (Figures 24, 25 and 26).

[6] Retrieved from https://www.maps4office.com/nuts-region-map-italy/

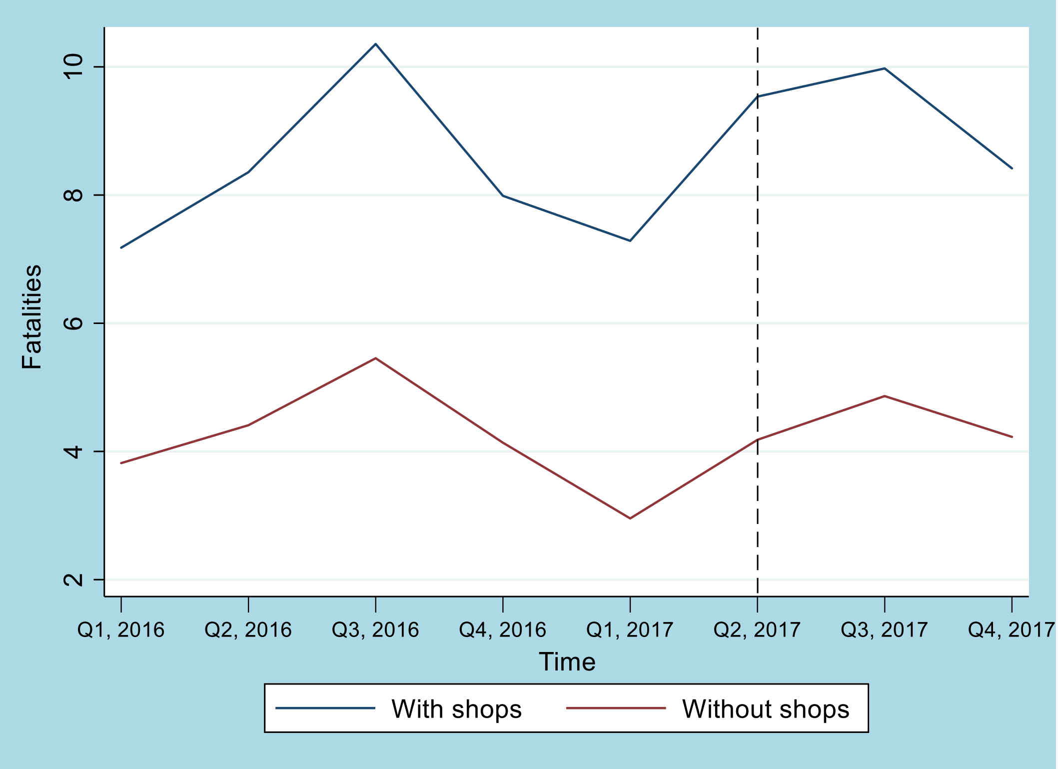

Figure 24: Average road fatalities per quarter grouped in provinces with shops vs. provinces without shops. (The dashed line represents the timing of the availability of the cannabis light retailers).

By looking at Figure 24, the pre-policy trends are parallel and the post-policy increase in road fatalities is consistent with the local availability in the treated provinces compared to the control provinces. This supports the credibility of the common trend assumption in this setting. This implies that those provinces that have experienced a timing of the local availability of light cannabis, which is the treatment group, and the provinces that never had any light cannabis shops (control groups) have considered the same pre-policy trends for the road fatalities. Additionally, the assumption that there are more road fatalities in provinces with cannabis shops seems to be right, because the-with-shops trendline lies above the trendline of the provinces without shops. Besides this, there should be noticed that from the first quarter of 2017 already an upward trend in road fatalities in both the control as the treatment group can be observed. This could indicate that this upward trend in road fatalities in the treatment group would have taken place anyway, whether or not the cannabis light was legalized.

Additionally, as can be seen in Figures 25 and 26 the pre-policy trends are also parallel in case of the road accidents and road traffic injuries. This implies that those provinces that have experienced a timing of the local availability of light cannabis and the provinces that never had any light cannabis shops have considered the same pre-policy trends for the number road accidents and road related injured people injured people as a consequence of a road accident.

Figure 25: Average road accidents per quarter grouped in provinces with shops vs. provinces without shops. (The dashed line represents the timing of the availability of the cannabis light retailers).

Figure 26: Average number of injured people because of road accidents per quarter grouped in provinces with shops vs. provinces without shops. (The dashed line represents the timing of the availability of the cannabis light retailers).

4 Results

The estimated impact of cannabis light market availability on road fatalities are presented in six log-level models in Table 2. Also, six log-level models will be used to estimate the impact of cannabis light market availability on respectively road accidents and road traffic injuries. The results of these log-level models are presented in case of the road accidents in Table 3 and in case of the road traffic injuries in Table 4[7]. To account for autocorrelation between pre/post in the same province, robust standard errors are added. The first log-level models of all outcomes consist of all provinces, while the other following five log-level models are divided per macro-region (respectively North-West, North-East, Centre, South and Insular (Appendix 1)). This distinction is made to find out if the entry of shops has another effect on the number of road fatalities, number of road accidents and road traffic injuries in certain groups of provinces (the macro-regions). Log-level models are created to interpret the results more easily. The dependent variables (the number of road fatalities, the number of road accidents and number of road traffic injuries) will be expressed in logs. This can help to interpret the coefficients as the average percentage change in the quarterly number of road fatalities / road accidents / road traffic injuries as a result of a certain variable in the regression. More specifically, the coefficient of interest, the entry-coefficient, will be interpreted as the average percentage change in the quarterly number of road fatalities / road accidents / road traffic injuries resulting from local availability of light cannabis.

[7] See for all output of the log-level models the Appendices

Road fatalities

Table 2: Difference-in-difference (log-level) regression results road fatalities

Variable	All provinces	North-West	North-East	Centre	South	Insular
Entry (DiD)	0.0477	0.054	0.165	0.276*	-0.299**	0.0345
	(0.063)	(0.135)	(0.117)	(0.147)	(0.129)	(0.151)
Oil price	-0.005	0.000	0.008	0.000	-0.034**	0.016
	(0.006)	(0.012)	(0.010)	(0.014)	(0.0127)	(0.018)
Weekend	0.077	2.21**	0.358	-0.928	-1.232*	0.585
	(0.452)	(0.966)	(0.952)	(1.051)	(0.697)	(0.927)
Year 2017	0.093	0.021	0.023	0.018	0.319	-0.093
	(0.077)	(0.135)	(0.143)	(0.126)	(0.212)	(0.276)
2nd Quarter	0.158***	0.034	0.070	0.085	0.404***	0.205
	(0.052)	(0.086)	(0.089)	(0.135)	(0.101)	(0.127)
Summer	0.362***	0.247*	0.293*	0.251*	0.579***	0.487*
	(0.067)	(0.135)	(0.146)	(0.133)	(0.141)	(0.225)
4th Quarter	0.148*	0.045	0.026	0.043	0.451**	0.099
	(0.082)	(0.158)	(0.127)	(0.178)	(0.184)	(0.263)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
N	848	200	176	176	192	104

*S.E. clustered at the province level between brackets. *** indicates significance at the 1% level, **, indicates significance at the 5% level, *indicates significance at the 10% level.*

Entry

A positive not statistically significant effect for the variable entry is documented. From the results can be concluded that when there is market availability of light cannabis because of an entry of at least one retailer in a given province, the number of road fatalities increases by about 4.8%. This is a mild average quarterly increase in the number of road fatalities.

Nevertheless, the extent of this effect does also reveal a considerable degree of heterogeneity between different macro-regions. The entry effect is larger in the North-West region when it is compared to the entry effect of all provinces. When there is market availability of light cannabis because of an entry of at least one retailer in the North-West, the number of road fatalities increases by about 5.4%. This largest increase is observed in the North-East and Centre macro-regions, which are respectively 16.5% and 27.6%. The effect of the Centre is statistically significant. Additionally, an effect of 3.45% is observed in the Insular region. An opposite statistically significant effect can be found for the South macro-region. The result in Table 2 for the South macro-region indicates that the market availability of light cannabis is associated with fewer road fatalities. The South, on average, experienced a 29% reduction in road fatalities following the market availability of light cannabis.

Other variables

Additionally, in Chapter 3, assumptions regarding the influence of oil prices, weekends, quarters and years on the number of road fatalities were made.

A small negative effect of 0.5% by the oil price on the average percentage change in the quarterly number of road fatalities is observed. Regarding the oil price, the assumption that a higher oil price is associated with a lower number of road fatalities, even it is a very small effect, seems to be satisfied. By looking at the results of the different macro-regions it can be concluded that the effect of the oil price on the average change in road fatalities seems ambiguous. The oil price does have a mild and statistically significant negative effect on the average change in road fatalities in the South. The quarterly number of road fatalities decreases with 3.4% when the oil price increases with €1. The effects are smaller in the other macro-regions. A positive effect can be found in the North-East and Insular regions and these effects are ranging between 0.8% and 1.6%, while there is no effect of the oil price on the quarterly number of road fatalities in the North-West and Centre.

The weekend has a mild positive effect on the quarterly number of road fatalities. The road fatalities are increasing on average with 7.7%. Meaning, there occur more road fatalities in the weekends compared to no weekends, which is also in line with the assumption that more road fatalities happen in the weekends.

Just like the oil price, the effect of the weekend seems to have an ambiguous effect on road fatalities, regarding the macro-regions. The weekend seems to have a very large effect, as well negative as positive, depending on the macro-region, on the quarterly number of road fatalities. The effect is negative in two macro-regions, namely: the Centre and the South. In the South, the effect is statistically significant and the quarterly number of road fatalities decreases with 123% in the weekends compared to no weekends. Additionally, a very large effect is found for the Centre: a 92.8% decrease in the quarterly number of road fatalities in the weekends. Besides these negative effects, the North-West, North-East and Insular all have large positive effects. In the North-West the number of road fatalities increases with 221% when it is weekend compared to no weekend, this effect is also statistically significant. Other large positive effects can be observed for the Centre and Insular, which are 35.8% and 58.5%.

Additionally, a mild positive effect can be found for the year 2017 compared to 2016, which is also in line with the expectations. The quarterly number of road fatalities increases on average with 9.3% in 2017 compared to 2016. There is a small positive effect on the quarterly number of road fatalities of 2017 compared to 2016 in the North-West, North-East and Centre which ranges between 1.8% and 2.3%. The effect is a lot larger in the South, which is 31.9%. In Insular there is a mild negative effect of 9.3%.

Also, the quarters do have a positive effect on the quarterly number of road fatalities. All these effects are large and statistically significant for the all provinces-model. The second quarter, the third quarter (which represents the summer) and the fourth quarter have positive large effects on the quarterly number of road fatalities compared to the first quarter, respectively 15.8%, 36,2% and 14,8%. The third quarter has by far the largest effect, so it can be concluded that the quarterly number of road fatalities do increase in a very high extent in the summer months, which is also in line with the assumption that more road fatalities happen in the summer.

As well, in all macro-regions all quarters have a positive effect on the average number of road fatalities, compared to the first quarter. Overall, these are large effects.
The effect of the second quarter compared to the first quarter is highly statistically significant and very large in the South: 40.4%. The effect is also large but not statistically significant for the Insular region, 20.5%. The effects are a lot smaller and not statistically significant for the remaining macro-regions.

The effects of the summer compared to the first quarter, are by far the largest for all macro-regions. Besides that, the effects are also statistically significant. They range from 24.7% to 57.9%. Especially the South and the Insular region have the largest effects, respectively 57.9% and 48.7%. In these two macro-regions, the effects are a lot larger compared to the effects of the other macro-regions, this could be because these macro-regions are more popular for tourists in the summer months. The assumption that the summer does have a positive effect on the average number of road fatalities seems satisfied.

At last, in the fourth quarter, almost all macro-regions have a mild positive effect. However, there is one macro-region with a very large and statistically significant effect, which is the South region. The fourth quarter compared to the first quarter is associated with a 45.1% increase in the average number of road fatalities.

Road accidents

Table 3: Difference-in-difference (log-level) regression results road accidents

Variable	All provinces	North-West	North-East	Centre	South	Insular
Entry (DiD)	-0.009	-0.007	-0.028	0.025	-0.058*	-0.009
	(0.017)	(0.036)	(0.033)	(0.033)	(0.030)	(0.085)
Oil price	-0.004***	-0.002	0.000	-0.007**	-0.009**	-0.004
	(0.001)	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)
Weekend	0.042	0.577**	0.278	-0.083	-0.127	0.126
	(0.135)	(0.279)	(0.315)	(0.308)	(0.252)	(0.263)
Year 2017	0.036**	0.025	0.009	0.054*	0.001	0.109*
	(0.017)	(0.042)	(0.037)	(0.029)	(0.039)	(0.054)
2nd Quarter	0.224***	0.200***	0.263***	0.258***	0.249***	0.113*
	(0.015)	(0.025)	(0.036)	(0.024)	(0.036)	(0.059)
Summer	0.261***	0.201***	0.272***	0.315***	0.313***	0.157**
	(0.021)	(0.041)	(0.054)	(0.044)	(0.042)	(0.059)
4th Quarter	0.176***	0.165***	0.165***	0.249***	0.199***	0.043
	(0.019)	(0.041)	(0.042)	(0.033)	(0.048)	(0.047)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
N	848	200	176	176	192	104

*S.E. clustered at the province level between brackets. *** indicates significance at the 1% level, **, indicates significance at the 5% level, *indicates significance at the 10% level.*

Entry

A negative not statistically significant effect for the variable entry is documented. From the results can be concluded that when there is market availability of light cannabis because of an entry of at least one retailer in a given province, the number of road accidents decreases by about 0.9%. This is a small average quarterly decrease in the number of road accidents.

Additionally, the extent of this effect does reveal, like also in the case of road fatalities, a considerable degree of heterogeneity between different macro-regions. The entry effect is in absolute terms the smallest in the North-West of Italy when it is compared to the entry effect of all provinces. When there is market availability of light cannabis because of an entry of at least one retailer in the North-West, the number of road accidents decreases by about 0.7%. The largest decreases are observed in the North-East and South regions, which are respectively 2.8% and 5.8%. The effect in the South is statistically significant. Additionally, a negative effect of 1.0% is observed in the Insular region. An opposite effect can only be found for the Centre region. The result in Table 3 for the Centre indicates that the market availability of light cannabis is associated with more road accidents. Namely, the Centre, on average, experienced a 2.5% increase in road accidents following the market availability of light cannabis.

Other variables

A small statistically significant negative effect of 0.4% by the oil price on the average percentage change in the quarterly number of road accidents is observed. By looking at the results of the different macro-regions it can be concluded that the effect of the oil price on the average change in road accidents is negative in most macro-regions, which is in line with the assumption that a higher oil price is associated with a lower number of road accidents. The oil price has a small negative statistically significant effect on the average change in road accidents in the South and the Centre. The quarterly number of road fatalities decreases with respectively 0.9% and 0.7% when the oil price increases with €1. The effects are smaller in the other macro-regions. There is no effect of the oil price on the quarterly number of road accidents in the North-East.

The weekend has a mild positive effect on the quarterly number of road accidents. The road accidents are increasing on average with 4.2%. Meaning, there occur more road accidents in the weekends compared to no weekends, which is also in line with the previously made assumption.

When looking at the macro-regions, the effect of the weekend seems to have an ambiguous effect on road accidents. The weekend has a (very) large effect, as well negative as positive depending on the macro-region, on the quarterly number of road accidents. The effect is negative in two macro-regions, namely: the Centre and the South. In the South, the quarterly number of road accidents decreases with 12.7% in the weekends compared to no weekends. Additionally, a mild effect is found for the Centre: an 8.3% decrease in the quarterly number of road accidents in the weekends. Besides these negative effects, the North-West, North-East and Insular all have large positive effects. In the North-West the number of road accidents increases with 57.7% when it is weekend compared to no weekend, this effect is also statistically significant. Other large positive effects can be observed for the North-East and Insular, which are 27.8% and 12.6%.

Additionally, a mild and statistically significant positive effect can be found for the year 2017 compared to 2016. The quarterly number of road accidents increases on average with 3.6% in 2017 compared to 2016. Only positive effects can be found for the different macro-regions. There is a mild positive effect on the quarterly number of road accidents of 2017 compared to 2016 in the North-West, Centre and Insular which ranges between 2.5% and 10.9%. The effect of the Centre is statistically significant. The effects are a lot smaller in the South and the North-East, which are 0.1% and 0.9%.

Also, the quarters do have a positive statistically significant effect on the quarterly number of road accidents. The second quarter, the third quarter (which represents the summer) and the fourth quarter have large positive effects on the quarterly number of road accidents compared to the first quarter, respectively 22.4%, 26.1% and 17.6%. The third quarter has the largest effect, so it can be concluded that the quarterly number of road accidents do increase in a very high extent in the summer months, which is again in line with the assumption.

As well, in all macro-regions all quarters have a large statistically significant positive effect on the average number of road accidents compared to the first quarter, except the effect of the fourth quarter of the Insular region.

The effect of the second quarter compared to the first quarter is highly statistically significant and largest in the North-East: 26.3%. This effect is smallest in the Insular region, 11.3%.

The effects of the summer compared to the first quarter, are by far the largest for all macro-regions. They range from 15.7% to 31.5%. Especially the South and the Centre have the largest effects, respectively 31.3% and 31.5%.

At last, in the fourth quarter, almost all macro-regions have a large positive effect. However, there is one macro-region with a very small and not statistically significant effect, which is the Insular region. The largest effect can be found in the Centre, in which the fourth quarter compared to the first quarter is associated with a 24.9% increase in the average number of road accidents.

Road traffic injuries

Table 4: Difference-in-difference (log-level) regression results road traffic injuries

Variable	**All provinces**	**North-West**	**North-East**	**Centre**	**South**	**Insular**
Entry (DiD)	-0.011	0.006	-0.030	0.011	-0.059**	-0.004
	(0.017)	(0.034)	(0.031)	(0.036)	(0.026)	(0.096)
Oil price	-0.006***	-0.003	-0.001	-0.008***	-0.012***	0.000
	(0.002)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)
Weekend	0.149	0.739**	0.362	0.095	0.023	0.106
	(0.149)	(0.292)	(0.297)	(0.318)	(0.302)	(0.288)
Year 2017	0.041**	0.028	0.013	0.069**	0.015	0.092
	(0.018)	(0.043)	(0.037)	(0.032)	(0.039)	(0.075)
2nd Quarter	0.217***	0.182***	0.258***	0.258***	0.247***	0.094
	(0.016)	(0.027)	(0.035)	(0.026)	(0.029)	(0.070)
Summer	0.256***	0.186***	0.281***	0.319***	0.299***	0.156**
	(0.021)	(0.046)	(0.055)	(0.046)	(0.036)	(0.060)
4th Quarter	0.175***	0.147***	0.170***	0.258***	0.220***	0.003
	(0.022)	(0.047)	(0.043)	(0.041)	(0.042)	(0.071)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
N	848	200	176	176	192	104

*S.E. clustered at the province level between brackets. *** indicates significance at the 1% level, **, indicates significance at the 5% level, *indicates significance at the 10% level.*

Entry

Regarding the road traffic injuries, a negative not statistically significant effect for the entry-variable is documented. From the results can be concluded that when there is market availability of light cannabis because of an entry of at least one retailer in a given province, the number of road traffic injuries decreases by about 1.1%. This is a small average quarterly decrease in the number of road traffic injuries.

Just like the road fatalities and road accidents, the extent of the effect does also reveal a considerable degree of heterogeneity between different macro-regions. The entry effect is smallest in absolute terms in the Insular region when it is compared to the entry effect of all provinces. When there is market availability of light cannabis because of an entry of at least one retailer in the Insular region, the number of road traffic injuries decrease by about 0.4%. The largest declines are observed in the North-East and South macro-regions, which are respectively 3% and 5.9%. The entry effect of the South is statistically significant. Additionally, opposite effects can be found for the North-West and the Centre. The results in Table 4 for the North-West and Centre macro-regions indicate that the market availability of light cannabis is associated with more road traffic injuries. The Centre, on average, experienced a 1.1% increase in road related traffic injuries following the market availability of light cannabis and the North-West a 0.6% increase in road traffic injuries.

Other variables

A small statistically significant negative effect of 0.6% by the oil price on the average percentage change in the quarterly number of road traffic injuries is observed. This is in line with the assumption that a higher oil price is associated with a lower number of road traffic injuries. With regards to the results of the different macro-regions it can be concluded that the effect of the oil price on the average change in road traffic injuries is negative in most macro-regions. The oil price has a small negative statistically significant effect on the average change in road traffic injuries in the South and the Centre. The quarterly number of road traffic injuries decreases with respectively 1.2% and 0.8% when the oil price increases with €1. The effects are smaller in the other macro-regions. There is no effect of the oil price on the quarterly number of road traffic injuries in the Insular region.

The weekend has a large positive effect on the quarterly number of road traffic injuries. The road traffic injuries are increasing on average with 14.9%. Meaning, there occur more road traffic injuries in the weekends compared to no weekends. The weekend seems to have a (very) large positive effect on the quarterly number of road traffic injuries. The effect is largest and statistically significant in the North-West, the quarterly number of road traffic injuries increases with 73.9% in the weekends compared to no weekends. The effect is also large in the North-East with 36.2%. The effects in the other macro-regions are smaller and range between 2.3% and 10.6%. Overall, also the assumption that more road traffic injuries occur in the weekends is satisfied.

Additionally, a mild and statistically significant positive effect can be found for the year 2017 compared to 2016. The quarterly number of road traffic injuries increases on average with 4.1% in 2017 compared to 2016. There is a mild positive effect on the quarterly number of road traffic injuries of 2017 compared to 2016 in all the macro-regions which ranges between 1.3% and 9.2% The Centre has a positive statistically significant effect of 6.9%.

Also, the quarters do have a positive statistically significant effect on the quarterly number of road traffic injuries. The second quarter, the third quarter (which represents the summer) and the fourth quarter have positive large effects on the quarterly number of road traffic injuries compared to the first quarter, respectively 21.7%, 25.6% and 17.5%. The third quarter has the largest effect, so it can be concluded that the quarterly number of road traffic injuries do increase in a very high extent in the summer months.

As well, in all macro-regions all quarters have a large statistically significant positive effect on the average number of road traffic injuries compared to the first quarter, except the effects of the second and fourth quarter in the Insular region.

The effect of the second quarter compared to the first quarter is highly statistically significant and largest in the North-East and Centre: 25.8%. The effect is smallest and not statistically significant in the Insular region, 9.4%.

The effects of the summer compared to the first quarter, are by far the largest for all macro-regions. They range from 15.6% to 31.9%. Especially the South and the Centre have the largest effects, respectively 29.9% and 31.9%.

At last, in the fourth quarter, almost all macro-regions have a large positive effect. However, there is one macro-region with a very small and not statistically significant effect, which is the Insular region. The largest effect can be found in the Centre, in which the fourth quarter compared to the first quarter is associated with a 25.8% increase in the average number of road related injuries.

Table 5: Difference-in-difference (log-level) regression results of entry coefficient for all outcomes

Outcome	**All provinces**	**North-West**	**North-East**	**Centre**	**South**	**Insular**
Road fatalities	0.0477 (0.063)	0.054 (0.135)	0.165 (0.117)	0.276* (0.147)	-0.299** (0.129)	0.0345 (0.151)
Road accidents	-0.009 (0.017)	-0.007 (0.036)	-0.028 (0.033)	0.025 (0.033)	-0.058* (0.030)	-0.009 (0.085)
Road traffic injuries	-0.011 (0.017)	0.006 (0.034)	-0.030 (0.031)	0.011 (0.036)	-0.059** (0.026)	-0.004 (0.096)
N	848	200	176	176	192	104

*S.E. clustered at the province level between brackets. *** indicates significance at the 1% level, **, indicates significance at the 5% level, *indicates significance at the 10% level.*

Taking all results of the entry-variable together (Table 5), the results suggest that the concerns about the increases in road fatalities, road traffic injuries and road accidents because of the market availability of light cannabis are partly justified. As said before, overall a positive effect of the market availability of light cannabis is associated with an increase in the number of road fatalities, except this is not the case in the South macro-region, in which a negative effect of the market availability of light cannabis has been found.

Also, overall a small negative effect of the market availability of light cannabis has been found for the road accidents and the road traffic injuries. Meaning: the market availability of light cannabis is associated with a decrease in the number of road accidents and road traffic injuries. However, in case of the road accidents, a positive effect can only be found in the Centre region, which means that in the Centre the market availability of light cannabis is associated with an increase in the number of road accidents. Additionally, in case of the road traffic injuries, a positive effect can only be found in the North-West and Centre regions. Which implies that in these two regions, the number road traffic injuries increased after the market availability of light cannabis

5 Discussion and Conclusion

The legalization of cannabis has led to a lot of worldwide interest to economic, social and public health consequences. There are signs that indicate that road traffic injuries will become the seventh leading cause of death and will therefore rise on the causes of death ranking. According to the WHO, one of the most important risk factors of road fatalities is driving under the influence of drugs or alcohol (World Health Organization, 2018). Additionally, several studies have shown that the most frequently detected non-alcoholic substance in road crashes is cannabis (National Institute on Drug Abuse, 2019). Therefore, common named possible externalities are the increase in road fatalities, road traffic injuries and road accidents caused by drivers who are under the influence of cannabis. Very little is known about the effects of cannabis liberalization on these road-related outcomes, especially in Europe. With this study a contribution is made by using a staggered difference-in-difference model to compare the number of road fatalities, road traffic injuries and road accidents in Italian provinces in which shops have opened (treatment group) with Italian provinces in which no shops have opened (control group) since the legalization of light cannabis. Both groups have similar pre-legalization road- related trends, which means that the parallel trend assumptions are satisfied.

Generally, this research found some evidence supporting impact of light cannabis legalization on road fatalities, road traffic injuries and road accidents. The main findings of this research are that the local availability of light cannabis resulted in a positive average percentage change in the quarterly number of road fatalities in Italy and that the local availability of light cannabis resulted in a negative average percentage change in the quarterly number of road accidents and road traffic injuries in Italy. More specifically: the local availability of light cannabis resulted in a 4.8% increase in the number of road fatalities. This is a mild and not statistically significant effect. The local availability of light cannabis has had more effect on the number of road fatalities in some macro-regions compared to others. The effects were largest in the North-East (16.5%), the Centre (27.6%) and the South (-29%), while in the North-West (5.4%) and Insular (3.5%) the effects were a lot smaller. Only statistically significant effects are found in the Centre and South. As described in chapter 3, an upward trend in road fatalities in both the control as the treatment group can be observed since the first quarter of 2017. This could indicate that the upward trend in road fatalities in the treatment group would have taken place anyway, whether or not the cannabis light was legalized.

Regarding the road accidents, the local availability of light cannabis resulted in a 0.9% decrease in the number of road accidents. This is a small and not statistically significant effect. The local availability of light cannabis has had more effect on the number of road accidents in some macro-regions compared to others. The effects were largest in the North-East (-2.8%), the Centre (2.5%) and the South (-5.8%), while in the North-West (-0.7%) and Insular (-0.9%) the effects were a lot smaller.

Concerning the road traffic injuries, the local availability of light cannabis resulted in a 1.1% decrease in the number of road traffic injuries. Also, this is a small and not statistically significant effect. The local availability of light cannabis has had more effect on the number of road traffic injuries in some macro-regions compared to others. The effects were largest in the North-East (-3%) and the South (-5.9%), while in the North-West (0.6%), Insular (-0.4%) and the Centre (1.1%) the effects were smaller or the same as the effect in the all provinces model. Only a statistically significant effect for both road traffic injuries and road accidents can be found for the South.

From the above discussed findings can be concluded that this research shows mixed results. On the one hand, due to the positive effect of the legalization of cannabis light on the number of road fatalities, this legalization should be reversed, because it seems like it could unnecessarily cost human lives. On the other hand, the legalization seems to have a negative effect on the number of road accidents and road traffic injuries. Meaning, while the road fatalities increase, the road traffic injuries and road accidents both decrease as a result of the legalization of light cannabis. Therefore, based on this research no uniform answer can be given whether the legalization should be reversed or not.

The result that the local availability of light cannabis in Italy resulted in a mild positive average percentage change in the quarterly number of road fatalities is not in line with the results of two American studies, namely, Hansen et al. (2018) found no effects on road fatalities after legalization of cannabis. Also, Anderson et al. (2013) found an opposite effect compared to this study: they found that legalization of cannabis is associated with a decrease in road fatalities. Different data sources lead to different outcomes. Both above mentioned studies consisted of American data sources, while this study consists of Italian data sources. Other data sources will lead to different outcomes. Concerning Hansen et al. they obtained their data from the Fatal

Analysis and Reporting System (FARS) and they used a longer time frame, from 2000 to 2016, while in this study only data for the years 2016 and 2017 were available. Additionally, they did not use data about the opening of cannabis shops, but data on THC testing results of drivers.

Also, Anderson et al. used data from the FARS. They used another time frame than Hansen: 1990 to 2010. Anderson et al. did compare treated states, those that legalized medical marijuana and control states, those that did not legalize medical marijuana. They found that cannabis and alcohol are substitutes and that the reduction in traffic fatalities after the legalizing of medical marijuana seems to be because alcohol consumption plays a key role. They state that it could be possible that legalization of cannabis reduces the road fatalities because the effect of using a substance in public. People consume alcohol very often in bars and restaurants while the use of cannabis in public can be controversial. If the consumption of cannabis typically takes place at home, then the designation of a driver for the trip back from a public place (e.g. restaurant or bar) will become unnecessary. In that setting, the legalization of cannabis could reduce road fatalities even if driving under the influence of cannabis is as dangerous as driving under the influence of alcohol.

The assumptions concerning the oil price, the summer and the weekend are all satisfied in the model in which all provinces are included. The assumptions were: firstly, a higher oil price would decrease the number of road-related outcomes, meaning: a higher oil price leads to a reduction in the number of road fatalities, road accidents and road traffic injuries. Secondly, in the summer more road-related outcomes would occur. Lastly, in the weekend more road-related outcomes would happen. All these findings are in line with the study of Bruzzone et al. (2019).

Regarding the effects of these variables when dividing the effect in different macro-regions: in case of the road fatalities an ambiguous oil price effect is found. Meaning, in some macro-regions the effect of the oil price is negative, while in other macro-regions the effect of the oil price is either positive or there is no effect at all. Concerning the road accidents and road traffic injuries, all macro-regions have a negative oil price effect. However, this is not the case for road accidents in the North-East and road traffic injuries in the Insular. In both regions the oil price does not have any effect at all. With respect to the weekend: in the different macro-regions, the effect of the weekend on road fatalities and on road accidents is ambiguous. On the other hand, in all macro-regions the effect of the weekend on road traffic injuries is positive.

Ultimately, the effect of the quarters: the effect of the quarters in comparison to the first quarter is positive for all road-related outcomes. Additionally, the third quarter, which represents the summer, has the largest positive effect in all macro-regions.

While this research contributes to a better understanding of the impact of the legalization of cannabis on several road-related outcomes, it has some limitations. These limitation should be considered carefully when interpreting the results and some of these limitations can become avenues for future research. The first limitation is related to not taking the injury related costs and crash related costs (Bruzzone et al., 2019; Wijnen & Stipdonk, 2016) into account. Related to the injury related costs, no information about the severity of the injuries of the people that were involved in the road accidents was used. Consequently, as described before the number of road traffic injuries went down, however, it could be that the injuries that resulted from the road accidents are from a severe degree. As a result, high costs of hospital stay, medicines, rehabilitation and production loss could all be present. The same counts for the crash related costs. There could be a lot of damage to certain properties and vehicles, which are also not included in this study. By taking the injury related costs and crash related costs into account, a more complete understanding of the impact of the legalisation of light cannabis can be determined.

Furthermore, should be noticed that this research has a really small sample size, this is resulting in larger standard errors, which makes it more difficult to get statistically significant results. Due to the fact that a lot of the results are not statistically significant, the analyses of cannabis light legalization related to road-related outcomes provide little evidence to support the hypothesis that market availability of light cannabis increases road-related outcomes (e.g. road fatalities, road traffic injuries and road accidents). Therefore, the sample size is the second limitation of this research. Moreover, by getting access to monthly data instead of quarterly data, more observations can be used, which makes it less difficult to reject the null hypothesis and therefore get more statistically significant results.

Another limitation is that the distance from the accident to a cannabis shop is just a proxy. It would be more precise if there were testing results available from the persons that were involved in a road accident (e.g. whether someone tested positive for cannabis). This limitation reduces the validity of the research method. This information is not available in the Italian dataset, therefore this limitation cannot be resolved when studying the same impact with the same dataset in future research. Furthermore, an additional limitation is the time span of the research. It is limited to 8 quarters, longer panel data are required to obtain a more complete understanding of the effect.

Not the entire spectrum is covered in this research. The executed research just provides a possible drawback and some possible benefits of legalising cannabis light, while there could also be other benefits and drawbacks which are not taken into account. Future research might consider other potential externalities of legalising cannabis, besides the increase in road fatalities and decrease in road traffic injuries and road accidents, such as effects on hospital admissions and drug overdoses. To give an ultimate answer whether the legalization has a beneficial or detrimental effect for society, all potential benefits and drawbacks should be determined and considered. The legalization could lead to, as mentioned before, increased tax revenues. With more tax revenues, more public investments can be made that could eventually lead to safer road circumstances, e.g. training of law enforcement teams to notice impaired drivers and road infrastructure (such as improved road floors). This could also improve the safety on the roads which could also have an influence on the reduction of the number of (fatal or injury) accidents. These improvements will probably save lives and/or prevent injuries to people as a result of a road accident in the long run. This could be another avenue for future research. Another suggestion for future research is to determine why there is so much heterogeneity in magnitude and sign of the effects between the different macro-regions. More specific: what factors determine these differences between the macro-regions. In the Insular region, the number of shops (168) is by far less than the number of shops in the other macro-regions, which do range between 336 and 629 shops. This could indicate that cannabis light is not as popular in the other macro-regions compared to the Insular region. This could partly explain the different effects of the opening of cannabis shops on the road-related outcomes. As described before, future research could indicate if this is the case and what other factors would determine this.

Appendices

Appendix 1: Province (number) list

Province Number	***Provinces***	***Macro region***	***Category***
1	Turin	North-West	1
2	Vercelli	North-West	1
3	Novara	North-West	1
4	Cuneo	North-West	1
5	Asti	North-West	1
6	Alessandria	North-West	1
7	Aosta	North-West	1
8	Imperia	North-West	1
9	Savona	North-West	1
10	Genoa	North-West	1
11	La Spezia	North-West	1
12	Varese	North-West	1
13	Como	North-West	1
14	Sondrio	North-West	1
15	Milan	North-West	1
16	Bergamo	North-West	1
17	Brescia	North-West	1
18	Pavia	North-West	1
19	Cremona	North-West	1
20	Mantua	North-West	1
21	Bolzano	North-East	2
22	Trento	North-East	2
23	Verona	North-East	2
24	Vicenza	North-East	2
25	Belluno	North-East	2
26	Treviso	North-East	2
27	Venice	North-East	2
28	Padua	North-East	2
29	Rovigo	North-East	2
30	Udine	North-East	2
31	Gorizia	North-East	2
32	Trieste	North-East	2
33	Piacenza	North-East	2
34	Parma	North-East	2
35	Reggio Emilia	North-East	2
36	Modena	North-East	2
37	Bologna	North-East	2
38	Ferrara	North-East	2
39	Ravenna	North-East	2
40	Forli-Cesena	North-East	2
41	Pesaro	Centre	3
42	Ancona	Centre	3

43	Macerata	Centre	3
44	Ascoli Piceno	Centre	3
45	Massa	Centre	3
46	Lucca	Centre	3
47	Pistoia	Centre	3
48	Florence	Centre	3
49	Livorno	Centre	3
50	Pisa	Centre	3
51	Arezzo	Centre	3
52	Siena	Centre	3
53	Grosseto	Centre	3
54	Perugia	Centre	3
55	Terni	Centre	3
56	Viterbo	Centre	3
57	Rieti	Centre	3
58	Rome	Centre	3
59	Latina	Centre	3
60	Frosinone	Centre	3
61	Caserta	South	4
62	Benevento	South	4
63	Naples	South	4
64	Avellino	South	4
65	Salerno	South	4
66	L'Aquila	South	4
67	Teramo	South	4
68	Pescara	South	4
69	Chieti	South	4
70	Campobasso	South	4
71	Foggia	South	4
72	Bari	South	4
73	Taranto	South	4
74	Brindisi	South	4
75	Lecce	South	4
76	Potenza	South	4
77	Matera	South	4
78	Cosenza	South	4
79	Catanzaro	South	4
80	Reggio Calabria	South	4
81	Trapani	Insular	5
82	Palermo	Insular	5
83	Messina	Insular	5
84	Agrigento	Insular	5
85	Caltanissetta	Insular	5
86	Enna	Insular	5
87	Catania	Insular	5
88	Ragusa	Insular	5
89	Syracuse	Insular	5

90	Sassari	Insular	5
91	Nuoro	Insular	5
92	Cagliari	Insular	5
93	Pordenone	North-East	2
94	Isernia	South	4
95	Oristano	Insular	5
96	Biella	North-West	1
97	Lecco	North-West	1
98	Lodi	North-West	1
99	Rimini	North-East	2
100	Prato	Centre	3
101	Crotone	South	4
102	Vibo Valentina	South	4
103	Verbano-Cusio	North-West	1
108	Monza and Brianza	North-West	1
109	Fermo	Centre	3
110	BAT (Barletta-Andria-Trani)	South	4

Appendix 2: Output of difference-in-difference regression with road fatalities (in logs) as dependent variable (All provinces)

lnfatalities	**Coefficient**	**Robust Std. Err.**	**t**	**P>t**	**[95%**	**Confidence Interval]**
entry	.0477337	.0632742	0.75	0.452	-.0777274	.1731948
population	3.55e-06	9.64e-06	0.37	0.714	-.0000156	.0000227
density	-.0030133	.0009502	-3.17	0.002	-.0048974	-.0011292
post may	-.0631874	.06265	-1.01	0.315	-.1874109	.061036
oil price	-.0046907	.0061854	-0.76	0.450	-.0169553	.0075738
weekend	.0770616	.4521618	0.17	0.865	-.8194917	.9736149
y2	.0928605	.0766572	1.21	0.228	-.0591366	.2448576
q2	.1575109	.0516375	3.05	0.003	.0551233	.2598985
summer	.3618449	.0674793	5.36	0.000	.228046	.4956438
q4	.1478448	.0824871	1.79	0.076	-.015712	.3114016
constant	6500269	5.512706	0.12	0.906	-10.28065	11.5807
sigma u	1.3177962					
sigma e	.41907857					
rho	.90815521					
R-sq.:						
• **Within**	0.0945					
• **Between**	0.5614					
• **Overall**	0.4069					
Number of observations:	848					

Appendix 3: Output of difference-in-difference regression with road fatalities (in logs) as dependent variable (North-West)

lnfatalities	Coefficient	Robust Std. Err.	t	P>t	[95%	Confidence Interval]
entry	.0536163	.134512	0.40	0.694	-.2240029	.3312355
population	-.0000142	.0000211	-0.67	0.506	-.0000577	.0000293
density	-.0243636	.0230863	-1.06	0.302	-.0720114	.0232841
post may	.0475442	.1438274	0.33	0.744	-.2493009	.3443894
oil price	-.000056	.0117715	-0.00	0.996	-.0243512	.0242391
weekend	2.204511	.9656015	2.28	0.032	.2116074	4.197414
y2	.020944	.1352887	0.15	0.878	-.2582781	.3001662
q2	.0343339	.0860612	0.40	0.693	-.1432876	.2119555
summer	.2471309	.1346423	1.84	0.079	-.0307572	.525019
q4	.0450411	.1580049	0.29	0.778	-.2810649	.3711471
constant	19.90569	12.9914	1.53	0.139	-6.907233	46.71861
sigma u	21.559747					
sigma e	.42947031					
rho	.99960335					
R-sq.:						
• **Within**	0.1224					
• **Between**	0.4325					
• **Overall**	0.3121					
Number of observations:	200					

Appendix 4: Output of difference-in-difference regression with road fatalities (in logs) as dependent variable (North-East)

lnfatalities	**Coefficient**	**Robust Std. Err.**	**t**	**P>t**	**[95%**	**Confidence Interval]**
entry	.1654096	.1171477	1.41	0.173	-.0782125	.4090316
population	.0000244	.0000412	0.59	0.561	-.0000613	.0001101
density	.0298779	.0724904	0.41	0.684	-.1208742	.18063
post may	-.2374769	.1273314	-1.87	0.076	-.5022771	.0273234
oil price	.007753	.010282	0.75	0.459	-.0136296	.0291355
weekend	.3584445	.951596	0.38	0.710	-1.620508	2.337397
y2	.0227498	.1431636	0.16	0.875	-.2749751	.3204747
q2	.0700091	.0894132	0.78	0.442	-.1159358	.2559541
summer	.2927118	.1458022	2.01	0.058	-.0105004	.595924
q4	.0261605	.127223	0.21	0.839	-.2384143	.2907353
constant	-18.96776	17.11282	-1.11	0.280	-54.55581	16.6203
sigma u	9.4696134					
sigma e	.37475739					
rho	.99843629					
R-sq.:						
• **Within**	0.1171					
• **Between**	0.2684					
• **Overall**	0.1849					
Number of observations:	176					

Appendix 5: Output of difference-in-difference regression with road fatalities (in logs) as dependent variable (Centre)

lnfatalities	**Coefficient**	**Robust Std. Err.**	**t**	**P>t**	**[95%**	**Confidence Interval]**
entry	.2762821	.1470214	1.88	0.074	-.0294657	.5820299
population	-.00002	.0000147	-1.36	0.188	-.0000507	.0000106
density	.0424444	.041414	1.02	0.317	-.0436806	.1285695
post may	-.0522701	.154731	-0.34	0.739	-.3740508	.2695105
oil price	-.000204	.0141217	-0.01	0.989	-.0295718	.0291637
weekend	-.928224	1.05144	-0.88	0.387	-3.114813	1.258365
y2	.0179662	.1258088	0.14	0.888	-.2436675	.2796
q2	.0848086	.1349364	0.63	0.536	-.1958071	.3654242
summer	.2511145	.133221	1.88	0.073	-.0259337	.5281628
q4	.0431504	.1784217	0.24	0.811	-.3278978	.4141986
constant	3.701873	7.987	0.46	0.648	-12.908	20.31175
sigma u	13.657787					
sigma e	.45384238					
rho	.99889701					
R-sq.:						
• **Within**	0.1181					
• **Between**	0.7024					
• **Overall**	0.4740					
Number of observations:	176					

Appendix 6: Output of difference-in-difference regression with road fatalities (in logs) as dependent variable (South)

lnfatalities	Coefficient	Robust Std. Err.	t	P>t	[95%	Confidence Interval]
entry	-.2991154	.1288141	-2.32	0.029	-.5655876	-.0326432
population	-.0000559	.0000888	-0.63	0.535	-.0002396	.0001277
density	.0819526	.0885986	0.92	0.365	-.1013276	.2652329
post may	.0541836	.1333287	0.41	0.688	-.2216278	.329995
oil price	-.0338782	.0127078	-2.67	0.014	-.0601664	-.00759
weekend	-1.232324	.6969825	-1.77	0.090	-2.674142	.2094941
y2	.3192442	.2119006	1.51	0.146	-.1191056	.757594
q2	.4042344	.101084	4.00	0.001	.1951263	.6133426
summer	.5795952	.140567	4.12	0.000	.2888102	.8703803
q4	.4508959	.1836427	2.46	0.022	.071002	.8307898
constant	13.93289	34.66067	0.40	0.691	-57.76818	85.63395
sigma u	17.466794					
sigma e	.41208241					
rho	.99944371					
R-sq.:						
• **Within**	0.1806					
• **Between**	0.0770					
• **Overall**	0.0528					
Number of observations:	192					

Appendix 7: Output of difference-in-difference regression with road fatalities (in logs) as dependent variable (Insular)

lnfatalities	Coefficient	Robust Std. Err.	t	P>t	[95%	Confidence Interval]
entry	.0344645	.1505925	0.23	0.823	-.2936483	.3625774
population	-.0000218	.0000637	-0.34	0.738	-.0001607	.0001171
density	-.0025049	.0009027	-2.77	0.017	-.0044716	-.0005381
post may	-.2034665	.2049978	-0.99	0.341	-.6501182	.2431853
oil price	.0158997	.0178846	0.89	0.391	-.0230675	.054867
weekend	.5853291	.9270098	0.63	0.540	-1.434452	2.60511
y2	-.0934194	.2763303	-0.34	0.741	-.6954914	.5086526
q2	.2051305	.1266299	1.62	0.131	-.0707722	.4810333
summer	.486809	.2253353	2.16	0.052	-.0041544	.9777724
q4	.0994202	.2627421	0.38	0.712	-.4730456	.6718859
constant	12.38681	32.66901	0.38	0.711	-58.79285	83.56646
sigma u	8.2909313					
sigma e	.4127938					
rho	.99752723					
R-sq.:						
• **Within**	0.2340					
• **Between**	0.7256					
• **Overall**	0.4237					
Number of observations:	104					

Appendix 8: Output of difference-in-difference regression with the number of road accidents (in logs) as dependent variable (All provinces)

lnaccidents	Coefficient	Robust Std. Err.	t	P>t	[95%	Confidence Interval]
entry	-.0090782	.0170677	-0.53	0.596	-.0429203	.0247638
population	-7.42e-07	1.71e-06	-0.43	0.665	-4.14e-06	2.65e-06
density	-.0021079	.00129	-1.63	0.105	-.0046657	.00045
post may	-.0030391	.0142572	-0.21	0.832	-.0313086	.0252304
oil price	-.0044442	.0014668	-3.03	0.003	-.0073526	-.0015358
weekend	.0414608	.1349638	0.31	0.759	-.2261475	.3090691
y2	.0362297	.0169749	2.13	0.035	.0025717	.0698877
q2	.2244187	.0153695	14.60	0.000	.1939439	.2548935
summer	.2605328	.0208326	12.51	0.000	.2192256	.3018401
q4	.1759086	.0192586	9.13	0.000	.1377224	.2140949
constant	6.594106	.8907114	7.40	0.000	4.82799	8.360222
sigma u	1.8409058					
sigma e	.1154053					
rho	.99608542					
R-sq.:						
• **Within**	0.4362					
• **Between**	0.4363					
• **Overall**	0.4103					
Number of observations:	848					

Appendix 9: Output of difference-in-difference regression with the number of road accidents (in logs) as dependent variable (North-West)

lnaccidents	**Coefficient**	**Robust Std. Err.**	**t**	**P>t**	**[95%**	**Confidence Interval]**
entry	-.0071143	.0364952	-0.19	0.847	-.0824368	.0682082
population	4.77e-06	3.59e-06	1.33	0.197	-2.65e-06	.0000122
density	-.0123328	.0059432	-2.08	0.049	-.0245989	-.0000667
post may	-.0154132	.0284728	-0.54	0.593	-.0741783	.0433518
oil price	-.0018156	.0031676	-0.57	0.572	-.0083532	.004722
weekend	.576829	.2788666	2.07	0.050	.0012766	1.152381
y2	.0251141	.0418614	0.60	0.554	-.0612837	.1115119
q2	.2001032	.0245303	8.16	0.000	.1494751	.2507313
summer	.2013959	.0409594	4.92	0.000	.1168599	.2859318
q4	.165142	.0413738	3.99	0.001	.0797506	.2505334
constant	7.287025	1.276186	5.71	0.000	4.653107	9.920944
sigma u	5.4627669					
sigma e	.11043617					
rho	.99959147					
R-sq.:						
• **Within**	0.3905					
• **Between**	0.0508					
• **Overall**	0.0493					
Number of observations:	200					

Appendix 10: Output of difference-in-difference regression with the number of road accidents (in logs) as dependent variable (North-East)

lnaccidents	Coefficient	Robust Std. Err.	t	P>t	[95%	Confidence Interval]
entry	-.0282829	.0327142	-0.86	0.397	-.0963158	.03975
population	3.92e-06	7.71e-06	0.51	0.617	-.0000121	.0000199
density	.0048069	.0132441	0.36	0.720	-.0227357	.0323496
post may	.0037483	.0241383	0.16	0.878	-.0464501	.0539467
oil price	-.0002529	.0033543	-0.08	0.941	-.0072286	.0067228
weekend	.2777674	.3149876	0.88	0.388	-.377285	.9328199
y2	.0092622	.0370817	0.25	0.805	-.0678533	.0863777
q2	.2634049	.0360068	7.32	0.000	.1885246	.3382851
summer	.2722101	.0541968	5.02	0.000	.1595016	.3849186
q4	.1653112	.0417822	3.96	0.001	.0784203	.2522021
constant	2.363228	3.850451	0.61	0.546	-5.644223	10.37068
sigma u	1.2181958					
sigma e	.10367062					
rho	.99280976					
R-sq.:						
• **Within**	0.5769					
• **Between**	0.4922					
• **Overall**	0.4794					
Number of observations:	176					

Appendix 11: Output of difference-in-difference regression with the number of road accidents (in logs) as dependent variable (Centre)

lnaccidents	**Coefficient**	**Robust Std. Err.**	**t**	**P>t**	**[95%**	**Confidence Interval]**
entry	.0249002	.0327606	0.76	0.456	-.0432293	.0930296
population	-2.25e-06	2.29e-06	-0.98	0.338	-7.01e-06	2.52e-06
density	-.0003379	.0085686	-0.04	0.969	-.0181573	.0174814
post may	-.0389085	.0346624	-1.12	0.274	-.110993	.0331759
oil price	-.0066161	.0026759	-2.47	0.022	-.0121808	-.0010513
weekend	-.0829905	.308482	-0.27	0.791	-.7245139	.5585329
y2	.0543899	.0288871	1.88	0.074	-.0056841	.1144639
q2	.2576961	.0241195	10.68	0.000	.2075369	.3078554
summer	.3149085	.0441893	7.13	0.000	.2230119	.4068051
q4	.2498589	.033497	7.46	0.000	.1801981	.3195196
constant	7.103961	1.186755	5.99	0.000	4.635969	9.571953
sigma u	2.7026324					
sigma e	.1126211					
rho	.99826655					
R-sq.:						
• **Within**	0.5313					
• **Between**	0.7042					
• **Overall**	0.6648					
Number of observations:	176					

Appendix 12: Output of difference-in-difference regression with the number of road accidents (in logs) as dependent variable (South)

lnaccidents	**Coefficient**	**Robust Std. Err.**	**t**	**P>t**	**[95%**	**Confidence Interval]**
entry	-.0575547	.0303107	-1.90	0.070	-.1202572	.0051478
population	-.0000385	.0000143	-2.70	0.013	-.0000679	-8.98e-06
density	.0326501	.0156674	2.08	0.048	.0002397	.0650605
post may	.0502278	.0289047	1.74	0.096	-.009566	.1100216
oil price	-.0091982	.003785	-2.43	0.023	-.0170281	-.0013683
weekend	-.1273226	.2519786	-0.51	0.618	-.64858	.3939348
y2	.0011909	.0391699	0.03	0.976	-.0798383	.08222
q2	.249384	.0360063	6.93	0.000	.1748994	.3238687
summer	.3134035	.0422455	7.42	0.000	.226012	.400795
q4	.1993884	.0484797	4.11	0.000	.0991004	.2996763
constant	19.28179	5.564652	3.47	0.002	7.770428	30.79315

sigma u	11.473261
sigma e	.10997088
rho	.99990814
R-sq.:	
• **Within**	0.5490
• **Between**	0.7643
• **Overall**	0.7395
Number of observations:	192

Appendix 13: Output of difference-in-difference regression with the number of road accidents (in logs) as dependent variable (Insular)

lnaccidents	Coefficient	Robust Std. Err.	t	P>t	[95%	Confidence Interval]
entry	-.0097141	.0845297	-0.11	0.910	-.1938884	.1744603
population	.0000136	.0000201	0.68	0.511	-.0000302	.0000575
density	-.0022598	.0010585	-2.14	0.054	-.004566	.0000463
post may	-.004392	.0640015	-0.07	0.946	-.1438393	.1350554
oil price	-.0036859	.0033968	-1.09	0.299	-.0110869	.003715
weekend	.1258106	.2634615	0.48	0.642	-.4482227	.6998439
y2	.109887	.0542123	2.03	0.065	-.0082314	.2280054
q2	.1133983	.0595776	1.90	0.081	-.0164103	.2432068
summer	.1566645	.0591622	2.65	0.021	.0277612	.2855679
q4	.0434009	.0472188	0.92	0.376	-.05948	.1462817
constant	-1.423893	10.43465	-0.14	0.894	-24.15904	21.31125
sigma u	3.8578297					
sigma e	.13738722					
rho	.99873335					
R-sq.:						
• **Within**	0.3049					
• **Between**	0.7651					
• **Overall**	0.7464					
Number of observations:	104					

Appendix 14: Output of difference-in-difference regression with the number of injured people (in logs) as dependent variable (All provinces)

lninjured	**Coefficient**	**Robust Std. Err.**	**t**	**P>t**	**[95%**	**Confidence Interval]**
entry	-.0113078	.0173183	-0.65	0.515	-.0456467	.0230311
population	3.81e-07	1.83e-06	0.21	0.836	-3.25e-06	4.01e-06
density	-.0025353	.0013988	-1.81	0.073	-.0053089	.0002382
post may	.0006156	.0149766	0.04	0.967	-.0290802	.0303115
oil price	-.0057877	.0015252	-3.79	0.000	-.008812	-.0027635
weekend	.1495718	.1494887	1.00	0.319	-.1468367	.4459803
y2	.0412209	.0181655	2.27	0.025	.005202	.0772397
q2	.2167632	.0158723	13.66	0.000	.1852914	.2482349
summer	.2564	.0212877	12.04	0.000	.2141904	.2986096
q4	.1747571	.0217821	8.02	0.000	.1315672	.2179469
constant	6.460174	.9718573	6.65	0.000	4.533161	8.387188
sigma u	1.3813409					
sigma e	.12070158					
rho	.99242259					
R-sq.:						
• **Within**	0.4062					
• **Between**	0.1308					
• **Overall**	0.1169					
Number of observations:	848					

Appendix 15: Output of difference-in-difference regression with the number of injured people (in logs) as dependent variable (North-West)

lninjured	**Coefficient**	**Robust Std. Err.**	**t**	**P>t**	**[95%**	**Confidence Interval]**
entry	.0064613	.0336974	0.19	0.850	-.0630866	.0760093
population	1.11e-06	4.15e-06	0.27	0.792	-7.46e-06	9.68e-06
density	-.0100361	.006347	-1.58	0.127	-.0231357	.0030635
post may	-.0087889	.0331272	-0.27	0.793	-.0771601	.0595823
oil price	-.0028078	.0033942	-0.83	0.416	-.009813	.0041974
weekend	.7385293	.2918104	2.53	0.018	.1362622	1.340796
y2	.0278892	.0431957	0.65	0.525	-.0612623	.1170408
q2	.1822756	.0273593	6.66	0.000	.1258088	.2387424
summer	.186054	.0461198	4.03	0.000	.0908674	.2812406
q4	.1466132	.0471098	3.11	0.005	.0493834	.243843
constant	9.07001	1.363614	6.65	0.000	6.25565	11.88437
sigma u	5.4930496					
sigma e	.12011524					
rho	.99952207					
R-sq.:						
• **Within**	0.3267					
• **Between**	0.2836					
• **Overall**	0.2768					
Number of observations:	200					

Appendix 16: Output of difference-in-difference regression with the number of injured people (in logs) as dependent variable (North-East)

lninjured	**Coefficient**	**Robust Std. Err.**	**t**	**P>t**	**[95%**	**Confidence Interval]**
entry	-.0300363	.0305559	-0.98	0.337	-.0935807	.0335082
population	6.61e-06	6.40e-06	1.03	0.314	-6.70e-06	.0000199
density	-.0018568	.0107449	-0.17	0.864	-.0242021	.0204886
post may	.0122173	.023644	0.52	0.611	-.036953	.0613877
oil price	-.0014181	.00327	-0.43	0.669	-.0082184	.0053822
weekend	.361545	.2966426	1.22	0.236	-.255357	.9784469
y2	.0133495	.036951	0.36	0.722	-.0634942	.0901932
q2	.258437	.0347824	7.43	0.000	.1861031	.330771
summer	.28071	.0545763	5.14	0.000	.1672124	.3942077
q4	.1703449	.0428202	3.98	0.001	.0812954	.2593943
constant	2.968886	3.151367	0.94	0.357	-3.58474	9.522512
sigma u	1.3420288					
sigma e	.10402154					
rho	.99402798					
R-sq.:						
• **Within**	0.5805					
• **Between**	0.7449					
• **Overall**	0.7172					
Number of observations:	176					

Appendix 17: Output of difference-in-difference regression with the number of injured people (in logs) as dependent variable (Centre)

lninjured	**Coefficient**	**Robust Std. Err.**	**t**	**P>t**	**[95%**	**Confidence Interval]**
entry	.0113486	.035761	0.32	0.754	-.0630206	.0857177
population	-3.53e-06	2.83e-06	-1.25	0.226	-9.41e-06	2.35e-06
density	.0067321	.0105987	0.64	0.532	-.0153092	.0287733
post may	-.041067	.0362407	-1.13	0.270	-.1164338	.0342997
oil price	-.0084971	.0028771	-2.95	0.008	-.0144803	-.0025139
weekend	.0948541	.31766	0.30	0.768	-.5657559	.7554642
y2	.0687723	.0315374	2.18	0.041	.0031867	.1343578
q2	.2580234	.0263605	9.79	0.000	.2032038	.3128431
summer	.3191812	.0461589	6.91	0.000	.2231886	.4151738
q4	.2579769	.0411615	6.27	0.000	.1723769	.343577
constant	6.626697	1.325089	5.00	0.000	3.871025	9.38237
sigma u	2.9773909					
sigma e	.11534693					
rho	.99850139					
R-sq.:						
• **Within**	0.5090					
• **Between**	0.5655					
• **Overall**	0.5334					
Number of observations:	176					

Appendix 18: Output of difference-in-difference regression with the number of injured people (in logs) as dependent variable (South)

lninjured	**Coefficient**	**Robust Std. Err.**	**t**	**P>t**	**[95%**	**Confidence Interval]**
entry	-.0599873	.0268738	-2.23	0.036	-.11558	-.0043946
population	-.0000256	.0000151	-1.69	0.104	-.0000569	5.71e-06
density	.016276	.0146424	1.11	0.278	-.0140141	.0465661
post may	.0594402	.0312085	1.90	0.069	-.0051194	.1239999
oil price	-.012943	.0035209	-3.68	0.001	-.0202264	-.0056595
weekend	.0231191	.3018141	0.08	0.940	-.601231	.6474691
y2	.0151656	.0398406	0.38	0.707	-.0672509	.0975822
q2	.2474012	.0290519	8.52	0.000	.1873029	.3074996
summer	.2991192	.0364744	8.20	0.000	.2236661	.3745723
q4	.2201699	.0422115	5.22	0.000	.1328489	.307491
constant	16.70592	5.790213	2.89	0.008	4.727954	28.68389
sigma u	9.5597304					
sigma e	.11787349					
rho	.99984799					
R-sq.:						
• **Within**	0.5012					
• **Between**	0.7912					
• **Overall**	0.7638					
Number of observations:	192					

Appendix 19: Output of difference-in-difference regression with the number of injured people (in logs) as dependent variable (Insular)

lninjured	**Coefficient**	**Robust Std. Err.**	**t**	**P>t**	**[95%**	**Confidence Interval]**
entry	-.0038902	.0969046	-0.04	0.969	-.2150271	.2072467
population	.0000192	.0000193	1.00	0.338	-.0000228	.0000612
density	-.0027906	.0011181	-2.50	0.028	-.0052266	-.0003545
post may	-.0223598	.0597566	-0.37	0.715	-.1525582	.1078386
oil price	-.000138	.0036412	-0.04	0.970	-.0080714	.0077954
weekend	.1057624	.2880985	0.37	0.720	-.5219504	.7334753
y2	.0922291	.0754219	1.22	0.245	-.072101	.2565593
q2	.0938839	.0703109	1.34	0.207	-.0593104	.2470782
summer	.1561561	.0600718	2.60	0.023	.025271	.2870412
q4	.0025202	.0705695	0.04	0.972	-.1512376	.1562779
constant	-3.922675	9.9852	-0.39	0.701	-25.67856	17.83321
sigma u	5.7929481					
sigma e	.14018843					
rho	.99941471					
R-sq.:						
• **Within**	0.3387					
• **Between**	0.7640					
• **Overall**	0.7413					
Number of observations:	104					

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