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The unexpected effects of daylight-saving time: Traffic accidents in Mexican municipalities

Los efectos inesperados del horario de verano: Accidentes de tránsito en municipios mexicanos

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Abstract

Objective: Several countries implement the daylight saving time (DST) policy for energy saving purposes. However, by artificially changing the distribution of daylight, this practice can have unforeseen effects. The objective of this work is to measure the impact of DST on road accidents in Mexico.
Methodology: Using hourly data, two empirical strategies are used: regression discontinuity (RDD) and difference-in-differences (DD).
Results: The main finding is that DST significantly reduces the total number of accidents in metropolitan areas. However, there are no clear effects on the number of fatal accidents.
Limitations/Implications: DST is implemented regardless of demand conditions and the economic cycle. Seasonal changes in prices and production can be difficult to capture before and after the time change. We introduce variables that mitigate the (potential) identification problem.
Originality: this is the only study measuring these effects in Mexico (and one of the few with data from emerging countries).
Conclusions: The DST is currently being discussed in Mexico, and our study offers a more comprehensive evaluation of the policy, not only from the standpoint of energy efficiency.

Keywords: traffic accidents, daylight saving time, difference-in-differences, regression discontinuity, municipalities in Mexico.
JEL classification: O18, R41, D04.

Resumen

Objetivo: Varios países implementan la política de horario de verano Daylight Saving Time (DST) a los fines de ahorrar energía. Sin embargo, al cambiarse artificialmente la distribución de la luz del día, esta práctica puede tener efectos imprevistos. El objetivo del trabajo es medir el impacto de DST sobre accidentes viales en México.
Metodología: utilizando datos por hora, se emplean dos estrategias empíricas: regresiones discontinuas (RDD) y diferencia en diferencias (DD).
Resultados: El principal hallazgo es que el DST reduce de forma significativa el número total de accidentes en las áreas metropolitanas. Sin embargo, no hay efectos claros sobre el número de accidentes fatales.
Limitaciones/implicaciones: como el DST se implementa independientemente de las condiciones de demanda y del ciclo económico, cambios estacionales en precios y producción pueden ser difíciles de capturar antes y después del cambio de horario. En ese sentido, se introducen variables que sirven para mitigar el potencial problema de identificación.
Originalidad/valor: el trabajo es el único en su tipo con datos de México y uno de los pocos para países emergentes.
Conclusiones: actualmente se discute la viabilidad del DST en México, este estudio permite una evaluación más integral de la política, no solo desde el punto de vista de ahorro energético.

Palabras clave: accidentes de tránsito, horario de verano, diferencias en diferencias, regresiones discontinuas, municipios de México.
Códigos JEL: O18, R41, D04.

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1. Introduction

One of the pioneer notions of DST was first proposed by Benjamin Franklin in 1784. He suggested that if people got out of bed earlier in the morning, they could better make use of natural morning light and cut down on candles; thus, saving tons of wax. Today, in a similar fashion, daylight-saving practice is used worldwide to cut down on electricity consumption. Almost two billion people in about 70 countries set their clocks forward in spring for the Summer Time (or DST) and back in the fall for Standard Time. The rationale remains the same: if daylight is transferred to the hours when light is needed the most, we will need less artificial light and save electricity. However, empirical evidence on whether DST serves to cut down on our consumption of electricity is mixed, as there are cases of a slight increase in consumption, although, at times, there is a decrease in the daily peaks of power used –see, for example, Kellogg and Wolff (2008), Kotchen and Grant (2011), and Hancevic and Margulis (2018), among other relevant studies.

Aside from its effects on power consumption, an indirect effect of the shift to DST is the impact on traffic accidents. Three relevant articles support this logic. Sood and Ghosh (2007) find that until the 9th week after the transition, DST generates a 6-10% decrease in car accidents, and 8-11% decrease in traffic accidents involving pedestrians. Franco et al. (2015) find evidence that DST reduces traffic accidents in Brazil by 10%. Finally, Smith (2016) finds that DST causes a 6.4% increase in fatal traffic accidents in the United States during the first few weeks after the transition. However, due to the lack of consensus as to the direction and the magnitude of the effects, it is unclear whether these findings can be extrapolated to other contexts. The purpose of this work is precisely to address this concern for the Mexican case. Concretely, we evaluate the effects of DST on traffic accidents in non-rural areas of Mexico. This study is conducted through an econometric approach using data on traffic accidents from 2010 to 2016.

This study is especially pertinent in light of President Lopez Obrador's proposal for eliminating DST. In the coming weeks, the congress will therefore evaluate the policy's future. However, for a more comprehensive evaluation of a policy, other elements should be added to the analysis, even though the focus of the political discussion is on (the lack of) energy savings. The present study contributes to this goal by providing empirical evidence of the effect of DST on road accidents. The estimated total cost associated with road accidents in Mexico ranges between 0.8% and 2.6% of GDP, highlighting their economic significance. Therefore, significant increases or decreases in the number and severity of accidents may be very important factors to consider.

Two aspects are highlighted in our empirical approximation of the problem. On the one hand, the nature of the dataset used allows for measuring the effects of each hour in some detail. On the other hand, the differential manner in which DST has been applied throughout Mexico in past years makes it possible to apply different econometric estimation methods. Specifically, two identification strategies are used to find the results. First, the discrete nature of the shift to DST is exploited and a regression-discontinuity (RD) model is estimated. This allows for comparing traffic accidents hours before and after the time change. Secondly, the variation generated by a natural experiment that modified implementation of DST in the state of Quintana Roo serves to estimate a model of differences-in-differences (DID). This allows for comparing cities that observe DST to others on standard time and controlling for observable factors.

The main finding in this study is that DST decreases the number of non-fatal traffic accidents during the first week of implementation in metropolitan areas across the country. The exception is the Yucatan peninsula, where the application of DST does not seem to have a clear effect on accidents. With regards to fatal traffic accidents, there is no evidence of a significant effect (either positive or negative) of DST on the number of deaths.

The remainder of this paper proceeds as follows. Section 2 goes over the literature available on DST and effects thereof. Section 3 goes into detail on the matter as it applies to Mexico. Section 4 describes the dataset used for estimations. Section 5 explains the identification strategies for the quantitative analysis. Section 6 shows the results of the estimations. Finally, Section 7 sets forth a conclusion and offers a brief discussion on the implications of public policy on the results.

2. Prior Literature

2.1. Electricity consumption

The main justification for the shift to DST is power saving. The logic behind this is that with DST, mornings are darker and natural light during the afternoon lasts longer (as compared with Standard Time), and therefore, use of electricity can be expected to increase in the mornings (due to the lack of natural light) and accordingly, to decrease in the late afternoon and evenings. Based on this, there will be savings if the increase in the consumption of electrical power in the morning hours is below the decrease in consumption in the evenings. However, the following three notable articles analyze the hypothesis, and their conclusions are contrary to mainstream logic. First, based on a natural experiment conducted in Indiana, US, Kotchen & Grant (2011) conclude that DST increases the consumption of electrical power and generates an additional cost of nine million US dollars for consumers. Second, Kellog & Wolf (2008) examine DST in Australia following an exogenous change resulting from the Olympic games and finds that the time change makes no significant difference in the consumption of electricity. Lastly, Hancevic & Margulis (2018) used Argentina's differential practice of DST and found that it generates an average increase of 0.4-0.6% in the consumption of electricity, although it reduces peaks in daily demand.[1]

2.2. Traffic accidents

The collateral effects of the DST policy have taken on importance in the literature. Regarding traffic accidents, there are two aspects involving the DST policy which could affect the number and gravity of accidents. Firstly, evidence shows that with the shift to DST, people lose an average of 60 minutes of sleep, thus reducing sleep efficiency by 10% (Lahti, Leppamaki, Lonnqvist, & Partonen, 2006). As a result, the shift to DST increases the number of somewhat sleep-deprived drivers and could reduce their reaction time, thus giving rise to the number of accidents. Secondly, DST transfers natural light to the afternoon, cutting down on natural light during the mornings. Visibility is a significant factor in road traffic accidents. If daylight is transferred to peak traffic hours, visibility for a large number of motorists would be increased and therefore, the likelihood of traffic accidents occurring would decrease. The opposite is true if peak traffic hours received less daylight.

Many articles have attempted to prove this connection empirically, but no consensus has been reached on the matter. Firstly, some studies relate DST to a decrease in traffic accidents. Ferguson et al. (1995) is one of the pioneers of this literature. They use simple linear regression models to conclude that DST brings with it a reduction in traffic accidents; suggest that if DST had been practiced year-round (from 1987 to 1991),

1 Many other articles have also examined this hypothesis (Awad Momani, Yatim, & Ali, 2009; Fong, Matsumoto, Lun, & Kimura, 2007; Hill, Desobry, Garnsey, & Chong, 2010; Karasu, 2010; Mirza & Bergland, 2011; Rock, 1997). The three articles above were chosen for their robust methodology.

there would have been 180 fewer fatal accidents in the US. Using a negative binomial regression model and US data, Coate & Markowitz (2004) found that practicing DST year-round would reduce the number of traffic fatalities by 366 (annually). Using UK data, Whittaker (1996) found that DST (British Summer Time or BST) is also related to a decrease in traffic accidents and that adoption of DST year-round would have positive effects on these figures.

Secondly, some other articles reach the opposite conclusion. Coren (1996) studied this connection in Canada and concluded that the switch to DST is correlated to an increase in traffic accidents. Lastly, Hicks et al. (1998) finds that the switch to DST increases the number of fatal accidents involving drunk drivers in New Mexico, US.

However, most of these articles are plagued by methodological complications. On the one hand, since many of these studies are based on unconditional mean differences, it is difficult to tell whether the differences in traffic accidents are driven by the time change or by some other variable. On the other hand, articles using simple linear regression models could be controlled by other variables and reduce the first problem; however, they involve no control group (a group that does not practice DST) against which to compare the treatment group. Without this control group, the assumptions required to estimate an effect between DST and traffic accidents are not easily met. Smith (2016), Neeraj & Arkadipta (2007) and Franco, Sampiao, Sampiao, & T. Machado (2015) resolve these two problems using impact evaluation methods, as well as RD and DID models. Smith (2016) resolve them by estimating an RD model, controlled by observable variables. Their main finding is that fatal traffic accidents increase 5.4 to 7.6% in the weeks following the switch to DST, whereas there is no effect following the switch back to Standard Time. Their results suggest that the cost of this policy in the US reached 2.75 billion dollars (for the 2002-2011 period). Franco, R. Sampiao, Sampaio, & T. Machado (2015), using an RD method and a DID model, concluded that DST seems to reduce traffic accidents by 10%. Lastly, using a natural experiment conducted in 1986, Neeraj & Arkadipta (2007) estimate a DID model that suggests that traffic accidents show no significant decrease in the short term, but that in the long term (up to nine weeks after the shift), accidents involving pedestrians decrease 8-11% and overall traffic accidents decrease by 6-10%.

2.3. Other effects of the DST policy

Aside from the secondary effect on traffic accidents, there is evidence that DST generates other issues. One collateral effect that stands out is the decrease in criminal activity. Doleac & Sanders (2015) analyze his phenomenon, using US data. The study suggests that, in the early days of a switch to DST, there is a 7% decrease in criminal activity. Doleac & Sanders (2015) attribute this result to the change in daylight allocation under DST. Another relevant effect of the time change is the change in suicide rates. Berk. et al. (2008) study this connection using information from Australia and find that the suicide rate in men increases shortly after the shift to DST. Additionally, Toro, Tigre, & Sampaio (2015) use a regression discontinuity design to show that, days after the shift to DST, there is a 7.4-8.5% increase in heart attack cases in Brazil. Lastly, there is further evidence of repercussions from DST on the financial system. Worthington (2003), using data from Australia, and Kamstra et al. (2000), with data from Canada, the US, Great Britain and Germany, conclude that returns on shares are lower on the weekend after the shift to DST, whereas the opposite is observed with respect to the shift back to standard time.

3. The Mexican Case

3.1 DST in Mexico

Mexico began implementing DST regularly in 1996. One of the most important reasons for adopting DST was to avoid the time disparity between Mexico and the US.[2] Sharing the same time allows for avoiding misalignment in the times of financial operations and international flights.

Since 1996, most towns and cities in Mexico have adopted DST consistently. In Mexico, DST begins on the first Sunday in April (clocks are moved forward from 02:00 A.M. to 03:00 A.M.), ending on the last Sunday in October (clocks are moved back from 02:00 A.M. to 1:00 A.M). However, there are two exceptions to this rule:

- Two states (Sonora and Quintana Roo) do not observe DST for reasons unrelated to traffic accidents. Sonora abandoned DST in 1998 to keep up with Arizona time, as its neighbor does not observe DST. Quintana Roo, on the other hand, observed DST for the last time in February 2015 to be in sync with tourist destinations in the Caribbean. We use this second natural experiment to estimate the impact of the time change on traffic accidents.
- Some municipalities across the border with the US observe a different DST (Border DST) from that of the rest of the country. These municipalities (which are no farther than 20 kilometers from the border) begin Border DST on the second Sunday of March (clocks are moved forward from 02:00 A.M. to 03:00 A.M.), ending on the first Sunday in November (clocks are moved back from 02:00 A.M. to 1:00 A.M)[3]. **Table 4** in Appendix A lists the municipalities that are subject to border DST.

2 The US has observed DST consistently since 1966.

3 The list of communities that implement Border DST is provided in Appendix A.

Figure 1 provides a summary of how DST is implemented in Mexico.

As this article was being written, President Andrés Manuel López Obrador had sent a proposal to Congress to eliminate summer time, arguing that 71% of citizens opposed it and only 0.16% of electricity had been saved during 2021, with no impact on family income.[4]

3.2. Mexico and traffic accidents

In 2016, traffic accidents were one of the top ten causes of death in the world; 1.4 million people died from traffic-accident injuries (World Health Organization, 2017). Although these deaths are concentrated in less developed economies, member countries of the Organization for Economic Co-operation and Development (OECD) continue to show a significant number of traffic-accident-related deaths. More precisely, in 2016, traffic-accident-related deaths in OECD member countries totaled 102,974 (World Health Organization, 2016). However, even among OECD members, there are substantial differences: the mortality rates (for every 100,000 inhabitants) related to traffic accidents range from 2.7 (Norway) to 13.1 (Mexico). Clearly, Mexico is in an alarming position: it is the country with the highest mortality rate (with respect to traffic accidents) among the OECD members. **Figure 2** reflects these statistics.

Figure 3 shows the trend of traffic accidents in Mexico. Despite the decrease in fatal and non-fatal accidents in past years, in 2018, the last year for which there is data, INEGI (Mexico's National Institute of Statistic and Geography) reported 381,553 traffic accidents and 4,226 deaths involved in traffic accidents in Mexico.[5] In addition to

4 This news can be read at https://www.elfinanciero.com.mx/nacional/2022/07/05/horario-de-verano-amlo-intento-eliminarlo-donde-era-jefe-de-gobierno-y-esto -step/

5 This number includes accidents on urban and rural zones but excludes accidents on federal roads.

the implicit damage they imply, these accidents increase the public health expense, can affect people's ability to work and contribute to family impoverishment. Therefore, it can be said that Mexico has a great public policy opportunity to reduce its traffic accidents, and those traffic accidents continue to be a relevant source of a public problem.

The Mexican Institute for Competitiveness (IMCO 2021) identifies and quantifies the social and economic costs of material damage, as well as deaths and injuries caused by traffic accidents in Mexico during 2018. Between 111 and 121 billion pesos correspond to human costs or non-material costs associated with the suffering, pain and sorrow of the victims of traffic events and their families; between 19 and 39 billion pesos to the losses of human capital caused by premature deaths or injuries of individuals of productive age (i.e., from 15 to 65 years); 41 billion pesos for material damage caused by road events; and, approximately 3 billion pesos to the expenses in medical attention for the individuals who suffered an injury. These costs represent between 0.78% and 0.92% of GDP.[6]

Analysis of the determining factors of traffic accidents in Mexico is thus relevant. Due to the high number of accidents and accident victims, a small disturbance increasing them could result in a large disaster. Specifically, given the evidence from other countries (Smith, 2016), DST could be a potential source of disaster. As shown in **Figure 4**, in the last few years, traffic accidents have gone up in DST with respect to standard time. Although this offers no conclusive evidence on the issue, it represents a motivation to obtain formal evidence. This study is the first to test this hypothesis for the Mexican case.

4. Data

The empirical analysis uses the historical statistics (2010-2016) on traffic accidents in Mexico, taken from the Land Traffic Accidents in Urban and Suburban Areas (ATUS) of the National Institute of Statistic and Geography (INEGI). Said statistics are generated through administrative records provided by each State and Municipality's Department of Motor Vehicles.[7] The information gathered indicates the time and day on which the accident occurred, the municipality where it occurred and the number of deaths involved in each event (National Institute of Statistics and Geography, 2015).

It should be borne in mind that the information obtained from INEGI could underrepresent the number of deaths related to traffic accidents. While the World Health Organization reported that Mexico had approximately 15,000 deaths related to traffic accidents in 2013, (World Health Organization, 2015), INEGI reported only 5,058. This difference is due to the following:

(1) INEGI data does not consider accidents taken place on federal roads. Therefore, it excludes accidents on roads under federal regulation in Mexico. The Department of Communications and Transport, along with the Mexican Institute of Transport, reported that in 2012, there were 24,085 traffic accidents on federal roads involving 4,548 deaths (INEGI reported 5,469)(Instituto Mexicano del Transporte & Secretaria de Comunicaciones y Transportes, 2014).

6 The Mexican Institute of Transportation (Instituto Mexicano de Transporte, 2020) uses a different methodology that implies a direct relationship between life and injury values and GDP per capita. Consequently, each deceased person is estimated to be worth 686,521 USD, while each non-deceased injured person is valued at 171,630 USD. According to this alternative methodology, the economic cost of road accidents in Mexico in 2018 was 2.63% of GDP.

7 For Mexico City, the government bodies that provide this information are the Municipal Courts and the Public Prosecutors' Offices.

(2) Because the information is taken from administrative records, some accidents might not have been reported because the respective authorities failed to arrive at the scene in time.
(3) People might have died in a traffic accident but were classified as injured because they were still living at the time the accident was reported.

All the information used in this study is organized at the municipality level. In order to isolate the effect of DST on traffic accidents and deaths, our empirical analysis controls for several factors related to weather conditions. Concretely, in the estimating equations, we include the solar radiation, precipitation, relative humidity, temperature, wind speed and barometric pressure data gathered by the National Meteorological System (NMS).[8] Because all these variables may be correlated with the number of traffic accidents and the shift to DST, they must be used as controls in the estimation.[9] The dependent variables are the number of traffic accidents and related deaths.

The DST is implemented independently of demand conditions and the general business cycle. Due to this, seasonal changes in prices and output are difficult to capture before and after DST changes. A qualitative assessment of the impact of DST application on accidents might be addressed using indicators regarding the state of accident/death related motor vehicle fleets, vehicle year, weight, usage, and wear and tear, among other factors. Unfortunately, most of these variables are not available, and when they are, they are at the year-state level and cannot be incorporated into our fixed effects regression models. Due to the hourly periodicity of our data, any other variable like the average population density of the municipality or the vehicle circulation per head would be absorbed in any regression discontinuity or diff-in-diffs specification.

8 Municipalities with no meteorological stations of their own were paired with the nearest station of a location at similar altitude.

9 The information from the National Meteorological System was chosen for its accuracy. The calculations to obtain the meteorological variables are conducted via electronic devices that are strategically spread across the country.

5. Empirical strategy

5.1. Regression discontinuity

For most municipalities in Mexico, clocks are moved forward one hour on the first Sunday in April (the second Sunday in March for municipalities having adopted the border DST); generating sharp discontinuity between standard time and DST. Prior to the second Sunday in March, the probability of any municipality being on DST is zero, after which, the probability becomes one. This interruption allows for estimating a sharp regression-discontinuity (RD) model. If this shift has a significant impact on traffic accidents, there should be a pronounced difference in the number of accidents occurred immediately after the shift.

In order to assess the impact of this transition on municipalities that observe Border DST (see **Figure 1**), we used the dataset from 2010 to 2016.[10] However, to estimate the impact of this transition on other municipalities (those not located along the border), only 2011, 2014 and 2016 dataset can be used, because, for the remaining years (2010, 2012, 2013, 2015), the shift to DST took place close to Easter (one of the most important vacation periods in Mexico).[11] Given the fact that the number of vehicles in circulation could increase during this vacation period (thus increa-

10 We only used the most recent years to support our external validity and be able to assume that the effects will be similar in the future.

11 For 2010 and 2015, the shift to DST takes place in mid vacation period; for 2012, DST begins the same day at the beginning of the vacation period and, for 2013, the vacation period ends the day DST begins.

sing the probability of accidents occurring), it is difficult to distinguish between the effect of the change in time and the vacation period. For 2011, 2014 and 2016, the vacation period and the shift to DST occurred at different points in time, due to which, the estimation is not as problematic.[12]

The specification of the RD systematic process is shown in equation 1:

$$Y_{i,t} = \beta_0+\beta_1\, HoursT_{i,t} + \beta_2 DST_{i,t} + \beta_3 HoursT_{i,t} \times DST_{i,t} + \beta_4\, X_{i,t} + \delta_i + \alpha_h + \theta_d + \propto_y + \varepsilon_{i,t} \quad (1)$$

where $Y_{i,t}$ measures accidents or related deaths in the municipality i and for the time t (i.e., time, day, month, and year). $HoursT_t$ represents the number of hours before and after the shift to DST. It takes the value of zero the first hour of DST in the year, positive values for the hours after the start of DST and negative for hours before the start of DST. $DST_{i,t}$ is a binary variable that takes on the value 1 if the observation is under DST and 0 if it is under standard time. The vector $X_{i,t}$ includes meteorological variables for the municipality i at time t: solar radiation, rainfall, relative humidity, temperature, wind speed, and barometric pressure. Figure 5 shows the weather control variables before and after daylight saving time. δ_i, α_h, θ_{dd} and $\propto_y$ are fixed effects per municipality, hour, day of the week, and year, respectively. The idiosyncratic error term is $\varepsilon_{i,t}$. The main coefficient of interest is β_2. It represents the change in the intercept of traffic accidents after the shift to DST. If β_2 is positive (negative), it would suggest that, on average, more (fewer) traffic accidents were caused because of the shift.

The RD design only uses municipalities in metropolitan areas and accidents taken place one week before and one week after the shift. This allows the groups to be as similar as possible. Specifically, our group and our treatment group consist of the last hours before (—168 > *HoursT* > 0) and after (168 < *HoursT* < 0) the time change, respectively (the number of hours equivalent to a week is 168). The period of time used (one week before and one week after) is the minimum necessary to allow for comparing each day of the week with its analog for the prior week (the first Monday of DST against the last Monday of Standard Time). Moreover, if the analysis were to use an additional week (i.e., two weeks before and after the shift), the groups would be farther from the day of the shift and would be closer to Easter vacation.

Table 1 compares the two groups' observable variables. The sample used excludes municipalities in the state of Sonora (which hasn't implemented DST since 1998). The first two columns compare the average of the observable variables one week before (Standard Time) and one week after the shift (DST). Although some differences between the groups are small, all differences (except for Wind Speed) are statistically significant at a 99% confidence level (measured with *T*-tests). This shows that the groups are (slightly) unbalanced and suggests that, to avoid problems with omitted variables, these variables must be controlled for in the estimation. Aside from the balance in observable variables, continuity before and after the shift must also be checked. Appendix B contains a graph of observable variables before and after the shift to DST. **Figure 5** averages the values of the overall statistical sample for each of the hours used in this analysis. Although we can observe trends in the time series, most of the control variables seem to be fairly continuous before and after the shift to DST.

5.2. Differences in Differences

The second method used to quantify the impact of DST on traffic accidents is justified by a natu-

12 The shift back to standard time is problematic for all the above years, as it overlaps the Day of the Dead, a Mexican holiday celebrated throughout the country. This explains why we do not estimate the effect of this shift.

ral experiment conducted in the Mexican Yucatan peninsula. For reasons exogenous to traffic accidents, on February 1, 2015, the state of Quintana Roo implemented DST for the last time, shifting from Standard Time to DST. Since then, all municipalities in Quintana Roo have remained under DST. This provides enough conditions to allow for cataloguing the shift in the law as a natural experiment and to estimate the impact of the shift using a DD model. More precisely, this model's treatment group is the 11 municipalities from the state of Quintana Roo, whereas the control group is made up of the municipalities of the nearby states of Tabasco, Campeche and Yucatán. These municipalities were selected for their geographic proximity to Quintana Roo (the treatment group). **Figure 6** sets out the sample.

For the DD model, the sample includes records of accidents from October 25, 2014, to April 4, 2015.[13] This sample period is in line with the conditions of a standard DD model. The control group remains without treatment (Standard Time) throughout the period, whereas the treatment group begins without being treated, but after February 1, the law is implemented and shifts to DST. Prior to October 25, 2014, and after April 4, 2015, all municipalities were in DST, due to which, it is only plausible to use the data for these dates. The specification of the DD model is as follows:

$$Y_{i,t} = \beta_0 + \beta_1\, Qroo_i + \beta_2 Feb2015_t + \beta_3 Feb2015 * Qroo_{i,t} + \beta_4 FirstW_t + \beta_5 FirstW * Qroo_{i,t} + \beta_j X_{i,t} + \delta_i + \theta_{da} + \varepsilon_{i,t} \quad (2)$$

where $Y_{i,t}$, again, is the outcome variable for the total number of accidents or deaths in municipality i and for time t (time, day, month, year). $Qroo_i$ equals 1 for all municipalities in Quintana Roo and is equal to zero otherwise. $Feb2015_t$ equals 0 for all days before February 1, 2015 (i.e., prior to implementing DST in Quintana Roo permanently) and equals 1 for subsequent days. $FirstW_t$ equals 1 for all hours in the first week of DST application and equals 0 otherwise. $X_{i,t}$ is again the vector of weather control variables for municipality i and for time t. Parameters δ_i and θ_{da} are fixed effects per municipality and day of the year. The coefficients of interest in this estimation are β_3 and β_5, which measure the effects of DST on traffic accidents for the entire period and the first week of implementation, respectively.

13 For robustness testing, we estimate the same models with different temporary windows.

Estimation results

6.1. Regression discontinuity

Table 2 presents the estimation results of RD models. The specifications use two dependent variables and three different samples. The two dependent variables used are the total number of traffic accidents and related deaths. The first sample used (models 1 and 2) contains all the municipalities that make up Mexico's metropolitan areas; the second (models 3 and 4) excludes the border municipalities that practice a different DST (Border DST), and the third contains only the border municipalities that practice Border DST.

On the one hand, through the three samples, the coefficient of $DST_{i,t}$ on traffic accidents is negative and statistically significant. This suggests that DST generates a decrease in traffic accidents in the first week of DST. Additionally, the coefficient on $HoursT_{i,t} \times DST_{i,t}$ is also negative and statistically significant for traffic accidents in two of the three models, that is to say that the trend after the shift changes its slope downwards, which results in an additional reduction of traffic accidents. **Figure 8** illustrates this effect graphically. As can be observed, there is a detectable change in the intercept (measured by the coefficient on $DST_{i,t}$). However, the change in the trend of accidents (measured by the coefficient on $HoursT_{i,t} \times DST_{i,t}$) is not as easy to visually identify. On the other hand, the DST coefficient on deaths is negative and not significant at the conventional levels, which suggests that DST only impacts non-fatal accidents. However, the coefficient $HoursT_{i,t} \times DST_{i,t}$ is negative and statistically significant for deaths in two of the three models, which suggests that the trend on deaths does change after the shift to DST. Figure 9 illustrates this case. Although the intercepts for the two clock times are different, they are statistically indistinguishable from each other (as can be observed in the overlapping confidence intervals).

Of course, there is a key assumption for the estimators in Table 2 to be consistent: that there are no unobservable differences that affect the outcome variable and DST. One possible unobservable difference between these two weeks could be the number of vehicles in circulation. Irrespective of the meteorological variables and the variation absorbed by fixed effects, there may very well be more vehicles in circulation prior to the shift to DST (in April). This, and not DST per se, could be the reason why the estimators detect a decrease in accidents the week after the shift. However, Model 5 in Table 2 only uses the municipalities that shift to DST at a different date (Border DST municipalities shift in March) and the negative effect is consistent with the other models. In fact, the magnitude of the coefficient in this model is twice as high as that of the other models in Table 2. This suggests that the coefficients of models 1-6 do represent a robust causal effect of DST on traffic accidents.

A possible concern with our empirical strategy could be due to the (relatively) excessive number of zeros in the dependent variable that may occur in certain municipalities that show no accidents at certain times of the day. To be sure that our results are robust and were not driven by the structure of the data, the six specifications of Table 2 were estimated using aggregated data at the day level instead of hourly data. This way the "zeros" problem disappears. The daily data estimation results are shown in Table 5 of Appendix B. The directions of the coefficients are consistent with the findings of models 1-6 and also statistically significant at the regular confidence levels. Hence, the alternative estimates of Table 5 provide robustness to the original OLS results from Table 2. In sum, there is no real need for using alternative estimation methods that contemplate the problem of excessive zeros in the context of count variables such as Zero-inflated Poisson or Negative Binomial regressions. The latter would complicate the application of the regression discontinuity approach without proportioning any clear advantage. In addition, one can easily justify the application of the treatment (DST) at the day level rather than at the hour since the policy was designed to affect the daily electricity consumption. With this idea in mind, the relevant estimation results are those presented in Table 5 of Appendix B, which were shown to not differ much from the hourly estimates in Table 2.

Lastly, for assurance that the results were not dependent on the number of hours before and after the shift that were used to perform the analysis, we replicated the results of models 1 and 2 of Table 2 with smaller temporary windows. The sensitivity analysis can be viewed in the following figures. Figure 9 shows the $DST_{i,t}$ coefficient for different regressions using different temporary samples: from 168 (7 days) to as few as 72 hours (3 days) before and after the shift. As can be observed from Panel A, the coefficient of $DST_{i,t}$ for traffic accidents remains negative and statistically significant at the 95% level for all samples, which suggests that the result is not sensible to the number of hours chosen before and after the shift. Panel B, consistent with the results from Table 2, shows that the coefficient for is not statistically significant at the 95% level across all samples, which again suggests that the results are robust. Similarly, Figure 10 shows how the coefficient from the interaction $HoursT_{i,t} \times DST_{i,t}$ varies across different samples. As it can be seen from both panels, this coefficient is only negative and statistically significant with larger samples, suggesting that it is a lot more sensible across specifications and, therefore, should be interpreted carefully.

In substantive terms, as per the coefficient of Model 1 in **Table 2**, the total effect of DST is a decrease in non-fatal traffic accidents of 2,759 in the week following the shift; that is, 1.1 daily accidents per municipality. Specifically, with 95% confidence, it can be stated that the total effect of DST, in the first week of implementation, ranges from a decrease of 1,607 to as many as 3,898 traffic accidents for all metropolitan areas in Mexico. However, if the effect of DST on traffic accidents continues to follow the same patterns as concerns all other municipalities in Mexico (those not forming part of the metropolitan area), the total effect could be even greater.

6.2. Difference-in-Differences

Table 3 provides the results of the DD models. Like **Table 2**, it shows results for traffic accidents and related deaths. Moreover, it presents results for two different samples: the first (models 1 and 2) uses the data pertaining to all municipalities in the Yucatan Peninsula (see **Figure 7**) and the second (models 3 and 4) only uses the municipalities of the Yucatan Peninsula that form part of a metropolitan area.

The coefficients of the four models are very small and are not statistically significant at the conventional level. The coefficients of interest (*Feb2015*Qroo* and *First*Qroo*) do not reflect an accurate impact of DST on traffic accidents, which suggests that DST had no significant impact on traffic accidents in the case of Quintana Roo. However, the coefficient of *First*Qroo* from column three is similar in size and sign from those from the RD models, although it is not statistically significant.

Moreover, one probable bias in the estimations shown in **Table 3** could be that Quintana Roo (the treatment group) was affected by some holidays in late 2014 (such as Thanksgiving, Christmas and New Year's), as well as Easter.[14] This could be the cause of an omitted variable that changes the results. As a remedy, we estimate the same models of **Table 3**, altering the monthly period: rather than starting on the October 24, 2014, and ending on April 4, 2015, it begins on January 16, 2015, and ends on March 20, 2015. However, the results of these estimations are not substantively different from those in **Table 3**, suggesting that the results are robust. These alternative results are shown in **Table 6** of **Appendix C**. Moreover, for assurance that the results were not dependent on the structure of the data, we ran the same regression for daily data. These results continue to be consistent. The results can be viewed in **Table 7** of **Appendix C**.

7. Conclusion

Approximately 1.8 billion people in the world move to DST every year. The main goal of this shift is to save electricity. However, there is no robust evidence that suggests that this actually happens and there are reasons to believe that the shift to DST is linked to other phenomena. One of said phenomena is a change in traffic accidents.

This study uses two quasi-experimental methods to estimate the effect of DST on traffic accidents in Mexico. The most relevant finding of this study is that the shift to DST does in fact generate a decrease in the number of traffic accidents in the first week after its implementation, except for the Yucatan Peninsula where DST generates no significant change in traffic accidents. In addition, there is no clear effect of DST on fatal accidents.

In sum, the desirability of the DST policy is debatable. It is difficult to defend its permanence as we are unsure as to whether the main objective is met. That is, it is not clear that this policy actually

14 This is due to the disproportionate number of tourists that visit Quintana Roo on those dates.

saves electricity. Moreover, it is not yet possible to generate a concrete recommendation in terms of public policy on DST, as there could be other collateral effects (which are equally relevant) that have not been discussed, such as the impact on health and crime. In order to be able to generate an optimal proposal, the above investigation should explore the most relevant consequences of DST and consider its pros and cons in broader sense.

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Figure 1.
Implementation of DST in Mexico

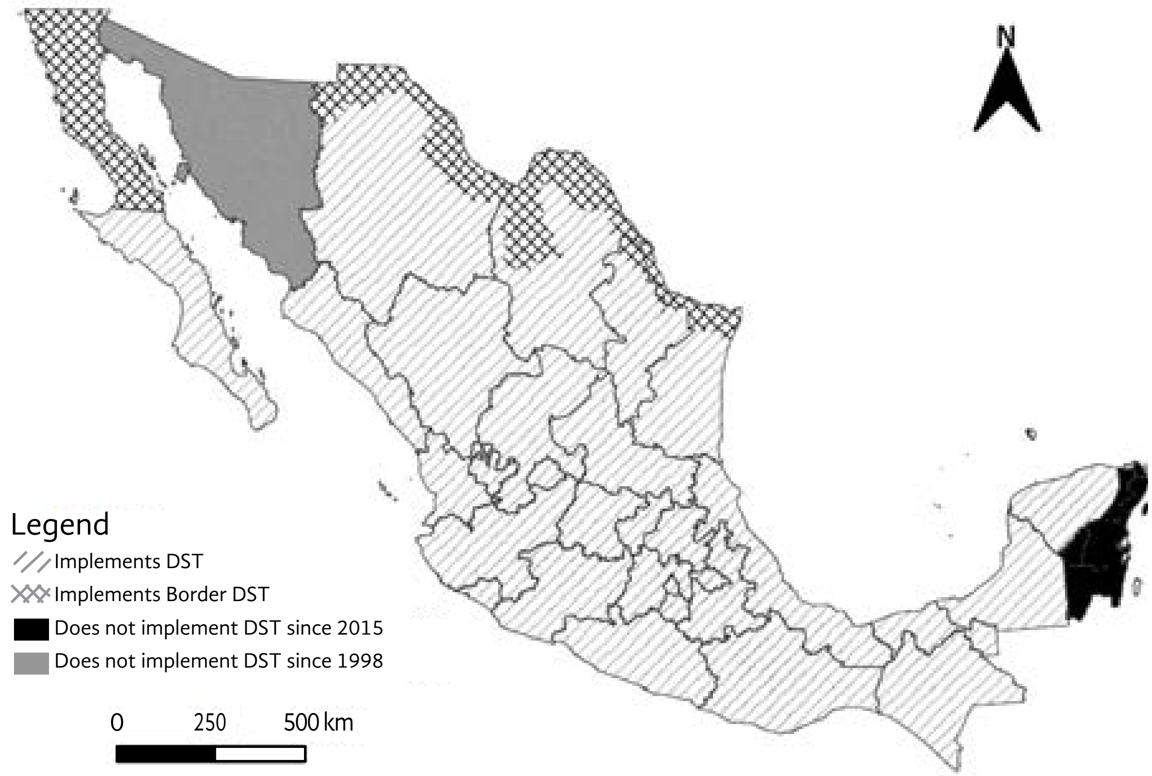

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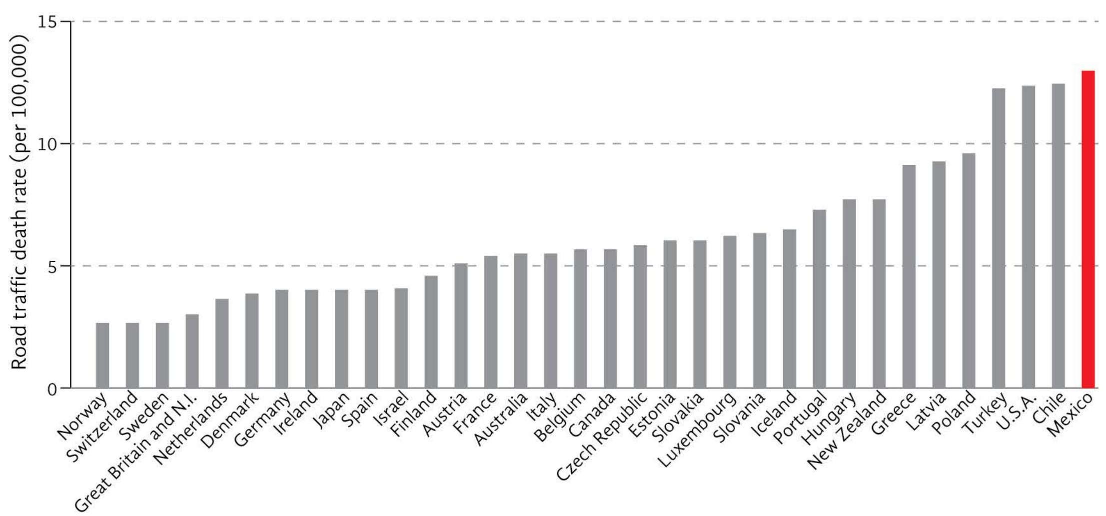
Figure 2.
Mortality caused by road traffic injury in OECD countries (2016)



Source: Global Health Observatory Data Repository. World Health Organization (WHO).

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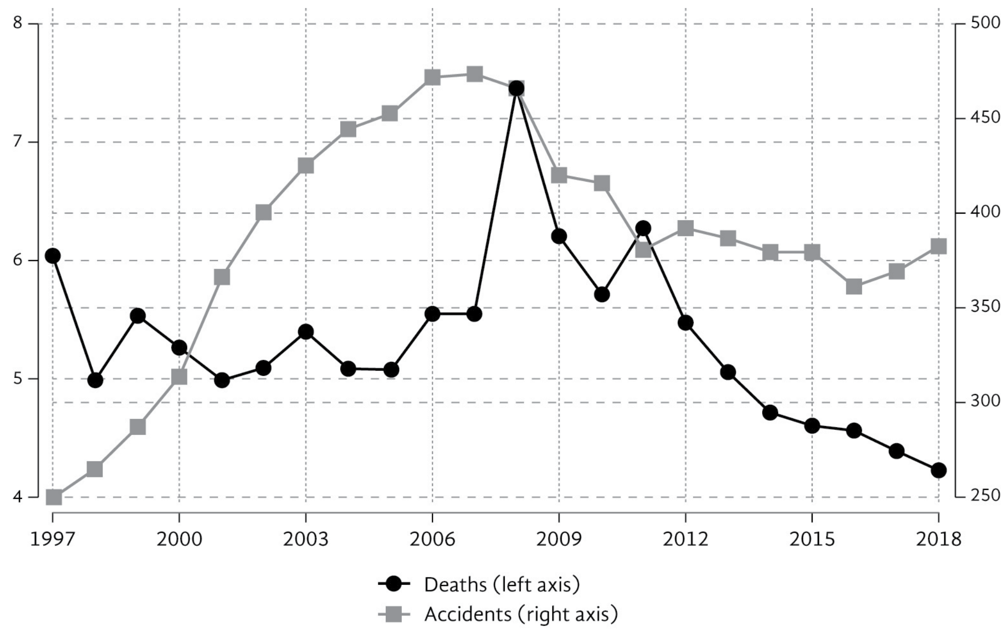
Figure 3.
Road traffic accidents and deaths in Mexico (in thousands)



Source: National Institut of Stadistics and Geography (INEGI).

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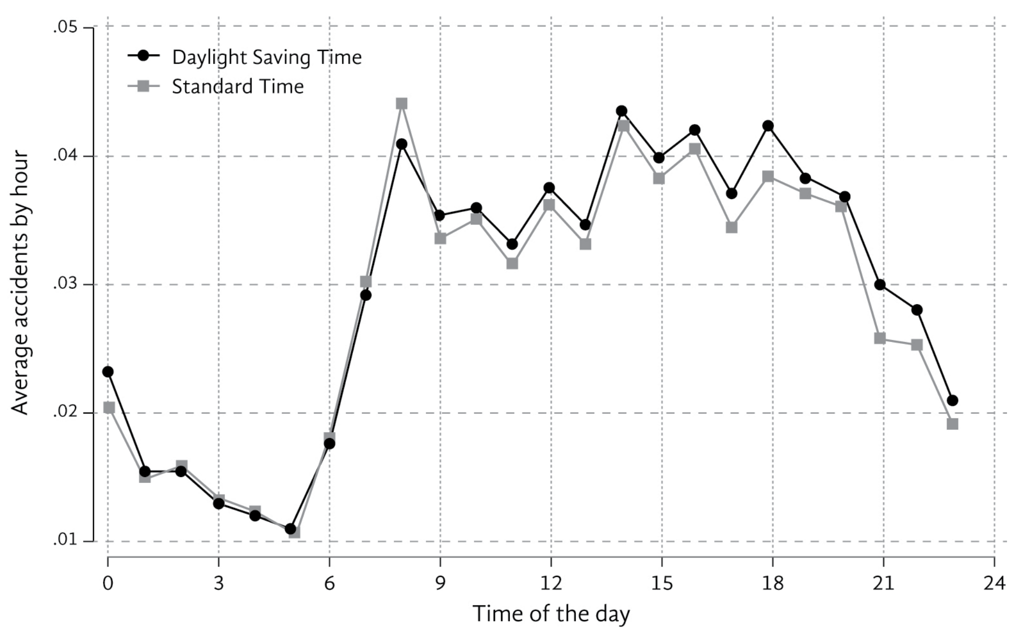
Figure 4.
Road traffic accidents in Mexico (2015)



Source: National Institut of Stadistics and Geography (INEGI).

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Table 1.
Balance between DST and Standard Time

Variable	Standard Time	DST	Difference in means	P-value	Number of observations
Solar radiation	262.901 (0.909)	270.723 (0.913)	-7.822 (1.289)	0.000	298,450
Rainfall (mm)	0.012 (0.001)	0.022 (0.003)	-0.010 (0.003)	0.003	310,582
Relative Humidity	47.890 (0.061)	44.878 (0.061)	3.012 (0.087)	0.000	310,582
Temperature (C°)	21.370 (0.016)	20.876 (0.016)	0.495 (0.023)	0.000	310,582
Wind Speed	3.804 (0.011)	3.800 (0.011)	0.004 (0.016)	0.793	310,582
Barometric Pressure	843.438 (0.218)	845.115 (0.217)	-1.677 (0.308)	0.000	305,864

Source: National Meteorological Service (SMN).
Note: standard errors are shown in parenthesis.

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Figure 5.
Weather controls before and after the shift towards DST

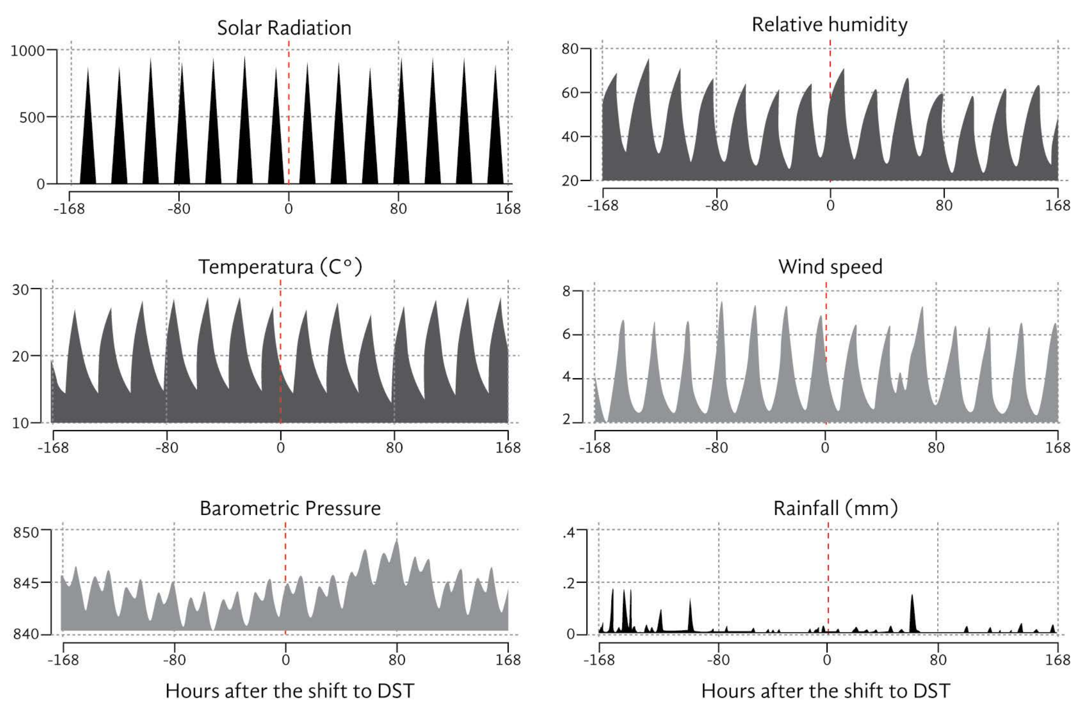

Figure 6.

Municipalities used in Differences in Differences Estimation

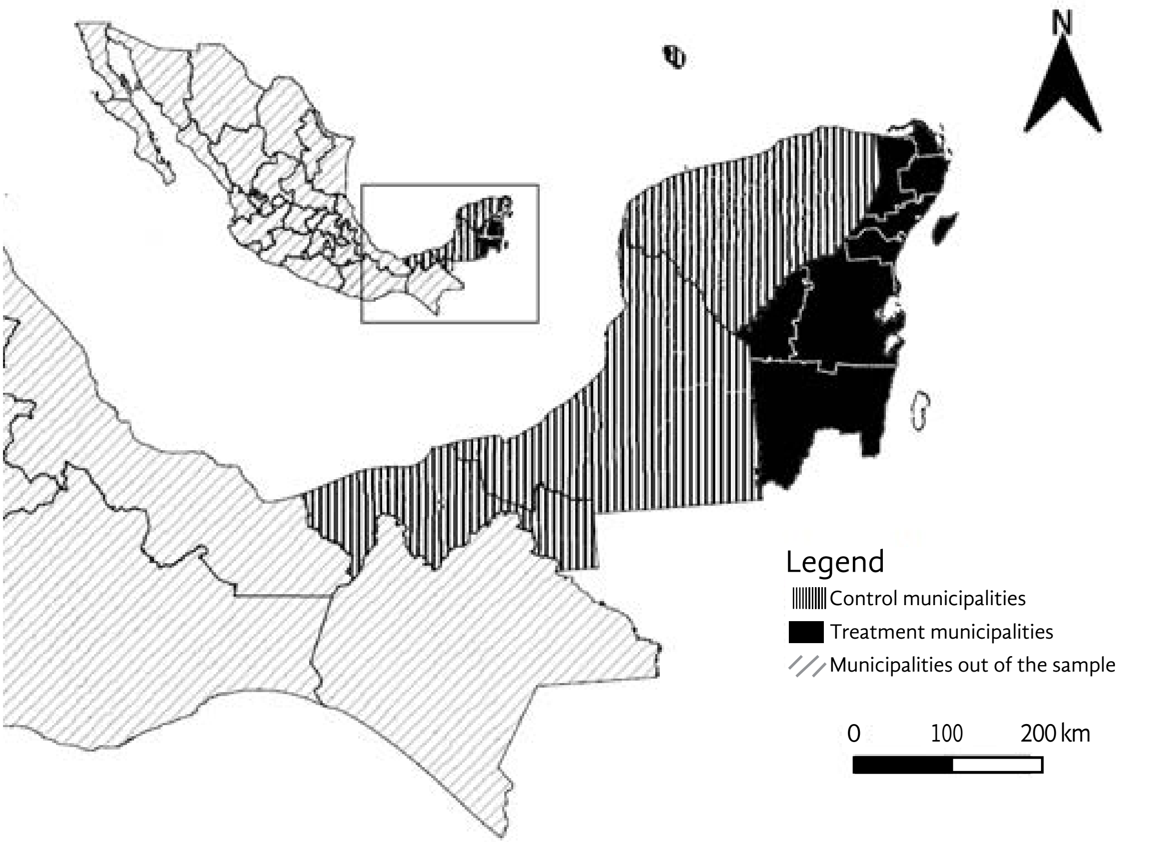

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Table 2.
Regression discontinuity model estimates

	All municipalities		Excluding border DST		Only border DST	
	(1) Accidents	**(2) Deaths**	**(3) Accidents**	**(4) Death**	**(5) Accidents**	**(6) Death**
$DST_{i,t}$	-0.046*** (0.0099)	-0.00022 (0.00077)	-0.043*** (0.010)	-0.00074 (0.00062)	-0.11** (0.034)	0.0088 (0.011)
$HoursT_{i,t}$	0.00032*** (0.000067)	0.0000043 (0.0000045)	0.00030*** (0.000070)	0.0000062* (0.0000034)	0.00056** (0.00022)	-0.000035 (0.000073)
$HoursT_{i,t} \times DST_{i,t}$	-0.000052** (0.000026)	-0.0000049* (0.0000025)	-0.000054** (0.000026)	-0.0000044* (0.0000023)	0.00017 (0.00023)	-0.000019 (0.000028)
Constant	-0.24 (0.20)	0.0028 (0.0088)	-0.29 (0.20)	-0.011 (0.0074)	1.70 (2.02)	0.31 (0.17)
Weather controls	Yes	Yes	Yes	Yes	Yes	Yes
Hour FE	Yes	Yes	Yes	Yes	Yes	Yes
Day of the week FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	294,743	294,743	281,263	281,263	13,480	13,480
Number of municipalities	357	357	349	349	8	8

Source: own estimation using ATUS data and NMS data. Full table containing all the regression coefficients (weather controls and different fixed effects) is available upon request.

Note: robust-clustered standard errors shown in parenthesis. Significance: *** p<0.01, ** p<0.05, * p<0.1

Figure 7.
Graphic results from Model 1 in Table 2

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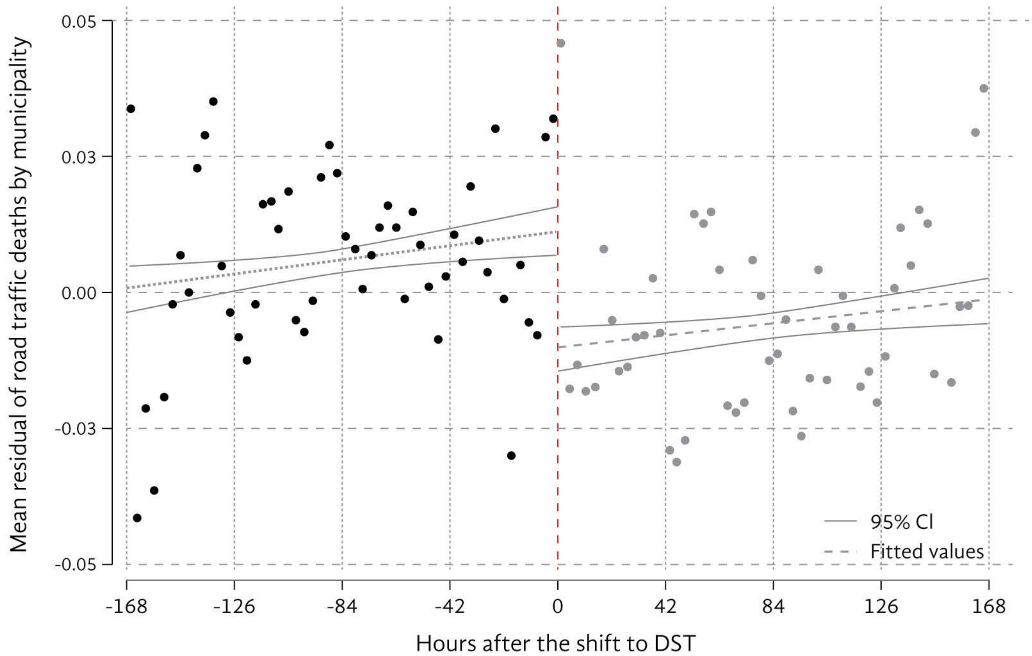

Figure 8.
Graphic results from Model 1 in Table 2

p. 9

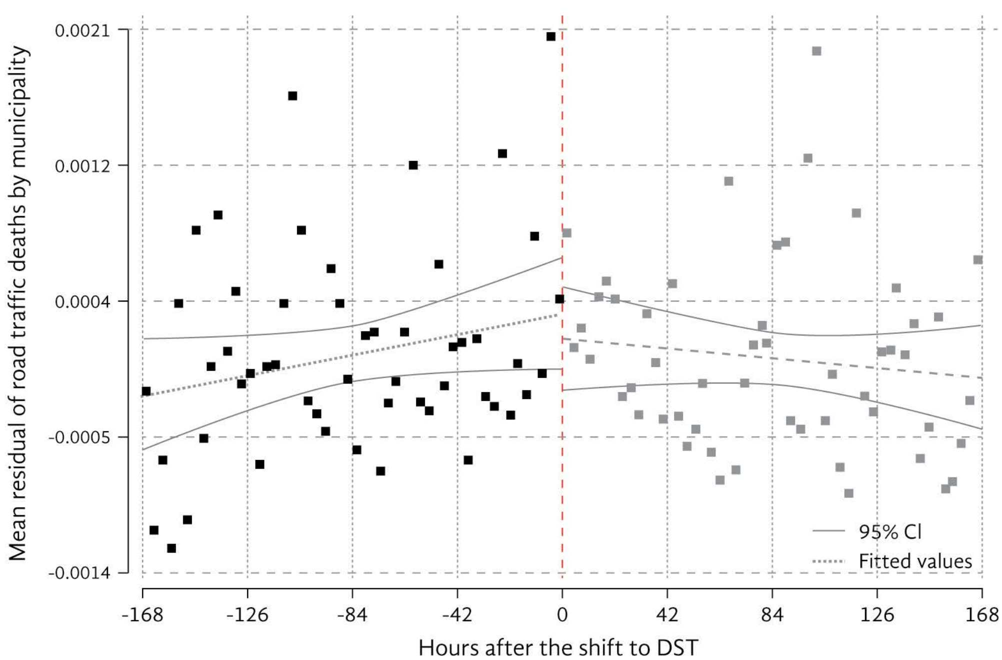

Figure 9.
Sensitivity analysis for β_2 from equation 1

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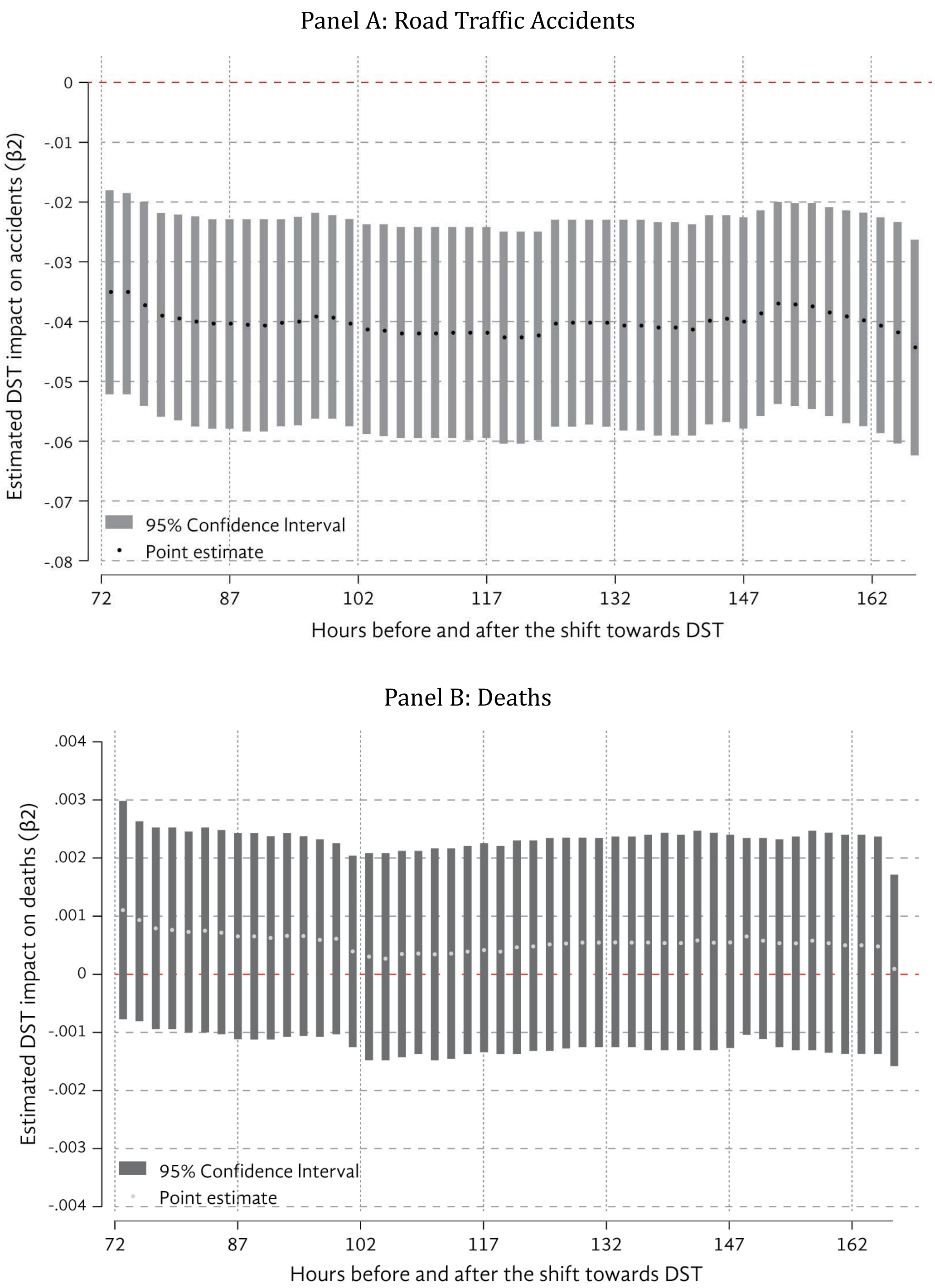

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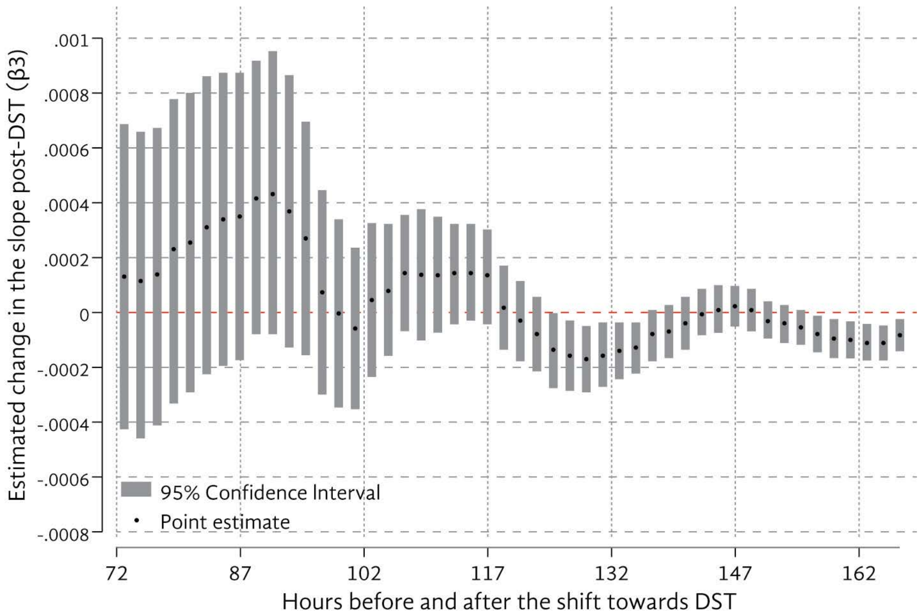
Figure 10.

Sensitivity analysis for β_3 from equation 1

Panel A: Road Traffic Accidents



Panel B: Deaths

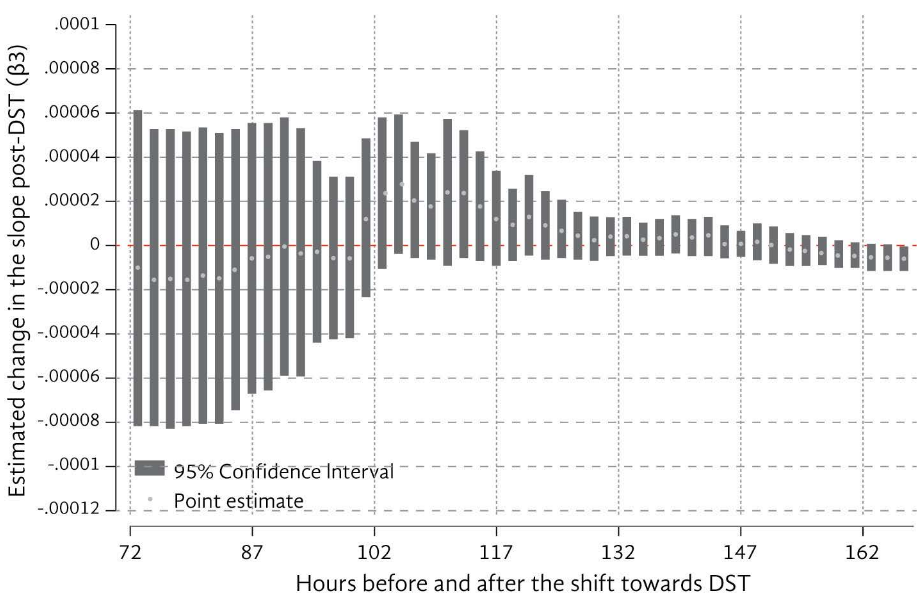


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Table 3. Hourly Difference-in-differences				
	All municipalities		Only metropolitan areas	
	(1) Accidents	(2) Deaths	(3) Accidents	(4) Death
Feb2015	-0.0047 (0.0044)	0.000049 (0.00012)	-0.017 (0.037)	0.000071 (0.0010)
Qroo	-0.0033 (0.0036)	-0.00038 (0.00029)	-0.083 (0.053)	-0.0011 (0.00082)
*Feb2015*Qroo*	0.0044 (0.0096)	0.00026 (0.00072)	0.062 (0.053)	-0.0021 (0.0013)
FirstW	0.0027 (0.0038)	0.000066 (0.00014)	0.052 (0.029)	-0.00030 (0.0013)
*FirstW*Qroo*	0.0031 (0.013)	-0.00018 (0.00048)	-0.054 (0.048)	0.0016 (0.0012)
Constant	-0.0047 (0.0044)	0.000049 (0.00012)	-0.017 (0.037)	0.000071 (0.0010)
Weather controls	Yes	Yes	Yes	Yes
Hour FE	Yes	Yes	Yes	Yes
Date FE	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes
Number of observations	434,138	434,138	30,696	30,696
Number of municipalities	117	117	9	9

Source: own estimation using ATUS data and NMS data. Full table containing all the regression coefficients (weather controls and different fixed effects) is available upon request.

Note: clustered-robust standard errors are shown in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Appendix A

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Table 4:
Municipalities under border DST

State	Municipality	State	Municipality
Baja California	Ensenada	Chihuahua	Ciudad Juárez
Baja California	Mexicali	Chihuahua	Manuel Benavides
Baja California	Tecate	Chihuahua	Ojinaga
Baja California	Tijuana	Chihuahua	Praxedis G. Guerrero
Baja California	Playa de Rosarito	Nuevo León	Los Aldamas
Coahuila	Acuña	Nuevo León	Anáhuac
Coahuila	Guerrero	Tamaulipas	Camargo
Coahuila	Hidalgo	Tamaulipas	Guerrero
Coahuila	Jiménez	Tamaulipas	Gustavo Díaz Ordaz
Coahuila	Nava	Tamaulipas	Matamoros
Coahuila	Ocampo	Tamaulipas	Ciudad Mier
Coahuila	Piedras Negras	Tamaulipas	Miguel Alemán
Coahuila	Zaragoza	Tamaulipas	Nuevo Laredo
Chihuahua	Ascensión	Tamaulipas	Reynosa
Chihuahua	Coyame del Sotol	Tamaulipas	Río Bravo
Chihuahua	Guadalupe	Tamaulipas	Valle Hermoso
Chihuahua	Janos		

Appendix B

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Table 5.
Regression discontinuity: daily-model estimates

	All municipalities		**Excluding border DST**		**Only border DST**	
	(7) Accidents	**(8) Deaths**	**(9) Accidents**	**(10) Death**	**(11) Accidents**	**(12) Death**
DST	-0.92*** (0.29)	0.015 (0.010)	-0.97*** (0.29)	0.0019 (0.0081)	0.12 (1.02)	0.22 (0.12)
DayT	0.16*** (0.041)	-0.000020 (0.0013)	0.16*** (0.043)	0.0011 (0.0012)	-0.0021 (0.100)	-0.017 (0.015)
*DST*DayT*	-0.059*** (0.018)	-0.0030* (0.0015)	-0.058*** (0.018)	-0.0027* (0.0014)	0.030 (0.15)	-0.011 (0.019)
Constant	-1.80 (5.06)	0.28 (0.25)	-4.96 (5.38)	-0.064 (0.12)	55.7 (59.9)	9.12* (4.72)
Weather controls	Yes	Yes	Yes	Yes	Yes	Yes
Day of the week FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	12,254	12,254	11,694	11,694	560	560
Number of municipalities	357	357	349	349	8	8

Source: own calculation using ATUS data and SMN data.

Note: clustered-robust standard errors shown in parenthesis. Significance: *** p<0.01, ** p<0.05, * p<0.1

Appendix C

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Table 6.
Diff-in-diffs hourly-model: from January 16, 2015 to March 20, 2015

	All municipalities		**Only metropolitan areas**	
	(1) Accidents	**(2) Deaths**	**(3) Accidents**	**(4) Death**
Feb2015	0.0013 (0.0052)	0.000082 (0.00045)	0.0062 (0.052)	-0.00061 (0.00100)
Qroo	-0.014 (0.011)	-0.00071 (0.00069)	-0.10 (0.074)	0.00045 (0.0011)
*Feb2015*Qroo*	0.013 (0.017)	0.00099 (0.00095)	0.086 (0.070)	-0.0017* (0.00081)
FirstW	-0.0039 (0.0052)	-0.00012 (0.00046)	0.014 (0.063)	0.00063 (0.0014)
*FirstW*Qroo*	0.0019 (0.013)	-0.00067 (0.00051)	-0.055 (0.050)	0.0013 (0.00095)
Constant	-0.16 (0.34)	0.050 (0.042)	2.34 (2.00)	0.16 (0.19)
Weather controls	Yes	Yes	Yes	Yes
Hour FE	Yes	Yes	Yes	Yes
Date FE	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes
Number of observations	164,352	164,352	10,752	10,752
Number of municipalities	117	117	9	9

Source: own calculation using ATUS data and SMN data.

Note: clustered-robust standard errors in parenthesis. Significance: *** p<0.01, ** p<0.05, * p<0.1

Table 7.
Difference-in-differences by day

	All municipalities		Only metropolitan areas	
	(13) Accidents	**(14) Deaths**	**(15) Accidents**	**(16) Death**
Feb2015	-0.17 (0.10)	0.0014 (0.010)	-0.062 (0.98)	-0.086 (0.10)
Qroo	-0.061 (0.098)	-0.011 (0.0085)	-1.29* (0.67)	-0.0054 (0.015)
*Feb2015*Qroo*	0.095 (0.23)	0.0055 (0.019)	1.10 (1.02)	-0.083 (0.059)
FirstW	0.025 (0.12)	0.0054 (0.0065)	1.15 (0.70)	-0.016 (0.056)
*FirstW*Qroo*	0.079 (0.31)	-0.0035 (0.012)	-1.13 (1.14)	0.061 (0.047)
Constant	-16.0* (8.62)	-1.00 (2.50)	16.1 (81.5)	-25.8 (21.7)
Municipality FE	Yes	Yes	Yes	Yes
Day of the year FE	Yes	Yes	Yes	Yes
Number of observations	18,091	18,091	1,279	1,279
Number of municipalities	117	117	9	9

Source: own calculation using ATUS data and SMN data.

Note: clustered-robust standard errors in parenthesis. Significance: *** p<0.01, ** p<0.05, * p<0.1

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Appendix D

This section shows the heterogeneous effects of DST per hour. More precisely, **figure 10** shows the effects per hour, estimated by the RD model (**Table 2**) and **figure 11** shows the effects estimated by the DD model (**Table 3**). According to **Figure 10** (the RD model), DST has significant negative effects on total accidents every hour of the day; whereas there were no significant effects on total deaths.

Figure 11.
RD model - DST's Impact by hour of the day

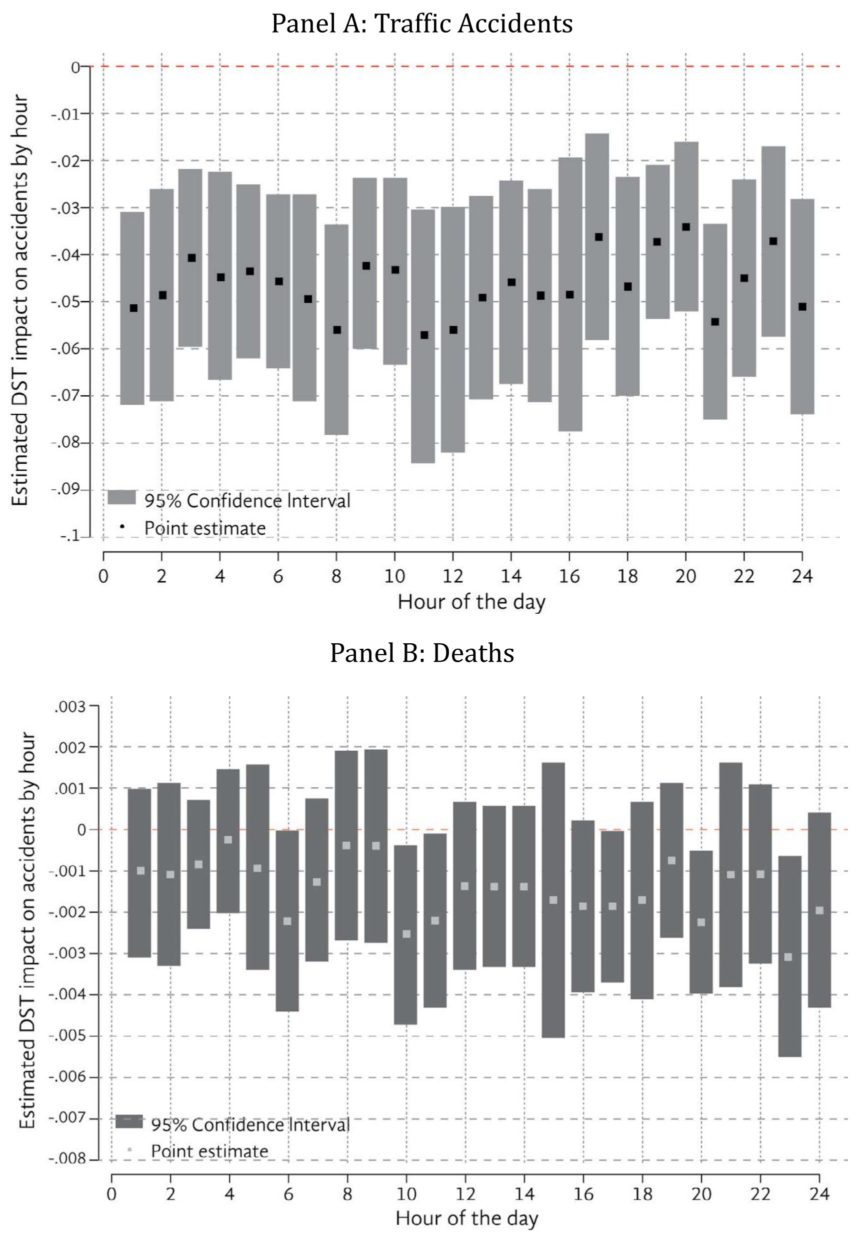

Figure 12 confirms the results of **Table 3**; DST seems to generate no significant effects on total accidents or deaths in the Yucatán Peninsula. As can be observed, most of the confidence intervals cross the value equal to zero of the vertical axis, which suggests that they are not statistically significant at 95% confidence. However, according to Panel A, it seems that DST generated negative and statistically significant effects in many hours of the day, although this is only true for the first week of DST.

Figure 12.
DD model - DST's Impact on the first week of implementation by hour of the day