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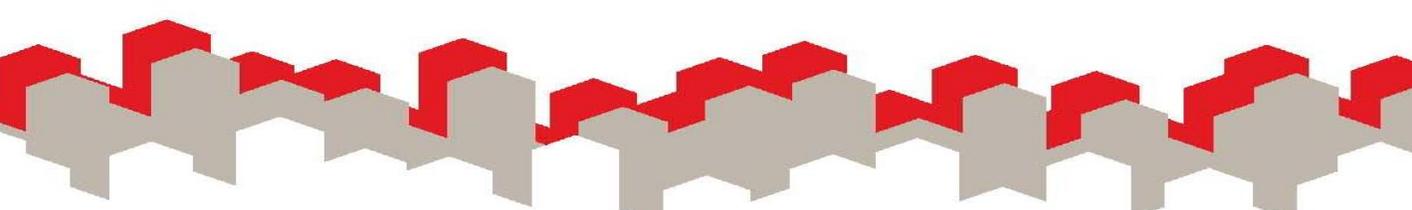
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Summertime and the drivin' is easy?

Daylight Saving Time and Vehicle Accidents

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Abstract

Although is commonly understood that light conditions affect driving behaviour, detailed evidence is scarce especially for EU countries. In this paper we use the exogenous variation in daylight caused by Daylight Saving Time (DST) shifts to examine the role of light conditions on vehicle accidents. We use a rich dataset from Greek administrative data covering the universe of all types of recorded vehicle accidents over the period between 01 January 2006 to 31 December 2016. Relying on a regression discontinuity design we attempt to provide a causal evaluation regarding the impact of exogenous time shifts on the number of vehicle crashes. Our results are supportive of an ambient light mechanism that reduces the counts of serious vehicle accidents during the Spring transitions and increases the count of minor ones during the Fall transition, especially during the most impacted hours within the day. We discuss the implications of our study both for the importance of light ambience conditions for car accidents and for the particular case of the adoption and preservation of DST policies.

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1. Introduction

It is rather unproblematic to imagine that differences in ambient light conditions affect driving capacity and hence, the incidence of vehicle accidents. However, causal evidence about this relationship is scarce, especially for EU countries. Indeed, on March 2019 the European Parliament voted for the abolition of obligatory seasonal clock changes by 2021, with member states keeping their right to decide on their time zone after that. The European Parliament had previously requested an ex-post evaluation of Directive 2000/84/EC regulating transition into and out of Summer Time in the EU countries (Anglmayer, 2017). Based on the findings of that study the European Parliament called on the European Commission to consider abolishing Daylight Saving Time (DST) for their member countries.

Among other potential implications, the report raised concerns about the impact of DST on road safety, mainly due to sleep deprivation and ambient light conditions. [1] Their recommendations relied on studies for the UK and the US which, however, arrived at mixed conclusions. The UK literature review suggested that collision risk reduces (increases) when entering (exiting) DST (Carey and Sarma, 2017). The US study used a regression discontinuity design to show that fatalities increase when entering DST through a lack of sleep mechanism that affects both drivers and pedestrians (Smith, 2016). As the European Parliament report suggested, the existing evidence on the issue is too thin – both regrading the transferability of the above findings to mainland European countries, due to different climate and ambient light conditions, and more generally. Our paper seeks to fill this gap, by providing detailed evidence on how exogenous variations in daylight ambience, due to DST shifts, affect vehicle accidents.

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[1] The report mentioned a number of other effects – for example, that DST causes health inconveniences through disruptions of the circadian rhythm of individuals (Kantermann et al., 2007) – but concluded that Summer Time is overall beneficial, as it benefits the transport sector and outdoor leisure activities and marginally reduces energy consumption. In the empirical economics literature, transition into DST has also been shown to increase heart attack incidences (Janszky and Ljung, 2008; Toro et al., 2015) and to exert a negative influence on life satisfaction and mood (Kountouris and Remoundou, 2014; Sexton and Beatty, 2014).

Transitions into and out of DST may affect individual driving behaviour through two major channels. The first one is by redistributing sunlight within the day. During the Spring transition, one hour of sunlight is reallocated from the morning to the evening. This creates a darker and riskier driving environment during the morning and one with better light conditions during the evening, while all other working and commuting schedules and patterns remain unchanged. During the Fall transition the extra hour of evening sunlight is returned back to the morning, hence creating a darker atmosphere in the evening. Light conditions have been shown to affect the circadian rhythm and drowsiness of drivers (Chipman and Jin, 2009). A recent study by Bünnings and Schiele (2018) for England, Scotland and Wales shows that darker environments are associated with increased year-round road safety costs. Thus, variation in ambient light conditions could be associated with the number of vehicle crashes.

An alternative channel through which DST shifts affect driving behaviour is sleep deprivation. Recent research has shown that DST causes significant behavioural changes, especially during the Spring transition. Individuals sleep less, on average, due to moving clocks on hour forward and they tend to spend more time at home in the morning and less time at home during the evening (Sexton and Beatty, 2014).[2] Sleep deprivation affects the level of alertness and there is experimental evidence regarding a negative relationship with driving performance (Otmani et al., 2005; Philip et al., 2005).

Therefore, DST transitions could affect road safety via both channels. We focus on Greece to examine which mechanism is more relevant in the European context. This choice is justified by the fact that it is a country with one of the highest fatality rates in the Eurozone. According to a 2017 Road Safety report of the European Commission, the country ranked sixth in the EU-28 (and first in the EU-15) with 69 fatalities per million inhabitants, 20 more than the EU-28 average.[3]

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[2] The amount of sleep loss is 15-20 minutes according to Sexton and Beatty (2014). In a previous study, Barnes and Wagner (2009) used the same dataset (American Time Use Survey) and found that individuals sleep 40 minutes less, on average, on the night of Spring transition. Both studies showed that sleep gains during the Fall transition are not statistically significant.

[3] https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/scoreboard_2017_en.pdf

At the same time, Greece ranks below the EU-28 average regarding the quality of its road network and second from the bottom regarding the efficiency of its train services which could be seen as an alternative to transportation using the road network.[4] Therefore, any factor that potentially affects driving behaviour could have important implications, especially when considering that vehicle accidents are a significant source of external mortality in the country. According to official vital statistics for the period 2000-2016 provided by the Hellenic Statistical Authority, more than 1,500 people die every year from vehicle accidents although this figure follows a declining trend since 2006. On average, this represents nearly 1.5% of the overall annual mortality in the country. However, apart from the extreme case of a fatal crash, there are lots of other implications associated with vehicle accidents. These include deterioration in general health status, greater use of healthcare and other public services, increased insurance premia, absence from work, foregone earnings, post-traumatic stress etc.

In this study we provide three main contributions to the literature. First and foremost, we attempt a causal evaluation of DST shifts on road accidents focusing on Greece, in order to provide further and updated empirical evidence for an EU member state. To this end, we use a very rich administrative dataset that has not been used for this purpose before, at least to our knowledge. Under a special licence agreement with the Hellenic Statistical Authority, we obtained detailed data on all reported vehicle accidents in Greece during the period between 01 January 2006 and 31 December 2016. Second, but quite importantly, unlike previous studies we consider the whole distribution of vehicle accidents (i.e. minor, non-fatal/serious and fatal ones) and not only a small portion of accidents causing fatalities Smith (2016). Third, our rich data allow us to provide an original heterogeneity analysis of the DST effects on road accidents depending on weather conditions, drinking behaviour, road type and economic conditions, thus allowing for a clearer identification of the DST impact.

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[4] https://ec.europa.eu/transport/facts-fundings/scoreboard/countries/greece/investments-infrastructure_en

As a country state of the European Economic Community, Greece adopts Daylight Saving Time since 1975. On the last Sunday of March each year, time in all member countries is set forward by one hour at 01:00 Greenwich Mean Time (GMT) until the last Sunday of October when it is set backwards by one hour at 01:00 GMT. Therefore, randomisation needed to identify the causal impact relies on the natural experiment generated by entering and leaving DST (Imbens and Lemieux, 2008). Using a sharp regression discontinuity design, we examine whether entering into DST affects various types of traffic accidents. The results indicate that entering into DST does not have any significant implication on the daily counts of total and minor accidents. There is a significant reduction in the daily count of serious accidents and a weak and imprecise increase for fatal accidents. Analysing the crash count by within-day hour intervals reveals that the reduction in serious crashes occurs during hours that are affected the most by the reallocation of sunlight into the evening. Regarding transitions back to the Standard Time in the Fall, our results suggest an increased count for total crashes, driven by a statistically significant increase in minor accidents. This result is stronger for the evening hours, which in this case are the ones to be affected the most by reallocating an hour of sunlight back in the morning. The ambient light mechanism is also supported by examining separately night accidents taking place in adequately lit locations versus locations with inadequate or no street lights. These results are backed up by an extensive series of robustness checks and falsification tests that we exploit in the paper.

The remainder of the paper is organised as follows: Section 2 outlines the data and presents some descriptive evidence regarding patterns in the data. Section 3 describes the empirical strategy and some basic assumptions. Section 3 discusses the results and Section 5 concludes.

2. Data

Under a signed agreement with the Hellenic Statistical Authority (EL.STAT hereafter), we were granted access to information extracted from the universe of the Road Accidents Reports

for the period between 01 January 2006 and 31 December 2016 in Greece. The inspecting road police officers fill in those reports after every vehicle accident. During their inspection, all aspects regarding the crash are recorded. Those refer to the type and severity of the accident and its precise date, time and location. According to the severity variable, an accident is classified as either fatal, serious or minor. A vehicle crash is defined as fatal if it resulted in the death of an involved individual within 30 days from the crash. By reporting results for non-fatal accidents, our study supplements the evidence provided by Smith (2016), who estimated the impact of DST on fatal crashes only. Moreover, information about the driver such as gender, age, nationality, and the year they got their driving licence is also collected. They also report whether they conducted any alcohol tests and the corresponding results. Details about the vehicles involved in the accident such as their type, safety features (airbags, seatbelts etc.), and manufacture year is collected as well. Inspecting officers also report information on weather conditions as well as the street light conditions for accidents occurring during night hours. Finally, they report information regarding the type of the road network an accident took place, e.g. whether it was highway, within a residential area, its number of lanes etc.

To address any concern regarding the fact that the first Sunday under DST is one hour shorter than the remaining days, we follow Smith (2016) and adjust the crash counts by several alternative ways. First, we counted the 03:00-04:00 hour twice, using it as a proxy for the missing 02:00-03:00 hour on the DST entering day. At the same time, we divided the crashes occurred from 01:00 to 02:00 by two on the DST exit day as this hour occurs twice on every Fall transition. Second, we multiplied Spring transition date crashes by 24/23. Because that specific date has only 23 hours, crash counts were inflated under the assumption that they evolve smoothly over the day. Fall transition date crashes were multiplied by 24/25. Third, we dropped the transition dates from the estimation sample. Regardless of the adjustment type chosen, our results remained identical to those obtained when using the officially recorded count of vehicle crashes.

In our estimations we use crash counts aggregated by day or hour interval. The main reason behind this aggregation is the scarcity of vehicle crashes, especially for fatal and serious ones. Regarding the total period, minor accidents represent 87.7% of the total, while serious and fatal accidents stand for 7.1% and 5.2% of the total count, respectively. Table 1 presents descriptive statistics by crash type. During the total period, the average daily count of total vehicle accidents in the country is 37, with a minimum of 8 and a maximum of 73 crashes. The total crashes distribution is mainly shaped by the minor accidents one. Fatal and serious accidents are rarer. Their daily averages are 1.9 and 2.6, respectively. Figure 1 displays the distribution and the daily profile for each type of accident. Distributions provide evidence regarding the rarity of fatal and serious crashes.[5] Aggregation to national-level time series also smooths out any confounders specific to weather conditions and other characteristics that could affect the daily crash count for a specific location but for not the total country.

[Table 1 about here]

[Figure 1 about here]

Hourly profiles suggest that vehicle accidents are more frequent during the evening and night hours as compared to morning ones, although fatal and serious counts are more uniformly distributed throughout the day. As previous studies have suggested, substituting ambient light from low traffic frequency hours, i.e. during the early morning hours, to high frequency ones, i.e. during the early evening, could indeed be a cost-effective policy in terms of road casualties (Broughton et al., 1999). Further descriptive evidence regarding the raw accidents data is provided in Table 2. Mean daily counts from the first week of both transitions are compared to mean counts from one week before and one week after. Moreover, in order to account for seasonal trends,

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[5] Originally, there were 74 administrative regions in our data. However, all vehicle crash types had a region-specific mode equal to zero.

counts from the first week after each transition are benchmarked against averages obtained using one and two weeks before and after. In general, it seems that there is a small accidents reduction when adopting DST in the Spring. Differences are less pronounced when returning back to Standard Time in the fall.

[Table 2 about here]

In order to examine whether changes during transitions vary within the day, we plotted the mean crash count by hour using a 5-day time window before and after each transition. This will provide some indications on whether differences vary around the clock, especially for hours that are more or less affected by moving clocks backwards and forward. Figure 2 displays the results. Regarding Spring transition (panel A) it seems that for total accidents the effects are small. However, there is a decrease in serious accidents in the evening, and an increase in fatal accidents in the morning hours during the Spring transition. Panel B graphs the hour-specific means before and after the Fall transition. Regarding fatal accidents, they seem increased during the evening hours on the first days after falling back to Standard Time, while serious crashes appear to decrease during the morning hours.

[Figure 2 about here]

3. Estimation strategy

The causal effect of DST on counts of various vehicle accident types is evaluated via a regression discontinuity (RD) design strategy. Our identification relies on a natural experiment based on the standard practice of advancing clocks by one hour each Spring and then moving them backwards by one hour in the Fall. This generates an exogenous reallocation of sunlight from

the morning to the evening and vice versa. Figure 3 plots the sunrise and sunset times (solid lines) alongside with their respective counterfactuals in the absence of the DST practice (dotted lines). Advancing clocks forward when entering and adjusting them backwards when exiting DST generates an exogenous variation in the supply of daylight, especially around sunrise and sunset. Either through the sleep deprivation or the ambient light conditions mechanism, this variation could have implications on driving behaviour and hence, the number of vehicle accidents. Under this framework, we compare the count of car crashes that occur before entering DST to the count of crashes that occur after. As explained in the Data section, at first we collapse the dataset in order to construct daily time series of accident counts covering the total period. Using those data series, we estimate reduced-form models of the following form:

$$Crashes_{iy} = b_0 + b_1 DST_{iy} + f(DaysToDST_{iy}) + f(DST_{iy} \times DaysToDST_{iy}) + u_{iy} \qquad (1)$$

In this baseline model specification $Crashes_{iy}$ is the count of accidents (either total, fatal, serious or minor ones) on day i, and year y. DST_{iy} is a binary indicator switched on conditional that the i-th day falls under the DST period in the y-th year. $DaysToDST_{iy}$ is the running variable measuring the number of days before and after the DST transition, i.e. it is centered on the transition dates in each year. Finally, f is a function of the running variable and u is the disturbance term. Our models control for a series of variables in order to eliminate effects due to day-of-week, general time trends and public holidays (Smith, 2016; Toro et al., 2015). In our preferred empirical specification, we use local Poisson regressions at both sides of the transition date cutoff, a uniform kernel and optimal data-driven bandwidths (Calonico et al., 2014). Compared to high order polynomials of the running variable, local linear regressions have been shown to perform better in RD settings (Gelman and Imbens, 2018; Smith, 2016). The robustness of the results is confirmed using also higher order polynomials as well as alternative kernels and bandwidths. In this

framework, the coefficient of interest is b_1 and it measures the overall DST effect on vehicle accidents right at the transition date. By using Poisson regressions we avoid any kind of transformation of the dependent variable. A log-transformation of the number of crashes would be problematic with our data since the number of fatal and serious crashes is zero for some days, but also because the conventional use of estimating log-linearised models with transformed dependent variables via OLS has been shown to produce biased estimates (Santos Silva and Tenreyro, 2006), especially under the presence of heteroscedasticity. The effect of entering DST on vehicle accidents is identified under the assumptions that factors influencing driving behaviour and vehicle accidents, other than the DST, are continuous at the transition dates. To this end, we test for discontinuities at the transition dates for fuel prices and vehicle miles travelled using data obtained from various sources. We also report results from falsification tests using placebo transition dates in order to provide support regarding the validity of the estimates. Moreover, we make use of several accidents features contained in the Road Accident Reports in order to explore possible mechanisms that drive the results, through the heterogeneity of roads conditions or driver's drinking behaviour.

[Figure 3 about here]

4. Results

4.1 Baseline estimates

We first present some graphical evidence regarding the impact of DST on vehicle crashes. We regress each crash count on day-of-week, month, year and public holiday fixed effects, using local Poisson regressions.[6] The obtained response residuals are then averaged by day over the total

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[6] Results were robust to the use of negative binomial regressions.

period covered by the data. Figure 4 presents the results. There is a clear drop in serious crashes and a weaker increase for fatal crashes at the Spring transition date (panel A). Regarding the Fall transition, in panel B, there is a visible increase for total accidents, driven by the jump in minor accidents, as well as a drop for serious accidents.

[Figure 4 about here]

Table 3 reports the estimated size of those breaks observed at the Spring transition for each accident type. For robustness we report estimates using regressions with first and second order polynomials of the running variable around the cutoff date, uniform and triangular kernels and optimally data-driven bandwidths (Calonico et al., 2014). As indicated in the graphical evidence, there is not a significant discontinuity for total and minor accidents in panels A and D, respectively. The estimated baseline effect of DST on fatal crashes (panel B) is positive, in line with the effect uncovered in the US study (Smith, 2016). However, the result is not robust when higher order polynomials, and different bandwidths and kernels are used instead. A statistically significant and negative effect of Summer Time is uncovered in the case of serious accidents (panel C). This shows that Spring transition is associated with a 22% decrease in serious crashes.[7] Overall, Table 3 suggests a weak positive impact on fatal crashes and a negative impact on serious ones. Considering that fatal crashes is an extreme case of a serious crash, then the results could possibly imply that there is not an aggregate effect of entering DST on the total sum of non-light accidents, but rather a reallocation of serious towards fatal accidents immediately following the Spring transition, although the evidence is rather weak.

[Table 3 about here]

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[7] This effect is calculated using the formula: $100 \times (e^b - 1)$, where b is the estimated coefficient.

Table 4 presents the corresponding RD estimates for falling back into Standard Time (Fall transition). There is a positive, statistically significant and robust effect regarding minor vehicle accidents (panel D) which shapes the baseline Fall transition effects for total accidents (panel A). The coefficient estimate in column 1 of Table 4 suggests that after the Fall transition, minor accidents increase by about 12.3%. There is not any significant or consistent effect of Standard Time on fatal and serious crashes (panels B and C, respectively). For both transitions, the results are identical when we use the transformed count variables in order to adjust for the missing hour during the first day of the DST period (results are available upon request).

[Table 4 about here]

Given that local linear regressions have been shown to perform better in RD settings relative to higher-order polynomials of the running variable (days from transition in our case) we use models corresponding to columns (1) of Tables 3 and 4 as our preferred specification. However, before exploring a series of candidate mechanisms driving these baseline effects, we present some robustness checks. The first one is to use alternative bandwidths around the cut-off dates for the crash types that we observe significant discontinuities. More specifically, we estimate our preferred model specification using a series of different time windows, i.e. ranging from 10 to 30 days around transition dates. The results are displayed in Figure 5. Horizontal dashed lines represent the baseline effect using the optimal data-driven bandwidths (column 1, Tables 3 and 4). Vertical dotted lines indicate the number of days around transition corresponding to those bandwidths. It is clear that the reported baseline effects are robust to the use of alternative time windows. Moreover, the baseline Fall transition impact on minor accidents is fading as the time window gets broader.

[Figure 5 about here]

To provide further reassurance regarding the validity of our estimates we conducted a series of placebo tests, i.e. by using fake transition dates instead of the actual ones. Again, we focus on fatal and serious accidents for the Spring transition and on minor accidents for the Fall transition, given that our baseline estimates were statistically significant only for those cases. More specifically, we replaced the actual DST transition date with a series of fake ones, starting from the first day outside the bandwidths used in Tables 3 and 4, and covering a three-month period after that. In this way, we avoid including days close to the actual transition during which individuals might still be affected by the change. The distributions of those estimates, along with the baseline point estimates (vertical lines) are plotted in Figure 6. For serious (Spring) and fatal (Spring) crashes the reported baseline estimates lie outside the plotted distributions (hence the reason why the related vertical line thresholds are not shown), ensuring the validity of the results. The vertical dotted line represents the baseline point estimate for minor accidents (Fall transition). Relative to the overall distribution of RD estimates, the true effect lies on the upper 10% and the larger coefficients are associated with dates occurring more than a month later from the Fall transition.

A final robustness check refers to the exogeneity of the treatment. Although transitions into and out of DST are exogenous, they happen in full certainty and therefore there might be concerns that individuals could adjust their sleeping behaviour beforehand, as up to one hour of sleep could be lost during the Spring transition.[8] To test this assumption, we replaced the actual Spring transition date with its one-day and two-day lags. Although the signs and magnitude of the estimated discontinuity parameters are in line with the baseline effects, they are imprecisely estimated, thus not supporting the anticipation bias hypothesis.

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[8] Although evidence using the American Time Use Survey showed that the amount of sleep lost during the Spring transition ranges from 15 to 40 minutes (Barnes and Wagner, 2009; Sexton and Beatty, 2014).

[Figure 6 about here]

4.2 Ambient light mechanism

Changes in the number of vehicle crashes observed after entering and exiting DST could be explained by mechanisms related to sleep and ambient light conditions. Therefore, a first step in explaining our baseline results is to provide some evidence about the operation of these two. In order to disentangle any effects associated with the sleep and ambient light mechanisms we apply our RD design on eight different three-hour intervals. In this way we examine whether the results obtained when using daily crash counts are driven from hour intervals within the day that could be mostly affected by sudden redistributions of sunlight. Figure 7 displays the hour-specific RD estimates for the Spring transition. With respect to fatal accidents, there are some positive but not significant estimates for the early morning hour intervals, during which drivers may be subject to both sleep deprivation and deteriorated ambient light conditions. There is also a negative but not precisely estimated coefficient for the 18:00-20:59 interval, that is one the mostly affected by the extra hour of sunlight. Regarding serious accidents, all estimates are not statistically significant except the one for the 18:00-20:59 interval. The estimates in this interval seem to be driving the overall baseline effect, which is supportive of a positive ambient light reallocation mechanism; its associated parameter estimate is -0.49 and significant at the 5% level. There is a positive and significant estimate for minor accidents but the hour interval (15:00-17:59) when it is observed is not much affected by the reallocation of sunlight, it is rather subject to the increased traffic and the high frequency of accidents during those hours (as seen in their hourly profile – see Figure 1). We also estimate a negative but not significant parameter for the most affected evening interval.

[Figure 7 about here]

Figure 8 graphs the estimated coefficients and their confidence intervals with respect to the Fall transition. As shown in the baseline results, exiting DST has a positive impact on minor (and total) vehicle accidents. Regarding those two types, the results also support the operation of the ambient light conditions mechanism. The hour-specific estimates are positive and significant for the evening hours that are mostly affected by returning one hour of sunlight back in the morning. The associated Fall transition parameter for minor accidents happening within the 18:00-20:50 interval is 0.14 and statistically significant at the 5% level.

[Figure 8 about here]

To further investigate the role of ambient light conditions we take advantage of the fact that for night accidents, our dataset contains information about street light conditions, i.e. lampposts, light poles etc., in locations where vehicle accidents took place. More specifically, the inspecting officers collected information on whether there was adequate street light on the accident location or it was inadequate/non-existent instead. In Figure 7 we showed that although the DST impact in Spring transition was negative for all crash types during the evening, it was statistically significant only for serious crashes (panel c). However, there were some positive estimates regarding the count of total and fatal crashes happening in the 03:00-05:59 hour interval. These are night hours, but they are also affected by the fact that one hour of morning sunlight is reallocated later on in the evening during the Spring transition. If ambient light is the driving force behind the patterns observed in the data, then the DST parameter estimates for this time interval should be stronger in locations where street light conditions are inadequate or there is not street light at all. Using our baseline specification, the DST impact for total accidents happening during the early morning in locations with inadequate street light conditions is 0.401 and statistically significant at the 10% level, while the estimated coefficient for total crashes in locations with adequate street light is 0.067 and not significant. Regarding fatal crashes in that time interval during

Spring transition, the DST impact in well-lit locations is 0.040 and in poorly-lit ones is considerable higher, i.e. 0.241 (but none of them is statistically significant). [9]

4.3 Sleep deprivation mechanism

Our results indicate that the Spring transition effect on vehicle accidents is not subject to a sleep deprivation mechanism because (a) the effect is negative and (b) it comes from changes in the evening hours. In the comparable US study (Smith, 2016) the DST impact was positive hence a part of it could be attributed to lack of sleep. This was tested in the following way: the post-transition period was split into an initial period of few days and a remaining one. The discontinuous jump was observed only in the initial short period and the accident count reverted to its pre-transition level after that providing some support for a sleep deprivation mechanism driving the results. Although our results do not favour this hypothesis, we perform a similar test. We do that for serious accidents during the Spring transition where we get a significant, but negative, result. More specifically, we split the post-transition period in spring into an initial 5-day sub-period and a remaining sub-period of 13 days (summing up to the preferred bandwidth from Table 3). In Figure 9 we reproduce the mean residuals plotted in Figure 4. The discontinuous jump for serious accidents is confirmed, over the first 5 days and then they evolve smoothly over the remaining period, however, this provides further evidence favouring the ambient light explanation of our results. We do not test for a sleep deprivation effect for minor accidents when exiting DST because the Fall transition is not subject to less sleep. Empirical evidence has shown that people gain some extra minutes of sleep although in a not statistically significant way (Barnes and Wagner, 2009; Sexton and Beatty, 2014).

[Figure 9 about here]

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[9] Although this could be subject to some sort of endogeneity because drivers might choose to use road networks with adequate streetlight as these might be better maintained, allow them to speed up etc. Full results are available upon request from the authors.

4.4 Crash factors

Previous results indicated that ambient light conditions are associated with reduced vehicle accident counts. However, there can also be other factors affecting the likelihood of a vehicle accident. Our data do not allow us to identify accidents where drowsiness is reported as crash factor as in the US paper (Smith, 2016), although drowsiness is more related to a sleep deprivation mechanism that does not seem to apply here. However, we can test for whether there is a discontinuous jump in counts of accidents characterised by bad weather conditions, drunk driving (measured at the accident scene or post-mortem for fatal crashes), whether they took place in residential or non-residential areas. An interesting feature of our dataset is that it covers a period of high economic turbulence. We also split the estimation sample according to the prevailing economic conditions to examine whether these may exert some influence on the results. If the economic turmoil during the Greek crisis resulted in a changing driving behaviour, this could be reflected on the relationship between vehicle crashes and transitions into and out of DST. There is already evidence that vehicle accidents mortality has been considerably decreased in Greece during the crisis (Laliotis et al., 2016; Laliotis and Stavropoulou, 2018). Reduced exposure in the amount of driving for work and leisure, and adoption of less risky behaviours like smoking, drinking and speeding during economic downturns have been shown to explain procyclical vehicle-related fatality (He, 2016; Ruhm, 2000). As seen in Figure 10, all crash counts decline and become less volatile over time. Although recent empirical analyses place the onset of the Greek crisis at the end of 2008, when the unemployment rate started to rise, we use the adoption of the austerity agenda in May 2010 (First Economic Adjustment Programme) in order to have more balanced samples before and after. Compared to the period before the crisis, there were 235 fewer total crashes every month, on average, and 28 fewer serious ones during the austerity period.

[Figure 10 about here]

Table 5 reports the RD estimates accounting for the heterogeneity of DST transitions by crash factor, type of area and period. Regarding weather conditions, bad weather seems to be associated with the increase in minor accidents observed during the Fall transition. For the Spring transition there is a negative, but not significant, effect on serious accidents, and a significant drop of minor accidents that may seem unexpected as weather conditions are generally improving during that time of the year. However, this could simply imply that better ambient light conditions brought by DST mitigate the effects of adverse driving conditions due to bad weather, especially for minor accidents – where indeed we should expect the mitigation effect to be stronger/more effective. Drunk driving (column 2) is related to vehicle accidents during transitions in a conflicting way. Minor accidents are reduced during the Spring transition and increase when adopting back the Standard Time. This could reflect the fact that people are more likely to drink when light conditions deteriorate while devoting more time to leisure and outdoor activities when gaining one extra hour of sunlight in the Spring. At the same time fatal and serious accidents where drunk driving is mentioned as a factor decrease during the Fall transition.

[Table 5 about here]

The baseline spring transition effects are primarily driven by accidents taking place in residential areas (column 3). These results should be expected given the higher traffic volume in more densely populated locations. Minor accidents decrease during the Spring transition in non-residential areas as well. This could also be in line with the ambient light mechanism, as those areas are more affected by the sunlight reallocation within the day. According to the data, the vast majority, 63.2%, of accidents in non-residential areas take place in locations with inadequate or inexistent street light. Finally, baseline effects seem to be driven by changes occurring before the financial austerity period. This could be an indication for smaller exposure to the amount of driving during the crisis and the adoption of less risky driving behaviours, e.g. smoking, drinking and

speeding. It could also be an indication of a substitution effect towards cheaper means of transportation, e.g. cycling, walking, use of public transport and car-pooling, when economic conditions deteriorate.

4.5 Omitted variables

In order to test the validity of the adopted RD design, we test for discontinuities of other factors that can affect driving behaviour. Fuel prices could be considered as such. Therefore, evidence that fuel prices are smooth at the cutoff should provide reassurance regarding the estimated effects of the DST policy. We apply the same estimation strategy using the two most popular fuel products: petrol (unleaded 95 octane) and diesel. According to the European Automobile Manufacturers Association, 91.7% of the vehicle fleet in Greece was using petrol and 4.9% was using diesel in 2015, with the remaining vehicles using some alternative fuels. We obtained daily data from the Fuel Price Observatory of the Ministry of Economy and Development, regarding the national average prices for these two products. The data series cover the period between 01 January 2012 and 31 December 2016 (earlier time series were not available). We regressed the logged fuel prices on the usual set of time fixed effects and tested for any discontinuous jumps when entering or exiting DST. Table 6 displays the results. The estimated RD coefficients are quite close to zero suggesting that fuel prices evolve smoothly during transitions into and out of Summer Time.

[Table 6 about here]

Another factor related to vehicle accident counts is the amount of driving. It could be argued that exposure to driving adjusts to the supply of daylight, at least for certain time intervals within the day. For example, people might drive more for leisure when the extra hour of sunlight is allocated in the evening after the Spring transition, and drive less during the respective time

interval when falling back to Standard Time. Smith (2016) tests for such behavioural changes at the Spring transition using vehicle miles travelled (VMT) data for major highways in California due to the absence of appropriate data series at the national level. He found no evidence of a statistically significant discontinuity at the Spring cutoff. We are also constrained by the lack of national daily time series on road usage. The only available data were those provided by the Observatory Unit of the Egnatia Road, a major highway network on northern Greece and part of the European E90 highway system. For a large part of their network, Egnatia Road S.A. provided daily time series on road usage, in terms of number of vehicles passing through toll stations, covering the period between 01 January 2012 and 31 December 2016. However, no significant discontinuities were uncovered at the transition dates. The estimated RD parameters for the Spring and Fall transitions were 0.054 (standard error 0.035) and 0.012 (standard error 0.043), respectively, both of them being not statistically significant.

4.6 Implications

The estimated effects of DST on vehicle accident counts may have serious implications on health, healthcare and other services utilisation, productivity and foregone hours of work and personal time. Hence, the exact evaluation of the overall impact is difficult. However, we attempt some back-of-the-envelope calculations in order to quantify the estimated baseline impacts of DST transitions in terms of vehicle insurance claims. For this reason, we use information extracted from the Statistical Yearbooks for Motor Insurance published by the Hellenic Association of Insurance Companies (HAIC). Those reports are available online for the period after 2010. This enables us to compute the number of the total insurance claims costs that could be spared in the absence of the DST policy.

We start by performing this exercise for the case of minor accidents when leaving DST, because the quantification of the costs implied by more serious crashes is relatively more difficult as it incorporates costs that cannot be reliably measured and also because the baseline Spring

transition impact on minor accidents was not statistically significant. In order to consider only minor accidents, we used vehicle insurance claims, excluding those related to fire and theft, supposing a maximum settlement amount of 2,000 euros. Because the HAIC Yearbooks report the annual number of claims, we multiplied those figures with 14/365, i.e. using the number of days suggested by the bandwidth choice. The results are presented in Table 7. The number of total claims net of those related to fire and theft, in column 4, is multiplied by $1 - (e^b - 1)$, where b is the baseline effect for minor accidents in Table 3. According to the results there would be 2,082 fewer claims worth up to 2,000 euros for motor accidents each year, on average. Multiplying the annual claims differences (column 6) by the total amount of settlements for insurance claims worth up to 2,000 euros implies an average extra cost of nearly 1.45 million euros each year. Of course, these results are determined by the use of the total period DST impact, incorporating both periods before and during the crisis. Using the post-2010 estimate, i.e. $b = 0.037$ but not statistically significant (column 6 in Table 5; panel B), in order to match exactly with the period covered by the HAIC Statistical Yearbooks suggests that there would be nearly 638 extra claims for minor vehicle damages due to leaving DST, inducing extra costs of about 445 thousand euros per year, on average.

Similar back-of-the-envelope calculations using the baseline for serious accidents during the Spring transitions (using the baseline estimate in Table 3, i.e. -0.253) can be performed although it is difficult to assume the settlement amount for a serious, non-fatal crash. Assuming settlements between 2,001 euros and 50,000 euros (and an 18-day bandwidth), suggests that entering DST is associated with nearly 4.8 thousand fewer claims each year, hence generating annual cost savings of about 10.3 million euros, on average.[10] Combining the insurance claims implications for serious accidents when entering DST and minor accidents when leaving DST implies an average cost reduction of about 8.8 million euros per year from adopting/not abolishing a DST policy.

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[10] Full results for insurance claims implications of serious accidents are available upon request.

[Table 7 about here]

However, these are conservative and lower bound estimates of the costs to be spared. Passengers involved even in minor traffic accidents are likely to visit hospitals to check their health status, forgo hours of work due to the accident, engage in administrative procedures to cope with insurance reimbursements, and suffer post-traumatic stress. These events respectively imply healthcare costs to be sustained by the individual and/or the state, forgone earnings due to absence from work, increased vehicle insurance premia, payment of charges for driver misconduct, and monetary and non-monetary expenses related to mental health distress, e.g. decrease in productivity, greater anxiety etc. Lack of reliable data on these events restricts us from a proper quantification of the overall costs faced by individuals involved into vehicle accidents.

An alternative way of quantifying the cost implications of DST would be to use the monetary values for the prevention of traffic injuries by type (fatal, severe, slight) recommended by the Developing Harmonised European Approaches for Transport Costing and Project Assessment (HEATCO) report (Bickel et al., 2006). They valuate each accident by dividing into: (a) direct and indirect economic costs (medical and rehabilitation cost, legal administrative cost, production losses), (b) a value of safety per se (willingness to pay for safeguarding human life) and (c) material damage from accidents. The reports suggest material damage monetary values by accident type as reliable values for (a) and (b) are not easily available. Regarding Greece, for fatalities, severe injuries and slight injuries the estimated costs avoided are 836,000 euros, 109,500 euros and 8,400 euros, respectively (in 2002 prices). In order to quantify the impact of DST transitions using these monetary values, we re-estimated our preferred model specification using the daily count of people died, seriously injured and slightly injured instead of the daily accident counts. Table 8 reports the results. They are in line with what was reported in Tables 3 and 4 for the DST impact on the number of accidents; there is a negative effect on the number of seriously

injured in Spring and a positive effect on the slightly injured count in Fall transition. Using a data-driven 15-day bandwidth for serious injuries before the Spring transition, the total sum for the period 2006-2016 is 638 accidents. The reported estimate in Table 8 implies that there are 132 fewer seriously injured people in the post-Spring transition period. According to the HEATCO valuation for serious accidents, this translates into avoided costs of 14.5 million euros. Similarly, the positive and significant RD estimates for the count of slightly injured implies over their post-Fall transition number during the total period is increased by 889 injuries. Based on the HEATCO valuation for slight injuries, the implied extra casualty cost for this accident type is about 7.5 million euros.[11]

However, all these estimates should be seen as the classic "tip of the iceberg" of the total potential amount of road safety costs associated to time changes. Moreover, to the extent that our baseline estimates are driven by an ambient light conditions mechanism, they indicate the importance of developing and maintaining appropriate road infrastructure networks that facilitate a higher level of road safety.

5. Conclusions

Although it is reasonable to assume that ambient light conditions are critical to driving behaviour and road safety, there is scarce evidence to establish such a causal link – especially in the European context. This paper explores this relationship relying on the exogenous variations in ambient light conditions generated by obligatory seasonal clock changes in Greece (2006-2016). Following a mandated ex-post evaluation of the Directive governing transitions into and out of Summer Time, the EU Parliament recently voted for the abolishment of seasonal clock changes for their member countries. Regarding the implications for road safety, the report was based on a UK and a US study and suggested to consider possible negative effects of practising DST due to

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[11] These are also downward biased estimates because the valuations are based on 2002 prices.

sleep deprivation and ambient light condition effects. However, it also raised the question about the transferability of the findings of such studies to mainland EU countries.

In this work we have attempted a causal evaluation of the impact of DST on driving behaviour, measuring the latter through daily counts of various vehicle crash types. In light of the ongoing discussion on whether EU should abolish DST, our study is timely and it could provide useful insights, as we report results not only on fatal but also on serious and minor accidents, hence complementing the evidence on the increase in the number of fatal crashes in the US found by Smith (2016).

According to our findings, entering DST does not affect the number of total and minor accidents. The results suggest that when entering DST in Spring there is a significant reduction in the daily count of serious accidents. An analysis by hour of the day reveals that this reduction occurs during the day interval that is mostly affected by reallocating an hour of sunlight into the evening. Splitting the Summer Time period into an initial 5-day period and a remaining one confirms that a sunlight rather than a sleeping deprivation mechanism is in operation behind changes being observed during the Spring transition. There is a discontinuous jump right at the Spring cutoff date, but after the initial 5-day period the daily count of serious accidents does not revert back to its seasonal Standard Time level. Similarly, serious accidents are reduced during the morning hours that are mostly impacted when falling backwards to Standard Time during the Fall transition. There is also evidence about a positive DST effect on fatal accidents. However, those statistically significant estimates are found during night hours when minor and total accidents also seem to increase. There is also a positive and significant impact on minor crashes when leaving DST, again associated with the evening hours that are mostly affected by reallocating an hour of sunlight back in the morning. The falsification tests that we perform provide further reassurance regarding the validity of our baseline estimates and also test for discontinuities in other factors that are related to vehicle accidents, i.e. fuel prices and road usage. Finally, we show that the results are driven from the period before the economic crisis and the implementation of the austerity agenda.

We speculate that this can be attributed to smaller exposure to the amount of driving and shifts towards less risky behaviours, e.g. smoking, drinking and speeding, during more turbulent times; taking these risk factors into considerations is also quite relevant to the implementation of any policy encompassing at the same time road safety, public transportation and the healthcare provision related to road accidents.

Overall, our analysis suggests that adopting DST has rather small effects on the realisation of car crashes, and that these effects are different with respect to different categories of road accidents by severity. Further research is needed to assess the full cost implications in terms of temporary or long-lasting effects on physical and mental health as well as changes in productivity and labour-related outcomes due to injuries and legal implications. But on the basis of our results for Greece it emerges that changes in road accidents are not a strongly compelling reason either for the abolition or the adoption of DST. However, they offer some first empirical evidence regarding the importance and benefits that better ambient light conditions could have on overall road safety.
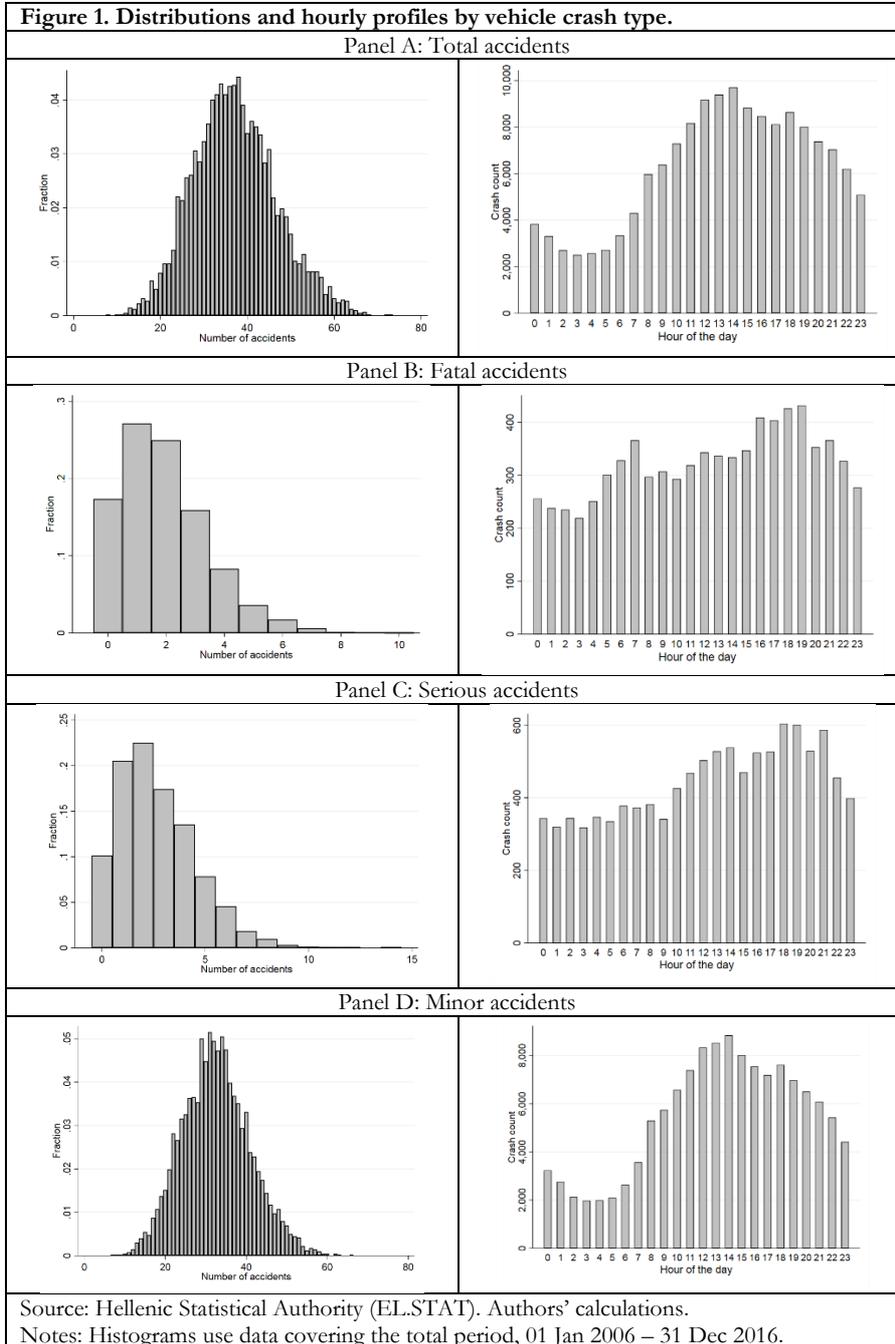
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Figures and Tables

Figure 1. Distributions and hourly profiles by vehicle crash type.

Panel A: Total accidents

Panel B: Fatal accidents

Panel C: Serious accidents

Panel D: Minor accidents

Source: Hellenic Statistical Authority (EL.STAT). Authors' calculations.

Notes: Histograms use data covering the total period, 01 Jan 2006 – 31 Dec 2016.

Figure 2. Mean crash count around the clock before and after each transition.

Panel A: Spring transition
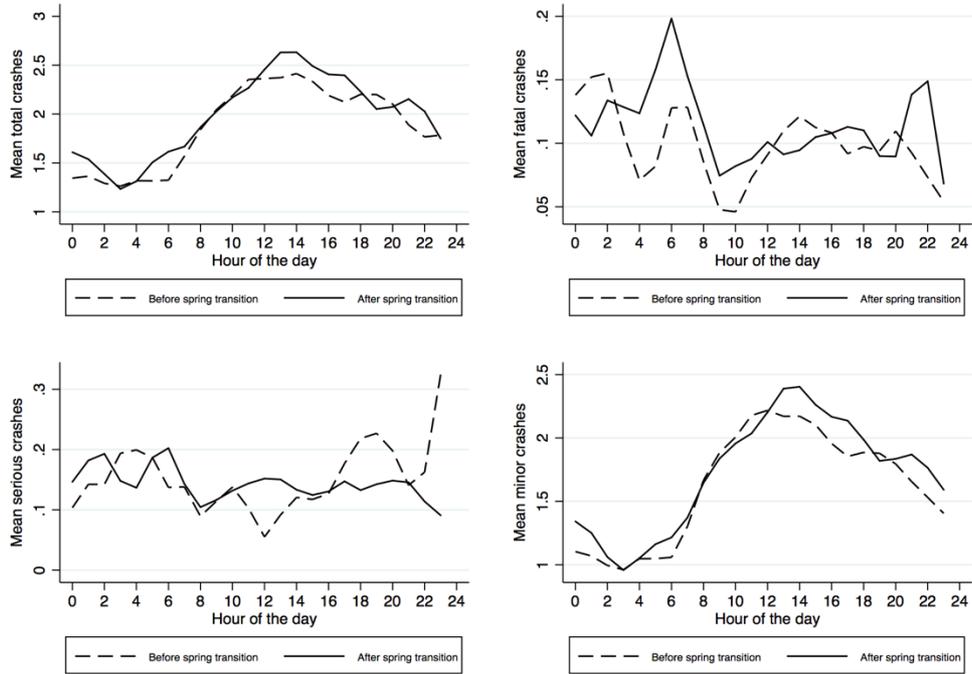
Panel B: Fall transition
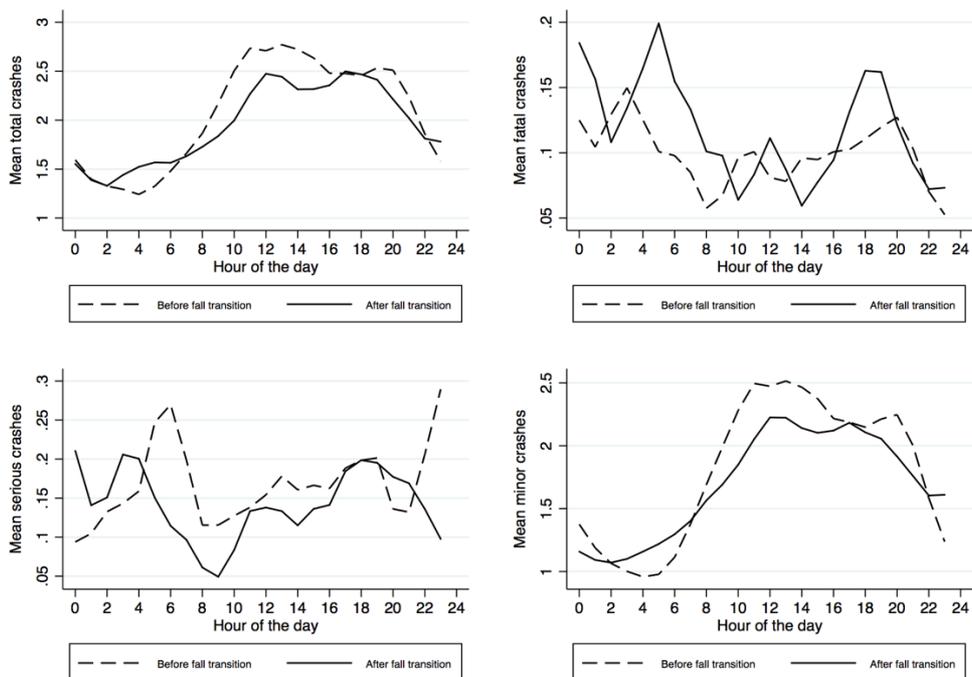
Source: Hellenic Statistical Authority (EL.STAT). Authors' calculations.
Note: Means correspond to 7-day averages on both sides of Spring and Fall transitions.

Figure 3. Sunrise and sunset times.
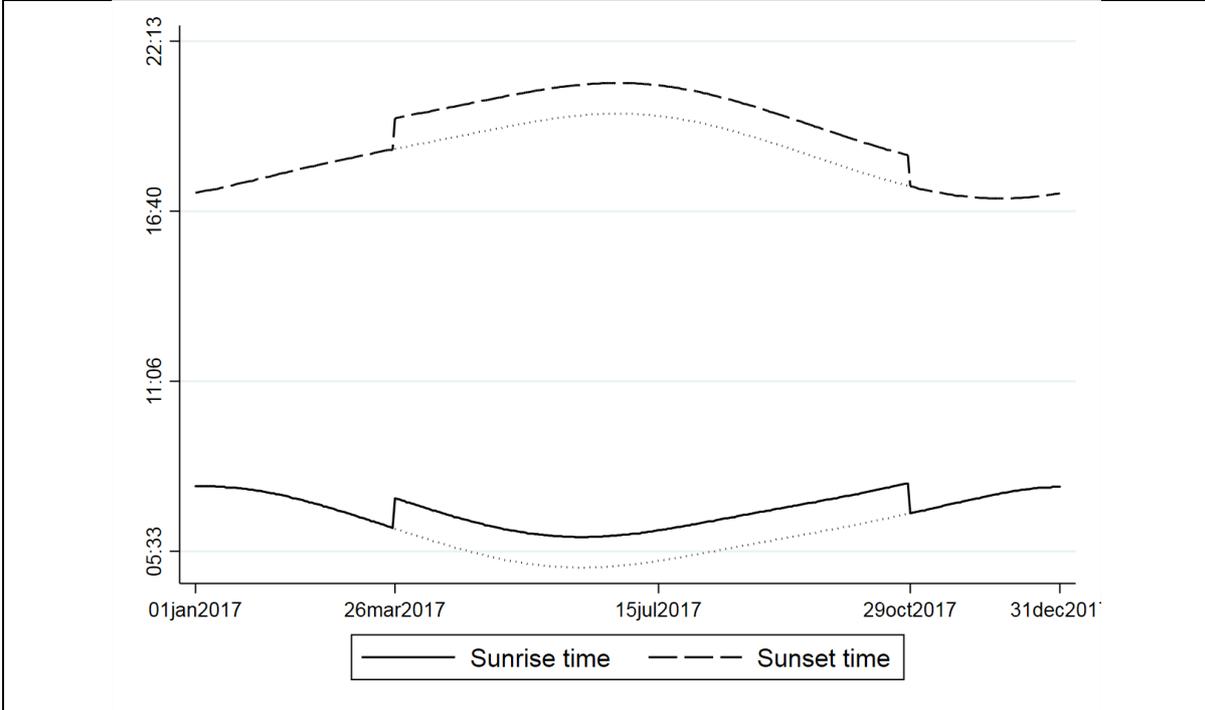
Source: www.meteo.gr.
Notes: Solid lines represent the actual sunrise and sunset times for 2017 (Athens city). Dotted lines represent the counterfactual sunrise and sunset times in the absence of the Daylight Saving Time practice.

Figure 4. Mean residual plots for the DST transition.
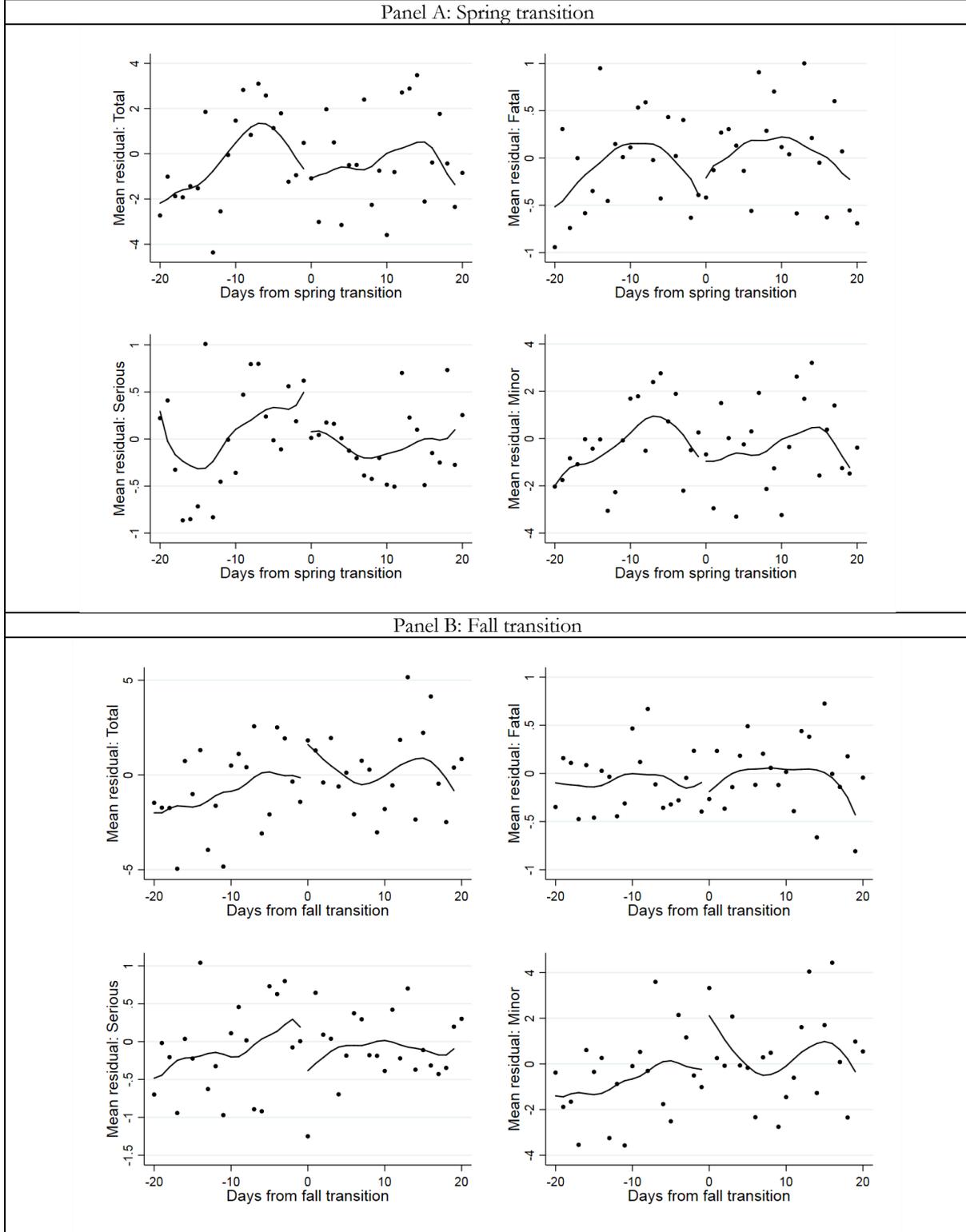
Panel A: Spring transition

Panel B: Fall transition

Source: Hellenic Statistical Authority (EL.STAT).

Notes: Dots represent the mean residuals, for the total period from 01 Jan 2006 to 31 Dec 2016, obtained after regressing the daily count of vehicle accidents on a set of day-of-week, year, month and public holiday fixed effects. Black lines are obtained from locally weighted regressions.

Figure 5. RD estimates using alternative bandwidths.

Panel A: Fatal crashes – Spring transition

Panel B: Serious crashes – Spring transition

Panel C: Minor crashes – Fall transition
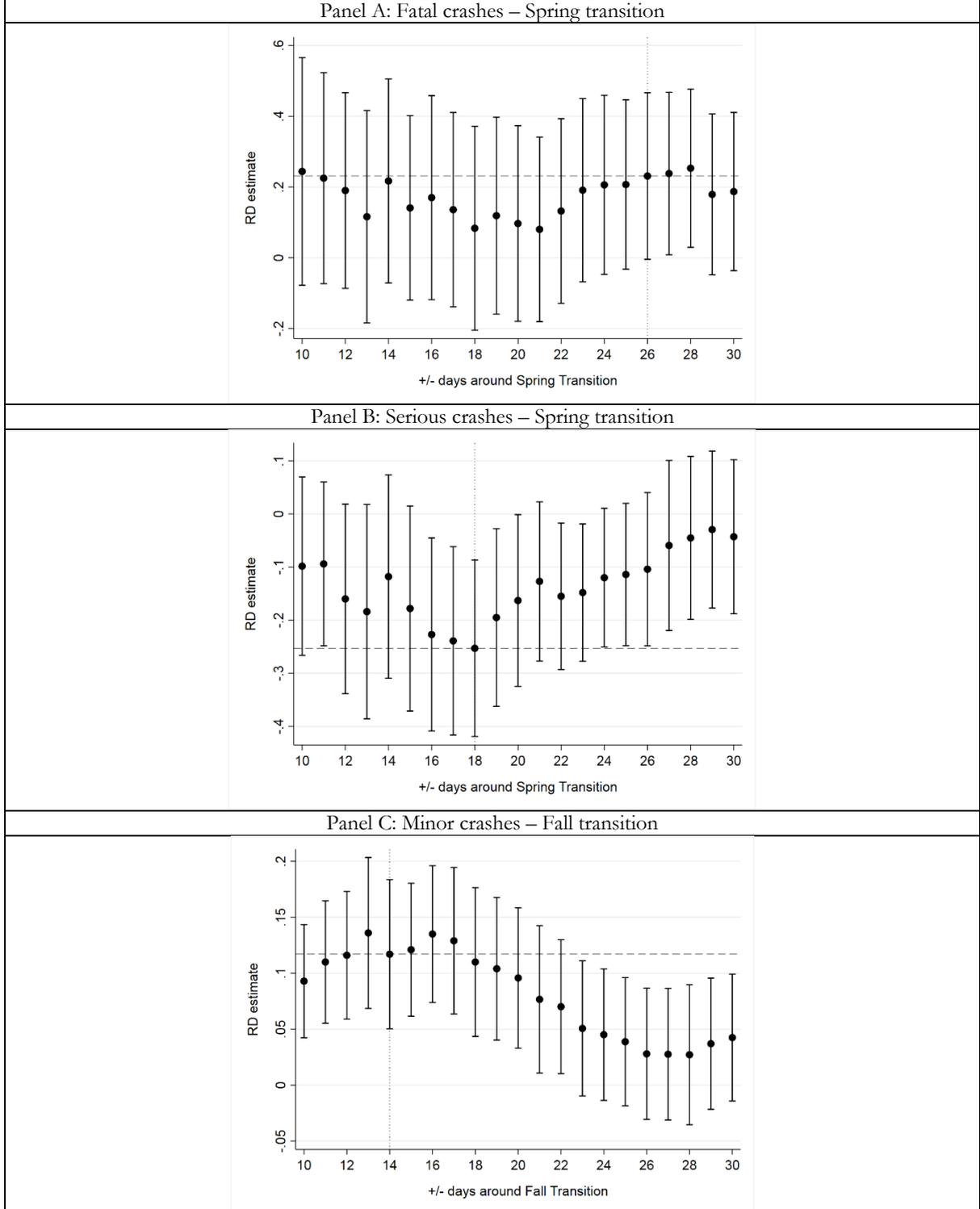
Source: Hellenic Statistical Authority (EL.STAT). Authors' calculations
Notes: Horizontal dashed line indicates the baseline effect reported in Columns (1) of Tables 3 and 4. Vertical dotted lines indicate the days around transition when using the optimal data-driven bandwidth.

Figure 6. Distribution of discontinuity parameters using placebo transition dates.
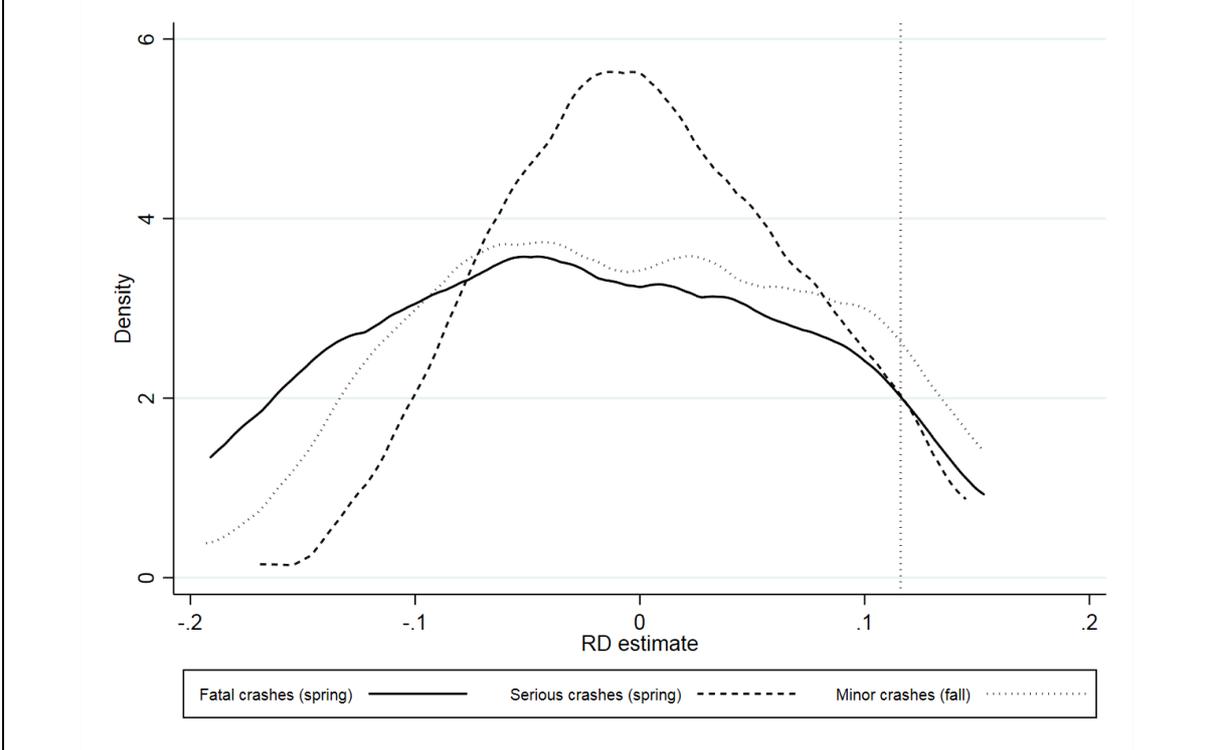
Source: Hellenic Statistical Authority (EL.STAT). Authors' calculations.
Notes: The density functions use an Epanechnikov kernel and represent the distribution of the estimated coefficients obtained from using placebo transition dates. Vertical lines represent the true effects obtained using the actual transition date (vertical lines for fatal and serious crashes lie well outside the respective distributions).

Figure 7. RD estimates of the impact of Spring transition around the clock.
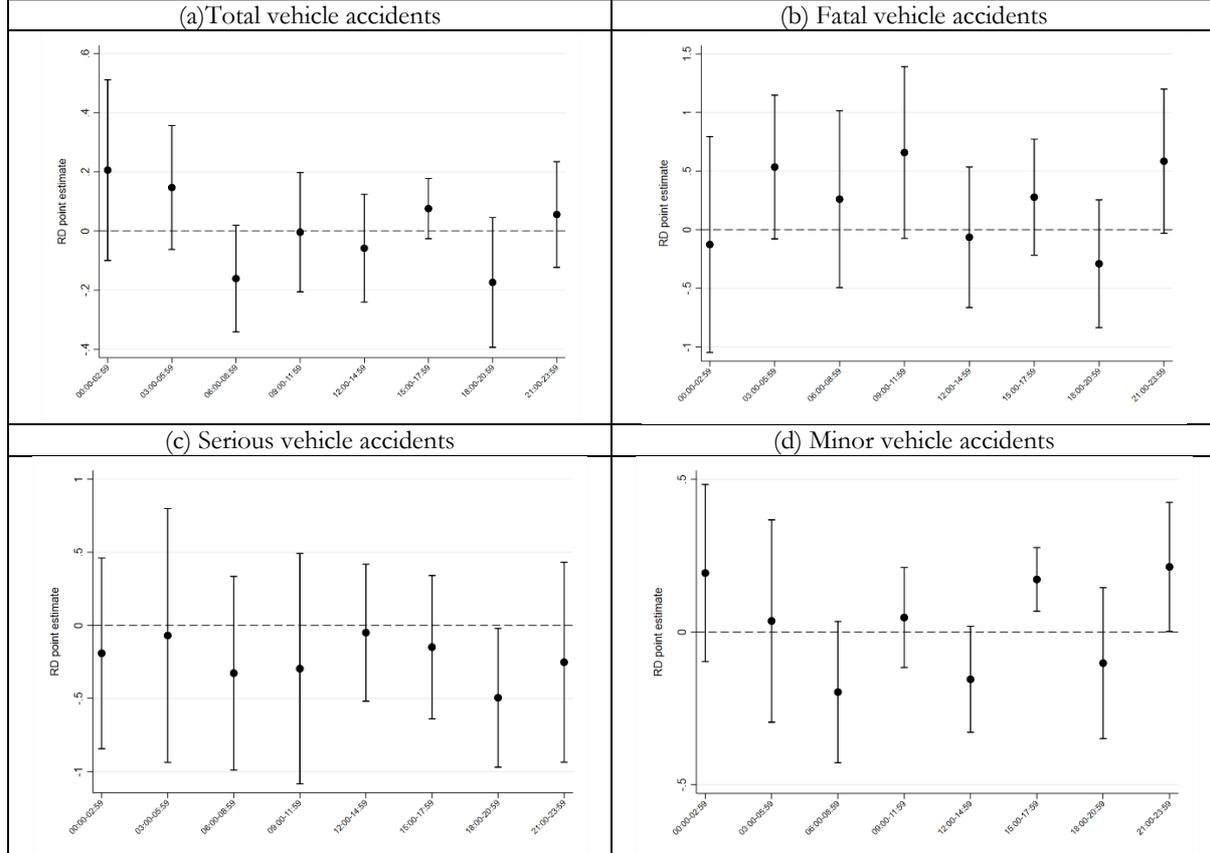
(a)Total vehicle accidents	(b) Fatal vehicle accidents

(c) Serious vehicle accidents	(d) Minor vehicle accidents

Source: Hellenic Statistical Authority (EL.STAT). Authors' calculations.

Notes: The dependent variable is the hour-specific daily accident count. All models control for day-of-week, year and public holiday fixed effects. Standard errors in parentheses are corrected for clustering by day from transition.

Figure 8. RD estimates of the impact of Fall transition around the clock.
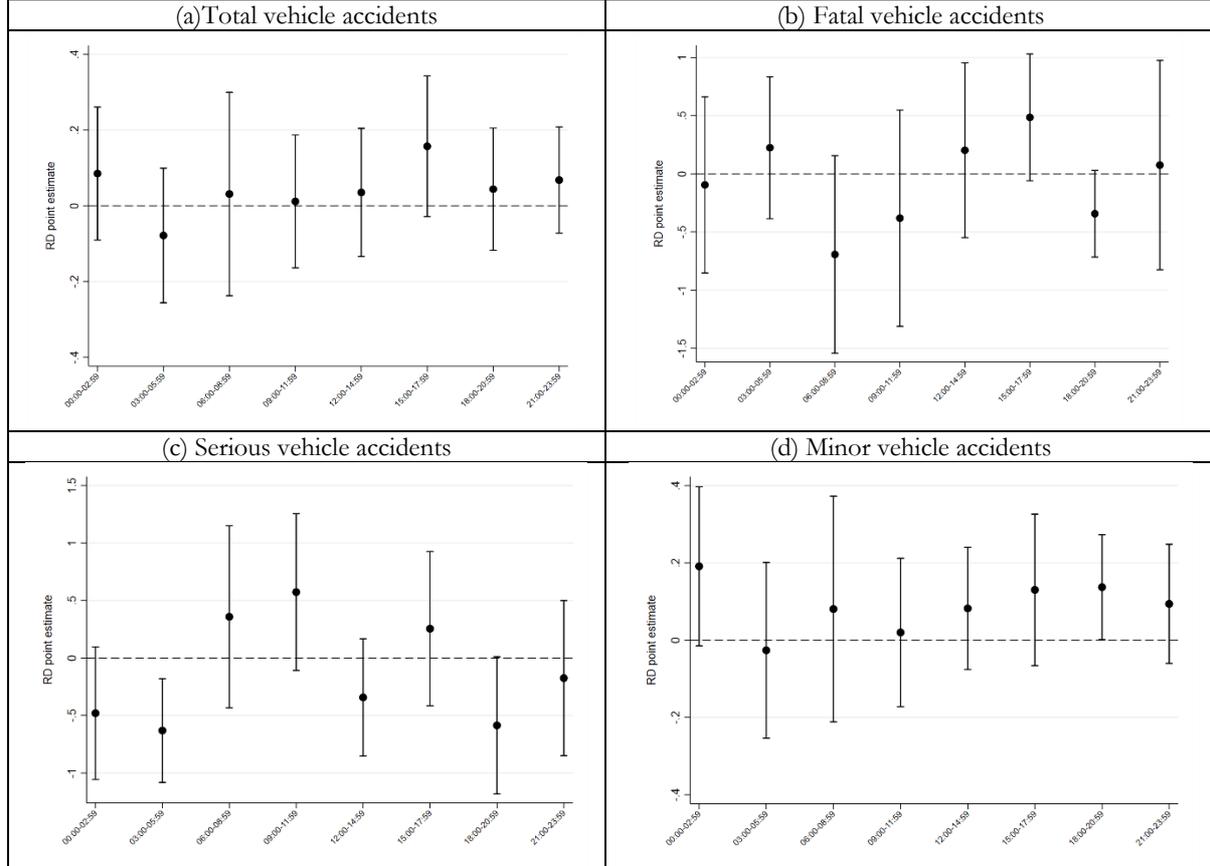
(a)Total vehicle accidents	(b) Fatal vehicle accidents

(c) Serious vehicle accidents	(d) Minor vehicle accidents

Source: Hellenic Statistical Authority (EL.STAT). Authors' calculations.

Notes: The dependent variable is the hour-specific daily accident count. All models control for day-of-week, year and public holiday fixed effects. Standard errors in parentheses are corrected for clustering by day from transition. ***, ** and * denote statistical significance at the 1%, 5% and 10% level, respectively.

Figure 9. Mean residual plots for the Spring transition: Testing for a sleep deprivation effect
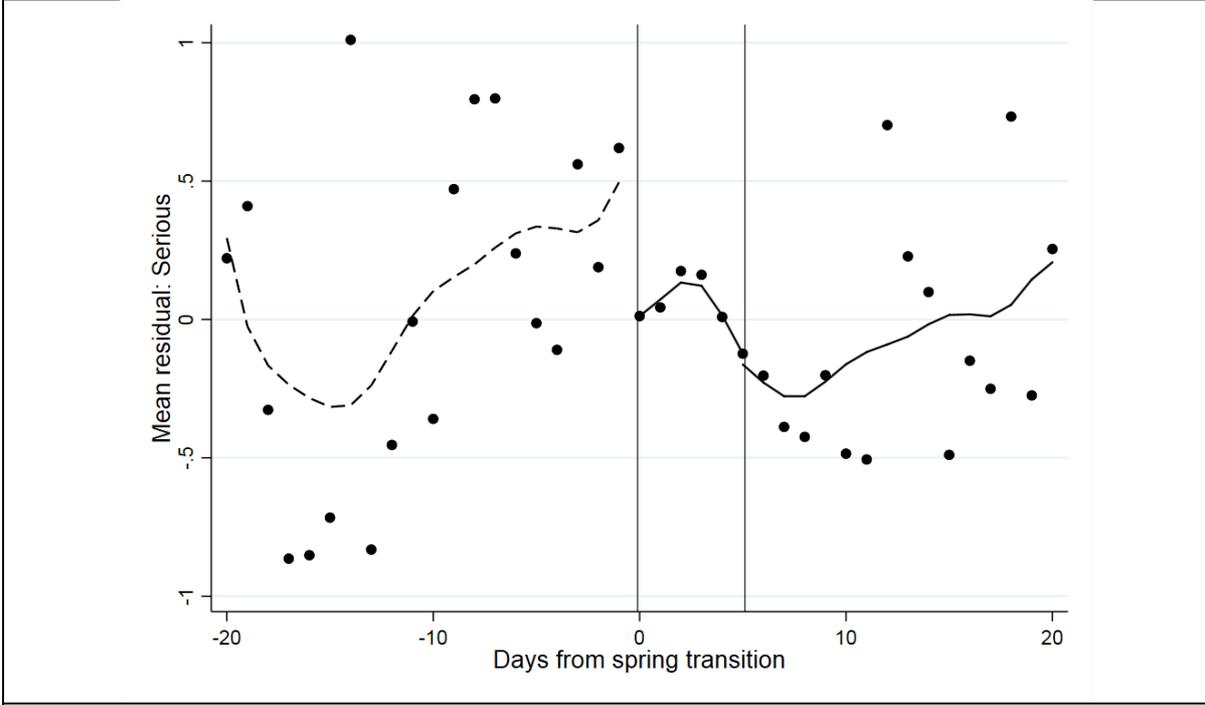
Source: Hellenic Statistical Authority (EL.STAT).
Notes: Dots represent the mean residuals, for the total period from 01 Jan 2006 to 31 Dec 2016, obtained after regressing the daily count of vehicle accidents on a set of day-of-week, year month and public holiday fixed effects. Black dashed and solid lines are obtained from locally weighted regressions.

Figure 10. Vehicle accidents over time.

(a) Total vehicle accidents	(b) Fatal vehicle accidents

(c) Serious vehicle accidents	(d) Minor vehicle accidents
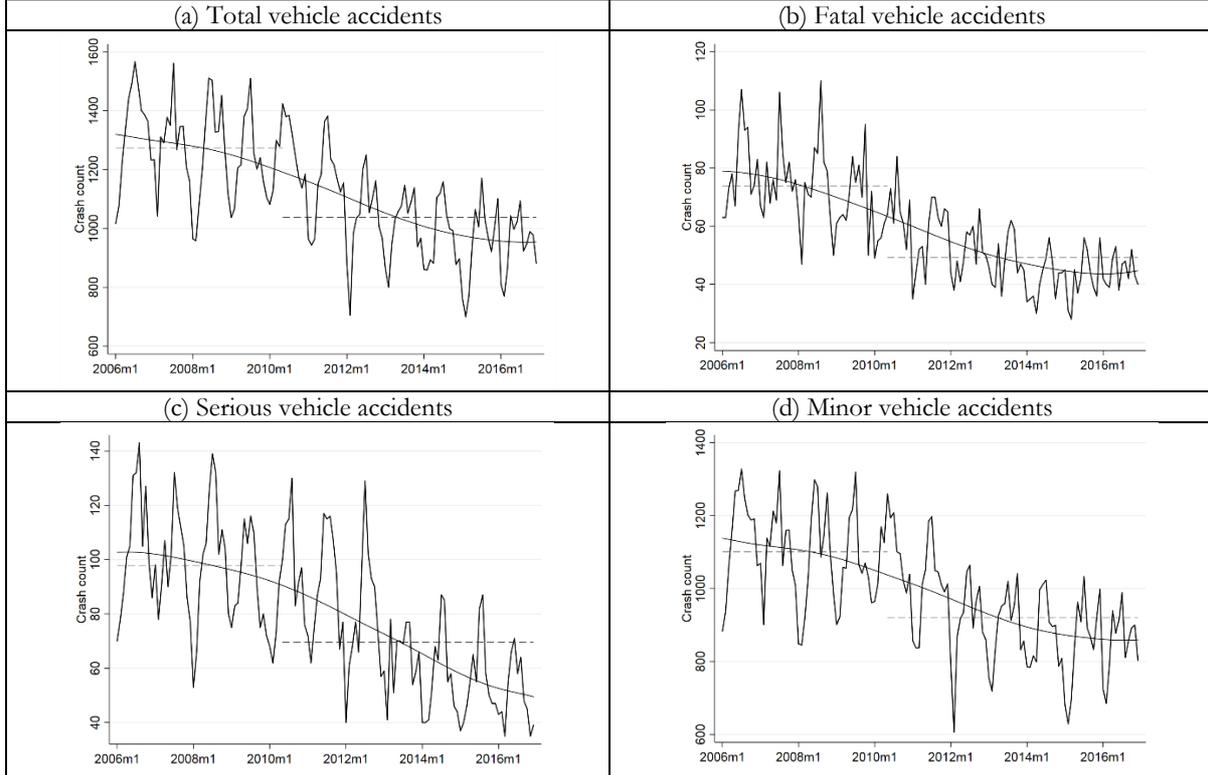
Source: Hellenic Statistical Authority (EL.STAT). Authors' calculations
Notes: Black lines are monthly totals. Smoothed lines are obtained from locally weighted regressions. Dashed lines are period-specific means, i.e. before and during the austerity period specified from May 2010 onwards.

Table 1. Descriptive statistics for accident variables.					
	Mean	Std. Dev.	Min.	Max.	Observations
	(1)	(2)	(3)	(4)	(5)
Total accidents	37.14	9.59	8	73	4,018
Fatal accidents	1.93	1.52	0	10	4,018
Serious accidents	2.65	1.87	0	14	4,018
Minor accidents	32.56	8.45	7	66	4,018
Source: Hellenic Statistical Authority (EL.STAT).					
Notes: Daily averages for the period between 01 Jan 2006 and 31 Dec 2016.					

Table 2. Mean accidents counts before and after transition.					
	First week	1 week before	1 week after	1 week before and after	2 weeks before and after
	(1)	(2)	(3)	(4)	(5)
Panel A: Spring transition					
Mean total crash count	33.74	34.77	37.42	36.09	36.05
t-test relative to 1st week	-	.505	.009	.061	.044
Mean fatal crash count	1.68	1.87	2.12	1.99	1.91
t-test relative to 1st week	-	.399	.053	.114	.212
Mean serious crash count	2.34	2.49	2.49	2.49	2.46
t-test relative to 1st week	-	.566	.520	.488	.565
Mean minor crash count	29.73	30.40	32.81	31.60	31.68
t-test relative to 1st week	-	.626	.017	.099	.056
Panel B: Fall transition					
Mean total crash count	37.25	38.08	35.00	36.54	37.31
t-test relative to 1st week	-	.573	.118	.578	.953
Mean fatal crash count	1.83	2.04	1.90	1.97	1.90
t-test relative to 1st week	-	.402	.782	.502	.708
Mean serious crash count	2.71	2.44	2.40	2.42	2.45
t-test relative to 1st week	-	.360	.320	.255	.255
Mean minor crash count	32.70	33.60	30.70	32.15	32.97
t-test relative to 1st week	-	.497	.123	.629	.796
Observations	77	77	77	154	308
Source: Hellenic Statistical Authority (EL.STAT). Authors' calculations.					

Table 3. RD estimates of the impact of Spring transition.				
	(1)	(2)	(3)	(4)
	Panel A: Total accidents			
RD estimate	-.016 (.040)	-.005 (.031)	-.031	-.035 (.038)
Kernel	Uniform	Triangular	Uniform	Triangular
Polynomial order	1	1	2	2
Days around transition	14	14	28	28
Observations	319	297	627	605
	Panel B: Fatal accidents			
RD estimate	.231* (.120)	.155 (.113)	.069 (.178)	.202 (.156)
Kernel	Uniform	Triangular	Uniform	Triangular
Polynomial order	1	1	2	2
Days around transition	26	26	24	24
Observations	583	561	539	517
	Panel C: Serious accidents			
RD estimate	-.253*** (.085)	-.169** (.074)	-.241*** (.083)	-.244*** (.087)
Kernel	Uniform	Triangular	Uniform	Triangular
Polynomial order	1	1	2	2
Days around transition	18	18	33	33
Observations	407	385	737	715
	Panel D: Minor accidents			
RD estimate	.010 (.041)	.006 (.032)	-.016 (.045)	-.029 (.038)
Kernel	Uniform	Triangular	Uniform	Triangular
Polynomial order	1	1	2	2
Days around transition	11	11	28	28
Observations	253	231	627	605

Source: Hellenic Statistical Authority (EL.STAT). Authors' calculations.
Notes: The dependent variable is the daily accident count. Models control for day-of-week, year and public holiday fixed effects. Standard errors in parentheses are clustered by day from transition. Asterisks ***, ** and * denote statistical significance at the 1%, 5% and 10% level, respectively.

Table 4. RD estimates of the impact of Fall transition.				
	(1)	(2)	(3)	(4)
	Panel A: Total accidents			
RD estimate	.079** (.037)	.084*** (.026)	.140*** (.042)	.112*** (.036)
Kernel	Uniform	Triangular	Uniform	Triangular
Polynomial order	1	1	2	2
Days around transition	14	14	25	25
Observations	319	297	561	539
	Panel B: Fatal accidents			
RD estimate	-.024 (.074)	-.148** (.060)	-.153 (.094)	-.112 (.082)
Kernel	Uniform	Triangular	Uniform	Triangular
Polynomial order	1	1	2	2
Days around transition	16	16	31	31
Observations	363	341	693	671
	Panel C: Serious accidents			
RD estimate	-.116 (.150)	-.106 (.161)	-.147 (.190)	-.210 (.191)
Kernel	Uniform	Triangular	Uniform	Triangular
Polynomial order	1	1	2	2
Days around transition	17	17	26	26
Observations	385	363	583	561
	Panel D: Minor accidents			
RD estimate	.116*** (.034)	.114*** (.024)	.172*** (.040)	.158*** (.036)
Kernel	Uniform	Triangular	Uniform	Triangular
Polynomial order	1	1	2	2
Days around transition	14	14	26	26
Observations	319	297	583	561

Source: Hellenic Statistical Authority (EL.STAT). Authors' calculations.
Notes: The dependent variable is the daily accident count. Models control for day-of-week, year and public holiday fixed effects. Standard errors in parentheses are clustered by day from transition. Asterisks ***, ** and * denote statistical significance at the 1%, 5% and 10% level, respectively.

Table 5. Impact of entering and exiting DST by crash factor, area type and period.						
	Bad weather	Drunk driving	Residential areas	Non-residential areas	Before crisis	During crisis
	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: Spring transition					
Fatal accidents	.405 (.338)	.168 (.365)	.244* (.134)	.218 (.196)	-.062 (.064)	.030 (.050)
Serious accidents	-.436 (.318)	.127 (.448)	-.347*** (.108)	-.063 (.216)	-.343* (.188)	.190 (.213)
Minor accidents	-.905*** (.283)	-.399*** (.120)	.048 (.044)	-.205*** (.078)	-.052 (.066)	.005 (.049)
	Panel B: Fall transition					
Fatal accidents	.484 (.464)	-1.340*** (.430)	.184 (.158)	-.265* (.152)	-.044 (.171)	.034 (.141)
Serious accidents	-.195 (.404)	-.702* (.376)	-.017 (.146)	-.315 (.292)	.091 (.253)	-.283 (.185)
Minor accidents	.454* (.263)	.418*** (.106)	.100** (.043)	.191** (.092)	.240*** (.063)	.037 (.038)
Prevalence	8.27%	7.79%	79.69%	20.31%	44.35%	55.65%

Source: Hellenic Statistical Authority (EL.STAT). Authors' calculations.
Notes: The dependent variable is the daily accident count by crash factor, area type and period. All models control for day-of-week, year and public holiday fixed effects and they are estimated over the bandwidth chosen for the baseline specifications. Standard errors in parentheses are corrected for clustering by day from transition. A uniform kernel is applied in all models. Asterisks ***, ** and * denote statistical significance at the 1%, 5% and 10% level, respectively.

Table 6. RD estimates on the impact of DST transitions on fuel prices.				
	Spring transition		Fall transition	
	Petrol	Diesel	Petrol	Diesel
	(1)	(2)	(3)	(4)
RD estimate	-.002 (.009)	-.001 (.011)	-.002 (.012)	-.001 (.016)
Kernel	Uniform	Uniform	Uniform	Uniform
Days around transition	16	21	12	13

Source: Ministry of Economy & Development; General Secretariat of Commerce and Consumer Protection; Fuel Prices Observatory. Authors' calculations.
Notes: Data cover the period between 01 January 2012 and 31 December 2016 (older series were not available). The dependent variable is daily price for each fuel product on a set of day-of-week, year and public holiday fixed effects. Standard errors in parentheses are clustered by day from transition. Asterisks ***, ** and * denote statistical significance at the 1%, 5% and 10% level, respectively.

Table 7. Estimates of insurance claims costs for minor accidents due to DST.						
Year	Total number of declared claims	Theft claims	Fire claims	Actual net total claims =(1)-[(2)+(3)]	Net total claims without DST	Difference due to DST =(4)-(5)	Estimated total cost (€) due to DST
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
2010	21,784	469	39	21,277	18,660	2,617	1,722,477
2011	20,197	525	37	19,636	17,221	2,415	1,590,423
2012	16,697	482	31	16,185	14,195	1,991	1,417,353
2013	15,737	389	24	15,324	13,439	1,885	1,391,358
2014	15,679	346	17	15,317	13,433	1,884	1,376,507
2015	15,481	359	18	15,104	13,246	1,858	1,359,461
2016	16,079	382	21	15,677	13,749	1,928	1,310,138

Source: Statistical Yearbook for Motor Insurance, 2010-2013 (Hellenic Association of Insurance Companies).
Notes: Column (5) is the counterfactual number of total claims in the absence of DST, computed as: Actual Net Total Claims×[1-(exp(0.116)-1)], where 0.116 is the baseline estimate for minor crashes during the fall transition date. Column (7) is column (6) multiplied by the total amount of settlements for insurance claims worth up to €2,000.

Table 8. RD estimates on the number of victims.			
	Fatalities	Serious injuries	Light injuries
	(1)	(2)	(3)
HEATCO value for each avoided casualty in Greece (2002 prices)	836,000 euros	109,500 euros	8,400 euros
	Panel A: Spring transition		
RD estimate	.091 (.102)	-.231* (.131)	.001 (.035)
Days around transition	22	15	16
Observations	495	341	363
	Panel B: Fall transition		
RD estimate	-.070 (.089)	-.218 (.150)	.126*** (.037)
Days around transition	17	14	13
Observations	385	319	297

Source: Hellenic Statistical Authority (EL.STAT). Authors' calculations.
Notes: The dependent variable is the daily victim count by accident type. Models control for day-of-week, year and public holiday fixed effects. Standard errors in parentheses are clustered by day from transition. First order polynomials of the running variable on both sides of the transition dates are used. Asterisks ***, ** and * denote statistical significance at the 1%, 5% and 10% level, respectively.