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Spring Forward at Your Own Risk: Daylight Saving Time and Fatal Vehicle Crashes

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Abstract

Despite mounting evidence that Daylight Saving Time (DST) fails in its primary goal of saving energy, some form of DST is still practiced by over 1.5 billion people in over 60 countries. I demonstrate that DST imposes high social costs on Americans, specifically, an increase in fatal automobile crashes. DST alters fatal crash risk in two ways: disrupting sleep schedules and reallocating ambient light from the morning to the evening. First, I take advantage of the discrete nature of the transitions between Standard Time and DST to measure the impact of DST on fatal crashes in a regression discontinuity design. Then, to measure the duration of the effect, I exploit variation in the coverage of DST created primarily by a 2007 policy change, in a day-of-year fixed effects model. Both models reveal a short-run increase in fatal crashes following the spring transition and no aggregate impact in the fall. Employing three tests, I decompose the aggregate effect into ambient light and sleep mechanisms. I find that shifting ambient light reallocates fatalities within a day, while sleep deprivation caused by the spring transition increases risk. The increased risk persists for the first six days of DST, causing a total of 302 deaths at a social cost of $2.75 billion over the 10-year sample period, underscoring the huge costs of even minor disruptions to sleep schedules. JEL Codes: R41, I18, Q48

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1 Introduction

Daylight Saving Time (DST) in the US was originally implemented as a wartime measure to save energy and was extended as part of the Energy Policy Act of 2005. However, recent research demonstrates that DST does not save energy and could possibly increase energy use (Kellogg and Wolff, 2008; Kotchen and Grant, 2011). Despite mounting evidence that DST fails in its primary goal, some form of Daylight Saving Time is still practiced by over 1.5 billion people globally. In this paper I demonstrate that DST imposes high social costs on Americans, specifically, an increase in fatal automobile crashes. Employing three tests to differentiate between an ambient light or sleep mechanism, I show that this result is most likely due to sleep deprivation caused by the spring transition and the result implies additional costs of DST in terms of lost productivity nationwide.

The procedure for DST is well characterized by the phrase "spring-forward, fall-back." Each year on the spring transition date, clocks are moved forward by one hour, from 2 a.m. to 3 a.m. The process is then reversed for the fall transition with clocks "falling back" from 2 a.m. to 1 a.m. This alters the relationship between clock time and solar time by an hour, effectively moving sunlight from the morning to the evening (see Figure 1). The procedure was first suggested by George Vernon Hudson, an entomologist who wanted more light in the evenings to pursue his passion of collecting insects (Hudson, 1895). While the policy was first used during World Wars I and II, it has since become a peacetime measure. In all instances, the rationale has been that aligning sunlight more closely with wakeful hours would save energy used for lighting.[1] However, as Hudson's personal motivation for the policy suggests, DST has many impacts on practicing populations.

This paper focuses on a major side-effect of DST, its impact on fatal vehicle crashes. DST alters the risk of a fatal crash in two ways: disrupting sleep schedules and reallocating ambient light from the morning to the evening. With an average of over 39,000 annual fatalities, motor vehicle crashes are the number one cause of accidental death in the US (CDC, 2005-2010). Given the large base level of fatalities, even a small change in fatal crash risk is a potentially large killer. I identify the impact of DST on fatal crashes by taking advantage of (i) detailed records of every fatal crash occurring in the United

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[1] DST is often mistakenly believed to be an agricultural policy. In reality, farmers are generally against the practice of DST because it requires them to work for an extra hour in the morning, partially in darkness, to coordinate with the timing of markets (Prerau, 2005).

sleep mechanism. Second, I isolate the sleep mechanism in the spring by examining a subsample of hours furthest from sunrise and sunset. These hours are least impacted by the light mechanism and a drowsy driver is presumably more at risk throughout the entire day, even in hours of full light or full darkness. Third, I compare the sleep impacted days of DST (up to the first two weeks) to the remainder of DST with common support.[5] All three tests suggest that the sleep deprivation is driving the increase in fatal crashes.

My preferred specification reveals a 6.3% increase in fatal crashes, persisting for six days following the spring transition. Over the 10-year sample period, this suggests the spring transition is responsible for a total of 302 deaths at a social cost of $1.2 to $3 billion, underscoring the huge costs of even minor disruptions to sleep schedules given the current sleep-deprived culture in the US.[6,7] The total costs of DST due to sleep deprivation could be orders of magnitude larger when worker productivity is considered (Wagner et al., 2012; Kamstra, Kramer, and Levi, 2000).[8]

This finding is timely, given the recent empirical research suggesting that DST does not reduce energy demand. Kellogg and Wolff (2008) use a natural experiment in Australia where DST was extended in some states to accommodate the Sydney Olympics. They find that while DST reduces energy demand in the evening, it increases demand in the morning with no significant net effect. Kotchen and Grant (2011) make use of quasi-experiment in Indiana where some Southern Indiana counties did not practice DST until 2006. Their work suggests that DST could actually increase residential energy use, as increased heating and cooling use more than offset the savings from reduced lighting use. For a failed energy policy to be justified from a welfare standpoint, the social benefits must outweigh the social costs. In this paper, I find a significant mortality cost that must be weighed against any perceived benefits of DST.

The remainder of the paper is organized as follows. The next section provides a brief background of DST in the US. Section 3 details the mechanisms through which DST influences crash risk, including reviewing existing evidence of the impact of DST on vehicle crashes. Section 4 introduces the data, highlighting the visual discontinuity in raw

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crash counts at the spring transition. Section 5 describes the RD and FE identification strategies, outlining the requirements for causal estimates. Section 6 presents results, including those that differentiate between the sleep and light mechanisms, and explores alternative explanations. Section 7 concludes with a brief summary and further remarks about the implications for DST as a policy.

2 Daylight Saving Time in the US

Daylight Saving Time has been a consistent feature in most US states since the Uniform Time Act of 1966.[9] This legislation allowed states to determine whether they practiced DST, but set uniform start and stop dates for any practicing states. Since 1966, Congress has twice made lasting changes to the DST transition dates, most recently as part of the Energy Policy Act of 2005. Starting in 2007, DST begins on the second Sunday of March and continues until the first Sunday of November, a 3-4 week extension in the spring and a 1 week extension in the fall.

Figure 1 illustrates the impact of DST on sunrise and sunset times throughout the year and highlights the 2007 extension. On the spring transition date, clocks skip forward from 2 to 3 a.m. pushing sunrise and sunset times back by one hour. In the fall, the process is reversed as clocks are adjusted back by an hour to facilitate the return to Standard Time. The 2007 extension to DST altered these transition dates and created an additional range of dates that are DST in some years and Standard Time in others.[10] In the next section, I discuss the primary mechanisms through which DST could influence fatal crash risk and how I disentangle the relative contributions of each.

3 Mechanisms

There are two mechanisms through which Daylight Saving Time could impact fatal crash risk. First, there is sleep loss associated with the spring transition when one hour the mapping of solar time to clock time by an hour, reallocating sunlight between the morning and the evening. Ambient light reduces fatal crash risk (Fridstrom et al., 1995; Sullivan and Flannagan, 2002), and this reallocation of light within a day creates riskier morning driving conditions and less risky evening driving conditions during DST.[11] I next discuss each mechanism individually, outlining its likely effect on fatal crashes and reviewing existing evidence of its impact through DST.

3.1 Sleep Mechanism

The spring transition into DST is facilitated by clocks jumping forward from 2 a.m. to 3 a.m. on the transition date. This creates a 23-hour transition day, rather than the standard 24-hour days people are accustomed to. While this missing hour could be cut from work or leisure time, Barnes and Wagner (2009) find that Americans make up the majority of the missing time by sleeping less. Using the American Time Use Survey, they find Americans sleep an average of 40 minutes less on the night of the spring transition. Depending on the individual, this transition could impact sleep patterns for anywhere from two days to two weeks (Valdez et al., 1997) with an average of about one week (Harrison, 2013).

In the fall, the opposite scenario occurs with a 25-hour transition day. However, in this case, Americans use very little of the extra hour for sleep, sleeping a statistically insignificant extra 12 minutes (Barnes and Wagner, 2009). This creates variation in treatment status for the sleep mechanism. The spring transition is treated (sleep loss), while the fall transition is untreated (insignificant change to sleep quantity).[12]

Previous research on the sleep impact of DST on vehicle crashes has been mixed. Coren (1996) and Varughese and Allen (2001) find an increase in crashes on the Monday following the spring transition into DST, while Sood and Ghosh (2007) and Lahti et al. (2010) suggest no effect. By focusing on one day, these tests can lack power and often cannot rule out a wide range impacts. In contrast to these studies, I gain statistical power by testing for a longer term sleep impact consistent with recent literature on sleep disruptions.

Additionally, these previous studies use data centered in 1992, 1985, 1987 and 1994 respectively. Average sleep quantity has been on the decline in the US, a phenomenon also seen in the lower tail of the distribution. According to the National Sleep Foun-

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[11] When switching out of DST in the fall, the mornings become less risky and evenings more risky than under DST.

[12]

Measurement System (PeMS) to examine whether adjustments to VMT are driving my results. To the extent that VMT on this subset of roads is representative of US driving patterns, this provides a useful test. In the national sample, I use weekly gasoline prices from the U.S. Energy Information Administration and the value of the S&P 500 index to help control for fuel prices and driving patterns.

5 Empirical Strategy

5.1 Regression Discontinuity (RD) Methods

bandwidth selector to determine how many days to use on either side of the DST transition and a uniform kernel. As Imbens and Lemieux (2008) argue, there is little practical benefit to other weighting schemes as they are primarily indicative of sensitivity to the bandwidth choice. For robustness I include results using alternative bandwidth selectors and Epanechnikov and triangular kernels.

In this context, a consistent estimate requires that conditional on day of the week and year, the treated and untreated number of fatal car crashes must vary continuously with date around the transition. Stated differently, if all other factors affecting fatal crash risk, besides DST, are continuous at the transition date, the RD design will provide consistent estimates of the effect of DST. Figures 4 and 5 begin to speak to this assumption, Time during the spring and their frequency under each regime. During the fall there is a similar, but smaller, region of switching dates because the fall transition date was only pushed back by one week.

Moving to a fixed effects framework, I run the following specification to take advantage of this variation in DST assignment:

$$\begin{aligned} \ln \mathrm{Fatals}_{dy} = {} & \beta_0 + \beta_1 \mathrm{SpDST}_{dy} + \beta_2 \mathrm{FaDST}_{dy} + \mathrm{DayofYear}_d \\ & + \mathrm{DayofWeek}_{dy} + \mathrm{Year}_y + V_{dy} + \varepsilon_{dy} \end{aligned} \qquad (2)$$

$\mathrm{DayofYear}_d$ is a separate dummy for each day of the year, flexibly controlling for the impact of seasonality on fatal crashes.[20] $\mathrm{DayofWeek}_{dy}$ and Year_y are day-of-week and year dummies respectively. V_{dy} is a vector of controls used in some specifications, including gasoline prices, the value of the S&P 500 index and non-stationary holidays. SpDST_{dy} is an indicator equal to one if the date falls under DST and is covered by the range of spring switching dates (March 8th - April 7th). Analogously, FaDST_{dy} is an indicator equal to one if the date falls under DST and is covered by the range of switching dates in the fall (Oct 25th - Nov 7th). These are the coefficients of interest and are interpreted as the average effect of DST on fatal crashes over the switching dates in that season.

Note, that b_1 here is a different parameter from what is found using the RD design. Regression discontinuity estimates the effect of DST right at the spring transition, whereas the fixed effects specification measures the average effect of DST over all dates that are sometimes DST and sometimes Standard Time during the spring. If DST only creates a short-run effect through sleep deprivation, this should be picked up in the RD, but would be averaged out across the full range of switching dates when using the fixed effects model. Likewise, b_2 is the average effect of DST across the roughly two weeks of fall switching dates, rather than the effect of leaving DST in the fall.

Beyond identifying the average effect of DST across the range of switching dates, this specification can aid in disentangling the mechanisms. I isolate the light mechanism in the spring, by focusing only on dates at least two weeks following the transition, at which time any sleep impact should have dissipated. Comparing this light impact to the initial impact from light and sleep provides another measure for just the sleep impact.

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[20] I create dummies for each month/day combination (e.g. an August 25th dummy). This is slightly different than creating a dummy for the 100th day of the year, because leap day would cause August 25th for most years to be matched with August 24th for 2004 and 2008. I use the month/day method as it better aligns with holidays and generates more conservative estimates.

6 Results

6.1 Spring RD Design

Figure 4 illustrates the regression discontinuity strategy for estimating the impact of DST on fatal crashes. The average residuals from a regression of log(daily fatal crash count) on day-of-week and year dummies are plotted, centered by the spring transition date. The plot follows a gradual arc demonstrating the seasonal pattern in fatal crashes, where crashes rise from winter lows, peaking in late summer before dropping again through the fall. If DST has an impact on fatal crashes, this should be evident in a trend break right at the transition date. Visually, there is a short-term spike in fatal crashes before the residuals resume the seasonal trajectory.

Table 1 shows the corresponding regression estimates.[21] The spring transition into DST is associated with a 6.3% increase in fatal crashes. This result persists using the bandwidth selectors of Imbens and Kalyanaraman (2012) and the cross-validation method of Ludwig and Miller (2007) seen in columns 2 and 3 respectively. To test whether the increase is due to one particular transition rule, I split the data into an early subsample (2002-06) that was subject to the April transition, and a late subsample (2007-2011) that is subject to the current March transition. While cutting the sample in half reduces precision, both time periods experience similar increases in fatal crashes at the transition.[22]

To address the possibility that both transition dates are associated with an increase in fatal crashes, unrelated to DST, I run the following placebo test in column 6. I assign the current transition date to 2002-2006 data and the old transition date to the 2007-2011 data. Running the same RD strategy measures the impact of these transition dates in years where there was no actual shift between Standard Time and DST on these dates. If these dates, rather than DST are responsible for the increased crash counts, this test should reveal a similar increase in crashes to those seen in columns 1-5. The zero result in column 6 suggests that the increase in crashes is not simply due to the

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[21] Clustering by week or year tends to decrease standard errors as the shocks are negatively correlated, so I report the more conservative uncorrected standard errors.

[22] Due to small sample size (pedestrian and pedacycle accidents account for only 15% of my sample), I am unable to address the question of whether pedestrians, or school-children in particular, would experience an even larger increase in the risk of being hit by a vehicle due to the darkened mornings of DST. Using the same RD design on this limited sample yields imprecise point estimates of similar magnitude to those using the full sample.

transition dates, but due to the actual policy.[23]

To address the concern that my results are driven by how I adjust the crash count for the transition date, I run two additional specifications. First, I follow the method used by Janszky et al. (2012) and multiply the the crash count on the transition date by 24/23rds to calibrate for the shorter time period. Alternatively, I throw out the transition date altogether. In both cases, results are qualitatively identical to my main specification (see Table A1). The remainder of Table A1 shows that results are robust to alternative kernel choice, while Table A2 shows they are robust to using a global polynomial RD design. Overall, these results demonstrate that spring transition into

net impact through DST. Crashes are simply reallocated between the morning and the study suggests a sleep impact could persist; and (iii) the remainder of spring DST with common support, days in which only the light mechanism should remain present.

Beginning with the entire spring period, column 1 shows that spring DST is associated with a significant 3.4% increase in fatal crashes over the roughly one month of switching dates. The fall estimate is insignificant from zero, again suggesting no impact of DST in the fall.[28]

6.5 Alternative Explanations

A key omitted variable in this analysis and previous studies is Vehicle Miles Traveled (VMT). If VMT increases at the DST transition date, this behavioral change could be driving results rather than sleep loss. While national VMT data is not available, the Performance Measurement System (PeMS) in California tracks VMT on many major highways within the state. Using the same regression discontinuity model from equation 1 with log(VMT) as the dependent variable yields an insignificant 0.016% increase in VMT. To the extent that driving habits on these California roadways are representative of national driving patterns, this suggests VMT is not the cause of increased crashes.

Adverse weather conditions increase the risk of fatal crashes (Fridstrom et al., 1995). Although weather is a pseudo-random phenomena, if adverse weather occurred just following the spring transition, this could lead to the short-term increase in fatal crashes. Using a FARS variable that indicates weather conditions at each fatal crash, I create a variable for the ratio of crashes within a day that are impacted by weather. Using the regression discontinuity model from equation 1 with weather-ratio as the dependent variable I find an insignificant 1.2 percentage point decrease in weather related crashes[30].

This analysis suggests that some of the most likely alternative pathways cannot explain the increase in fatal crashes. Further, if the increase is due to adjusting to a new schedule, the same increase should occur immediately following the fall transition, a phenomena that we do not see. While this is not an exhaustive list of competing explanations, the balance of evidence points strongly towards DST increasing fatal crash risk, through the mechanism of sleep deprivation. In the next section, I explore whether this result varies by region.

6.6 Geographical Heterogeneity

At the national level, the spring transition into DST leads to a significant increase in fatal crashes. However, this could be due to a constant treatment effect where all regions experience the same 6% increase in crashes, or a heterogeneous treatment effect where some regions experience a larger increase and others experience little or no effect. In this section, I explore two pathways through which geography could lead to heterogeneous impacts of DST, one through the sleep mechanism and the other through the light mechanism.

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[30] The residual plots and regression output for both of these alternative explanations are available in the appendix.

7 Conclusion

Daylight Saving Time is one of the most practiced policies across the globe, impacting over 1.5 billion people. Despite this worldwide coverage, many of the impacts of DST remain empirical questions. I exploit the discrete nature of transitions between Standard Time and DST, and variation in the coverage of DST created primarily by a 2007 policy change, to estimate the impact of DST on fatal vehicle crashes. My main finding is that the spring transition into DST increases fatal crash risk by 5.4-7.6%.

I employ three tests to determine whether this result is due to shifting of ambient light or sleep deprivation caused by the 23-hour transition date. These tests reveal that while ambient light reallocates risk within a day, it does not contribute to the increase in crashes. All three tests suggest that the sleep deprivation is driving the increase in fatal crashes. Consistent with literature investigating the impact of DST transitions on sleep, the impact persists for the first six days of DST. Back of the envelope calculations suggest that over the ten year study period, DST caused 302 deaths at a social cost of \$2.75 billion.[34]

In terms of DST, this result should be viewed as one piece of the puzzle, to be examined in conjunction with research on other impacts of DST. In previous research, when a benefit of DST is found it tends to be through the light mechanism. More light in the evening has benefits at reducing crime (Doleac and Sanders, 2013) and encouraging exercise (Wolff and Makino, 2013).[35] When costs are found, similar to my study, it tends to be due to sleep loss or disruptions associated with transitions (Janszky et al., 2012). Taking these points in combination, an ideal policy solution would leave the benefits of DST intact while eliminating the damage caused by the spring transition. Before a significant policy change is made, further research should be conducted on the welfare effects of the policy.

Finally, this paper fits into the small but growing literature examining the impact of sleep on worker productivity (Kamstra, Kramer, and Levi, 2000; Lockley et al., 2007; Barnes and Wagner, 2009; Wagner et al., 2012). Although fatal vehicle crashes are an extreme measure of productivity, driving is an activity that over 90% of American work-

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[34] Social cost is calculated as follows: Multiplying the 5.6% increase found in the FE model by the 489.3 fatal crashes averaged on Sundays-Fridays in March and April yields 27.4 additional fatal crashes per year. Multiplying this by the 1.104 fatalities per crash observed over my sample and the 10 year study period yields and extra 302 deaths over 10 years. Applying the Department of Transportation's \$9.1 million value of a statistical life, this a \$2.75 billion social cost.

[35] One concern about DST is that morning rise time relative to sunrise time is an important factor in clinical depression (Olders, 2003).

ers engage in (Winston, 2013) and DST provides an exogenous shock to sleep quantity. The increased risk of a fatal vehicle crash suggests significant costs of sleep deprivation, even when undertaking a routine task. Given the ongoing trend towards less sleep, particularly among full-time workers (Knutson et al., 2010), it is important that re-

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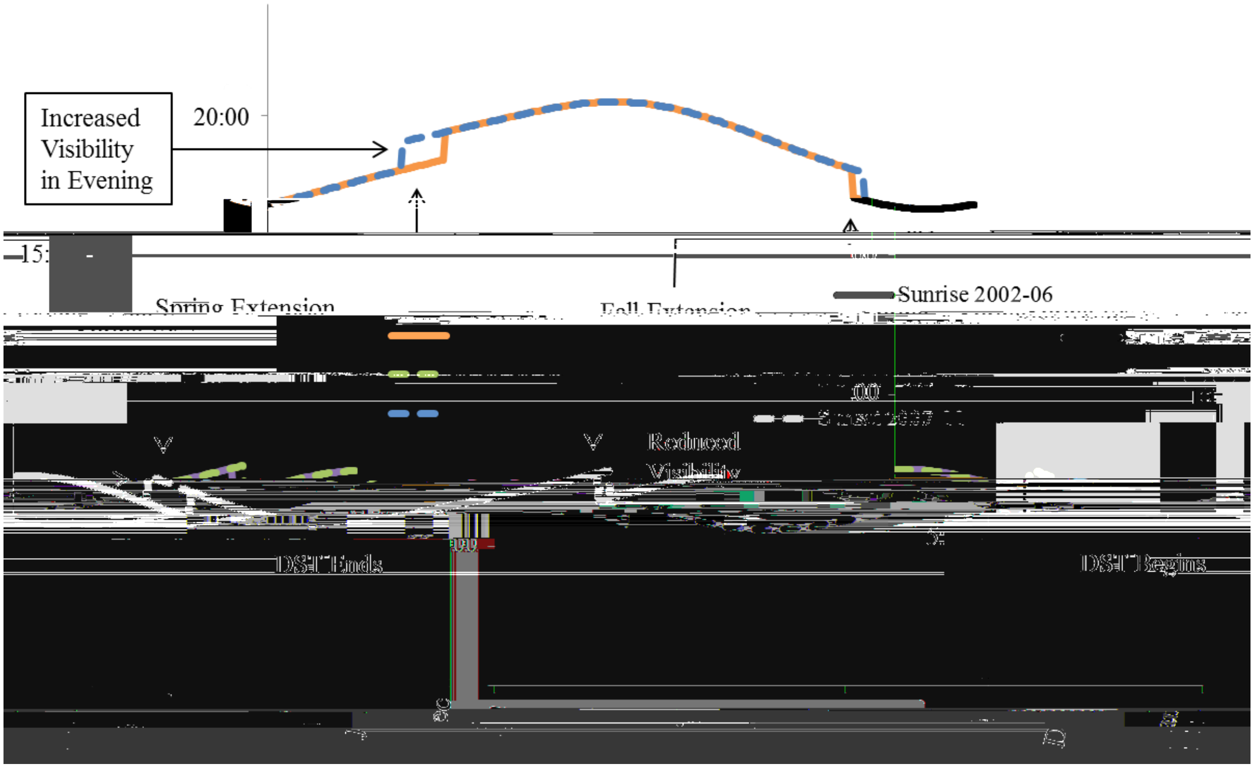
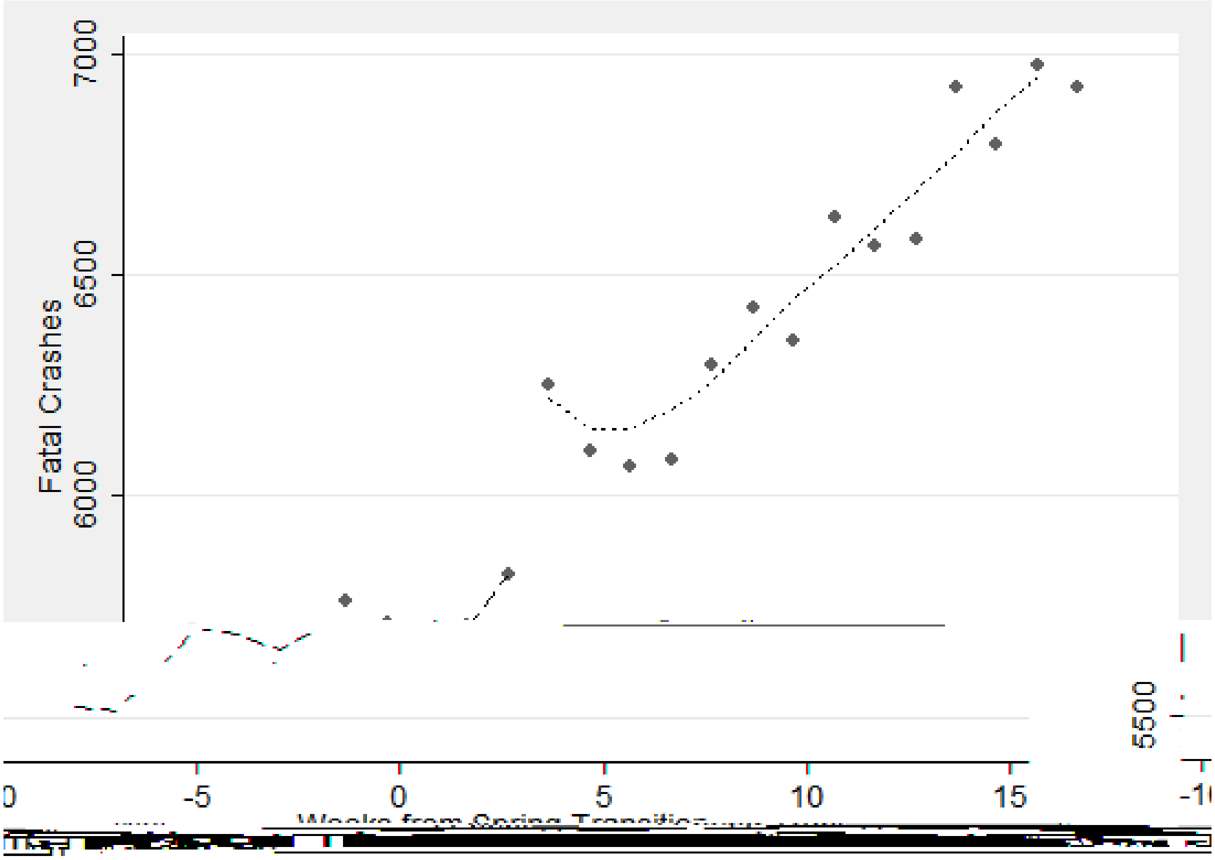
Figure 1 The Influence of Daylight Saving Time on Ambient Light



Note: The sunset and sunrise times are for St. Louis Missouri, the nearest major city to the population center of the US.

Figure2: Fatal Crashes Around the Spring Transition



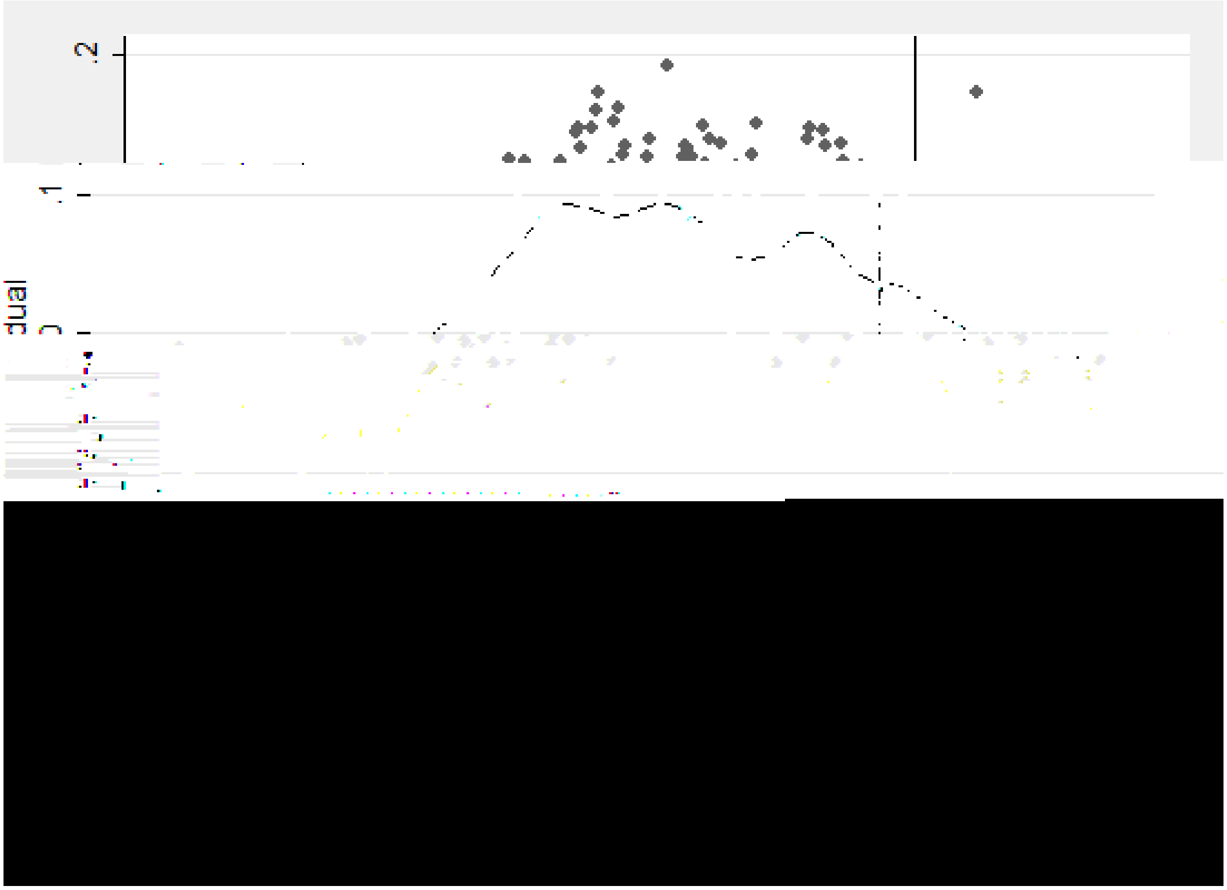
Notes:Each point represents the total number of fatal crashes occurring during that week from 2002-2011 Smoothed lines are results of locally weighted regression

Figure3: Variation in DST Coverage-Spring

Figure 4: Spring Residual Plot

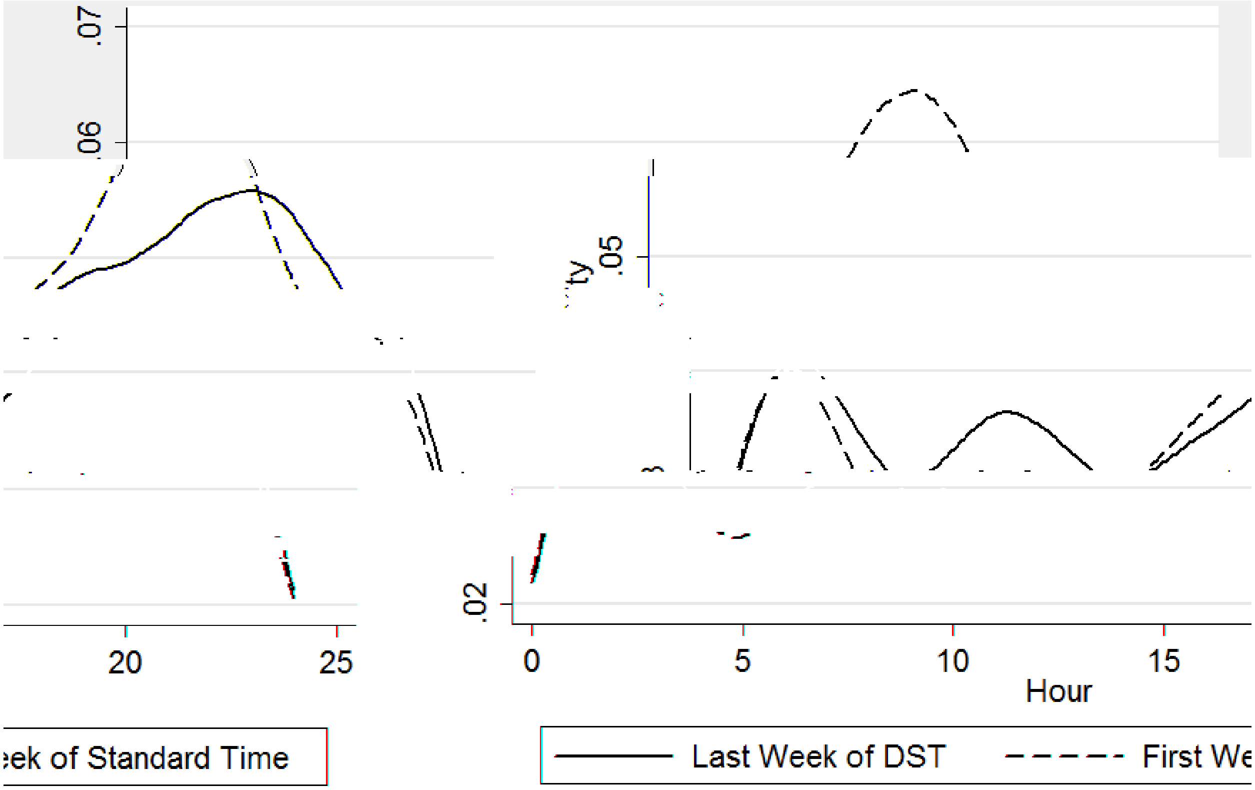
Notes: The residuals are generated from a regression of ln(fatal crash count) on day-of-week and year dummies. Each point is the average of all residuals for that date relative to the spring transition. Fitted lines are results of locally weighted regression.

Figure 5 Fall Residual Plot



Notes: The residuals are generated from a regression of ln(fatal crash count) on day-of-week and year dummies. Each point is the average of all residuals for that date relative to the fall transition. Fitted lines are results of locally weighted regression. Greater variability on the ends is largely due to these average residuals being formed by only 5 observations rather than 10 towards the middle. This is a product of the 2007 DST extension; in 2002-2006 there are about 9 weeks following the fall transition but in 2007-2011 about 8.

Figure 6: Reallocation of Fatal Crashes (Fall Transition)

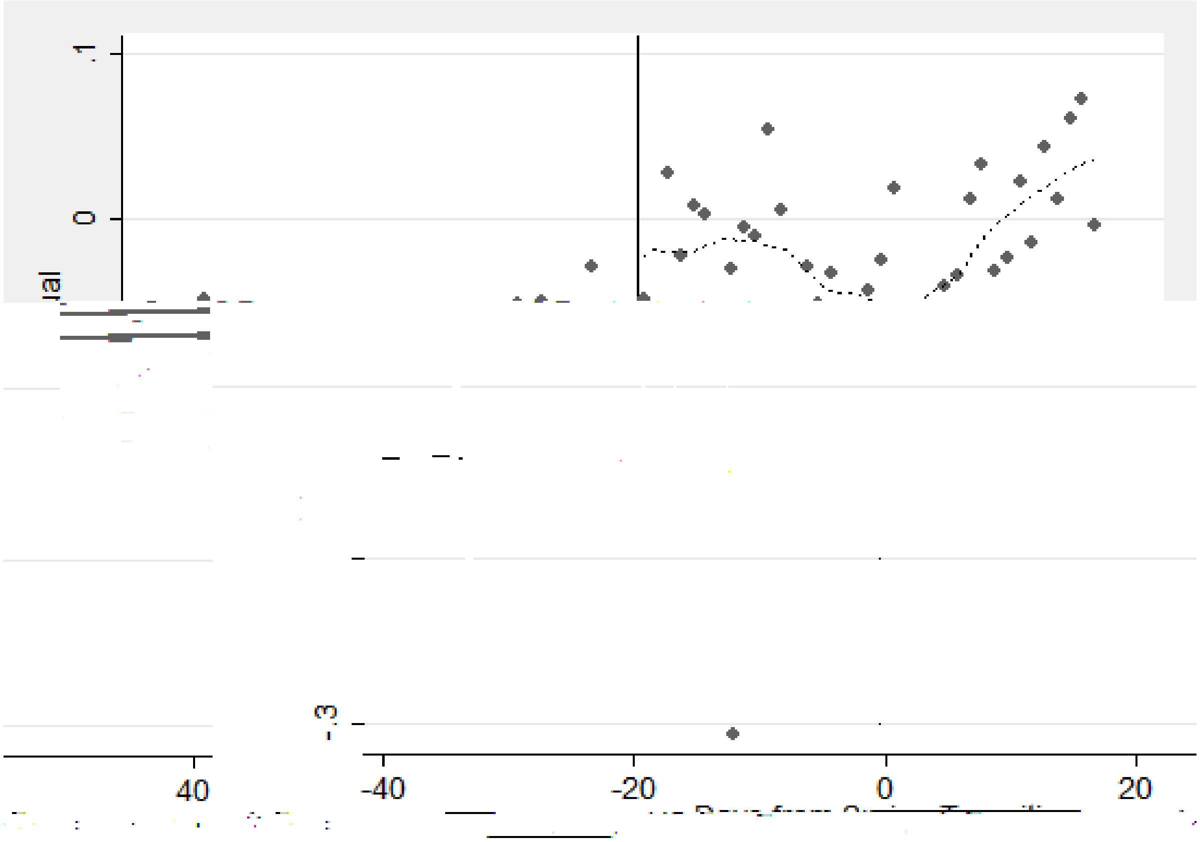


Notes: The kernel density functions use an Epanechnikov kernel. First week of standard time begins on the 25-hour transition date (Sunday).

Figure7: SpringResidual Plot±Six Day Sleep Impact

Notes:The residuals are generated from a regression

Figure 8: Spring Residual Plot – Least Light Impacted Hours



Notes: The residuals are generated from a regression of ln(fatal crash count) on day-of-week and year dummies. Each point is the average of all residuals for that date relative to the spring transition. Fitted lines are results of locally weighted regression. Least light impacted hours are 9am-3pm and 8pm-4am.

Table 1: RD estimates of the impact of entering DST on fatal crashes

				2002-2006	2007-2011	Placebo
	(1)	(2)	(3)	(4)	(5)	(6)
DST	0.0631**	0.0536**	0.0756***	0.0682**	0.0949	-0.0174
	(.0309)	(.0215)	(.0218)	(.0341)	(.0583)	(.0278)
Bandwidth	CCT	IK	CV	CCT	CCT	CCT
# days left	18	41	57	20	12	20
# days right	19	42	58	21	13	21

Dependent Var: Log fatal crashes; all specs use day-of-week and year dummys, a first order polynomi
uniform kernel. DST is the estimate of the discontinuity in fatal crashes that occurs immediately followi
spring transition into DST. Placebo assigns the current March transition date to 2002-2006 data and th
April transition date to the 2007-2011 data. CCT refers to the bandwidth selector of Calonico, Cattane
Titiunik (2012); IK is Imbens and Kalyanaraman (2012); CV is the cross-validation method of Ludwig a
Miller (2007). Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 2: RD estimates of the impact of leaving DST on fatal crashes

				2002-2006	2007-2011	Placebo
	(1)	(2)	(3)	(4)	(5)	(6)
Leaving DST	0.0018	0.0226	0.0026	0.0189	-0.0233	0.0231
	(.0247)	(.0207)	(.0175)	(.0331)	(.0542)	(.0236)
Bandwidth	CCT	IK	CV	CCT	CCT	CCT
# days left	18	41	62	13	11	18
# days right	19	42	63	14	12	19

Dependent Var: Log fatal crashes; all specs use day-of-week and year dummys, a first order polynomia
uniform kernel. Leaving DST is the estimate of the discontinuity in fatal crashes that occurs immediatel
following the fall transition out of DST. Placebo assigns the current November transition date to 2002-2
and the old October transition date to the 2007-2011 data. CCT refers to the bandwidth selector of Cal
Cattaneo, and Titiunik (2012); IK is Imbens and Kalyanaraman (2012); CV is the cross-validation metho

	All Hours	Morning			Evening		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Leaving DST	0.0018	-0.1631**	-0.1182**	-0.1482**	0.1208**	0.2093***	0.1614***
	(.0247)	(.0703)	(.0555)	(.0657)	(.0506)	(.0499)	(.0323)
Bandwidth	CCT	CCT	IK	CV	CCT	IK	CV
# days left	18	16	30	57	13	61	16
# days right	19	17	31	58	14	60	17

Dependent Var: Log fatal crashes; all specs use day-of-week and year dummys, a first order polynomial and a unif
kernel. Leaving DST is the estimate of the discontinuity in fatal crashes that occurs immediately following the fall tr

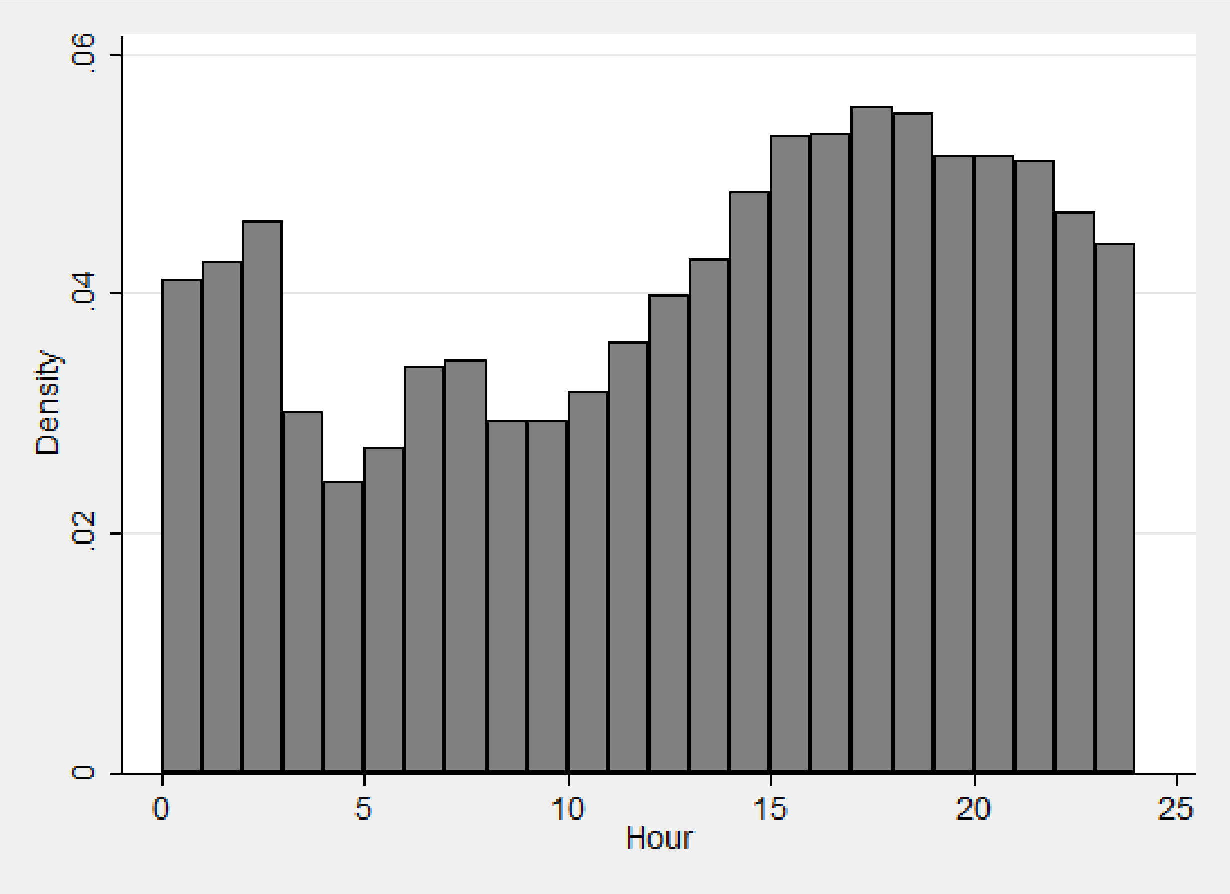
Table 4: RD estimates of the influence of sleep loss on fatal c

	All Hours	Least Light Impacted Hours		
	(1)	(2)	(3)	(4)
DST	0.0631**	0.0484	0.0601**	0.0773***
	(.0309)	(.0360)	(.0250)	(.0258)
Bandwidth	CCT	CCT	IK	CV
# days left	18	17	36	57
# days right	19	18	37	58

Dependent Var: Log fatal crashes; all specs use day-of-week and year dummys, a first o
polynomial and a uniform kernel. DST is the estimate of the discontinuity in fatal crashes
occurs immediately following the spring transition. Least Light Impacted Hours are 9am-3
and 8pm-4am. CCT refers to the bandwidth selector of Calonico, Cattaneo, and Titiunik (
IK is Imbens and Kalyanaraman (2012); CV is the cross-validation method of Ludwig and
(2007). Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

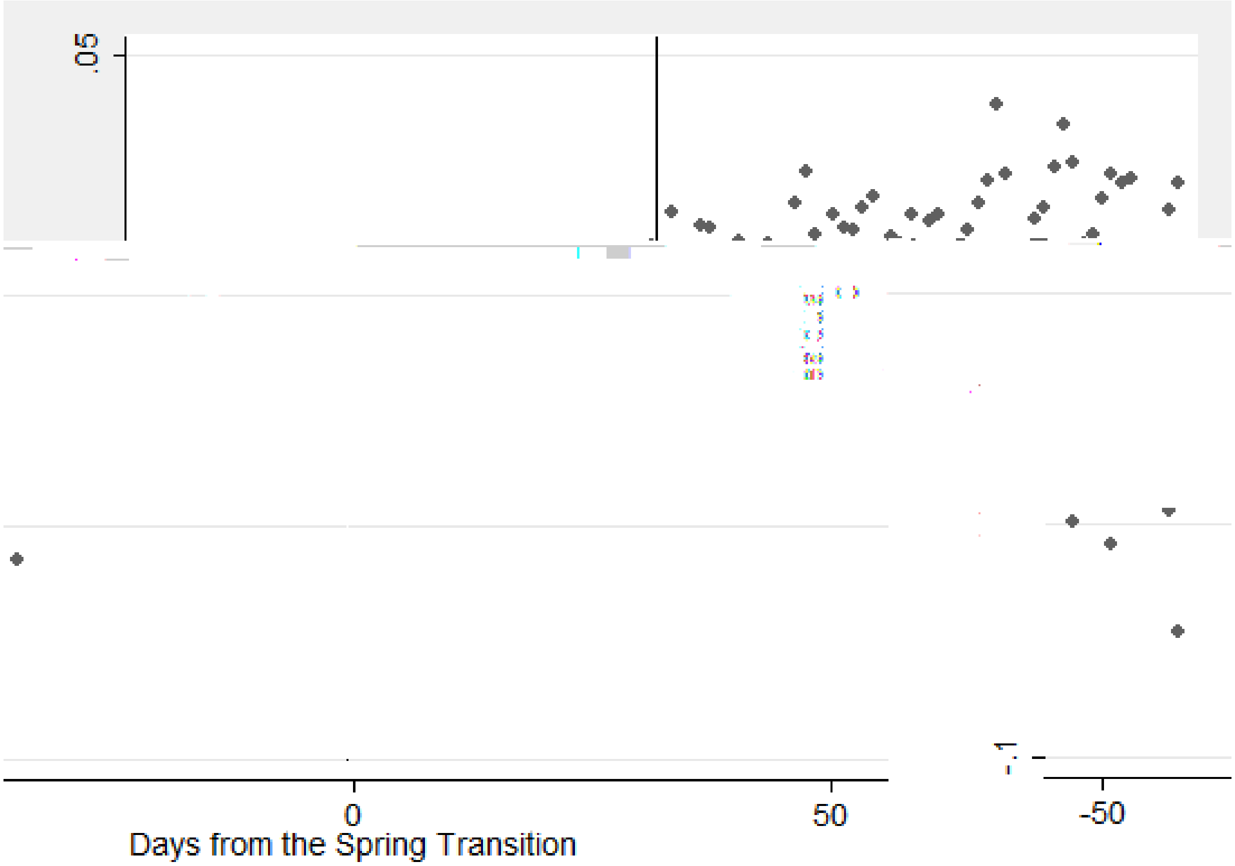
Supplementary Appendix (For Online Publication)

Figure A1: Frequency of Fatal Crashes by Hour



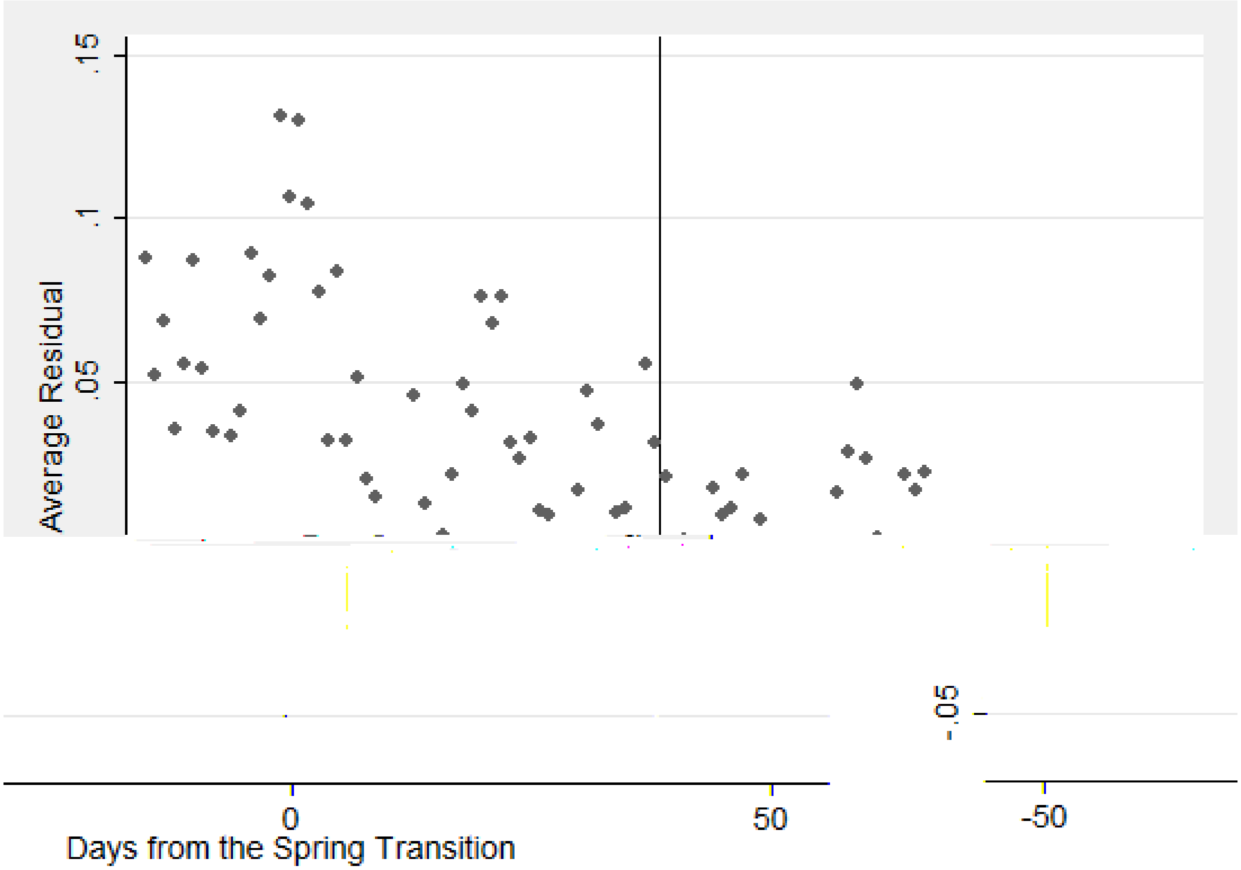
Note: Histogram uses all fatal crashes from 2002-2011 in the contiguous US except Arizona and Indiana.

FigureA2: VMT Residual Plot



Notes: Residuals from a regression of ln(VMT) on day-of-week and year dummies. Aggregate VMT data comes from Caltrans PeMS.

Figure A3: Weather Residual Plot



Notes: Residuals from a regression of Weather Ratio on day-of-week and year dummies. Weather ratio is the proportion of crashes within a day that are impacted by weather.

				24/23rds	No Trans
	(1)	(2)	(3)	(4)	(5)
DST	0.0631**	0.0587*	0.0584*	0.0566*	0.0685**

	(1)	(2)	(3)	(4)	(5)	(6)
DST	0.0805***	0.0844***	0.0646*	0.0727**	0.0828*	0.0583***
	(0.0299)	(0.0302)	(0.0355)	(0.0299)	(0.0434)	(0.0212)
Bandwidth	30	30				

Table A3: RD estimates of the impact of leaving DST on fatal crashes-additional robustness

	Alternative Kernels			24/25ths	No Trans
	(1)	(2)	(3)	(4)	(5)
Leaving DST	0.0018	-0.0099	-0.0062	0.0003	-0.0005
	(.0247)	(.0257)	(.0253)	(.0242)	(.0252)
Kernel	Uni	Tri	Epa	Uni	Uni
# days left	18	21	20	19	19
# days right	19	22	21	20	19

Dependent Var: Log fatal crashes; all specs use day-of-week and year dummys, a first order polynomial and the bandwidth selector of Calonico, Cattaneo, and Titiunik (2012). Leaving DST is the estimate of the discontinuity in fatal crashes that occurs immediately following the fall transition out of DST. Uni refers to a uniform kernel; Tri refers to a triangular kernel; Epa refers to an Epanechnikov kernel. 24/25ths is an alternative correction for the fall transition date where the crash count is weighted as 24/25ths. No Trans drops the spring transition date from the sample. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table A4: RD estimates of the impact of entering DST on fatal crashes, by county risk level

	High Risk Counties			Low Risk Counties		
	(1)	(2)	(3)	(4)	(5)	(6)
DST	0.0817	0.0919**	0.1213***	0.0466	0.0352	0.0576**
	(.0530)	(.0417)	(.0421)	(.0346)	(.0222)	(.0237)
Bandwidth	CCT	IK	CV	CCT	IK	CV
# days left	23	50	57	16	42	57
# days right	24	51	58	17	43	58

Dependent Var: Log fatal crashes; all specs use day-of-week and year dummys, a first order polynomial and a uniform kernel. DST is the estimate of the discontinuity in fatal crashes that occurs immediately following the spring transition. High and Low Risk Counties are based on a cut at the median county of fatal crashes per capita based on 2010 county population. CCT refers to the bandwidth selector of Calonico, Cattaneo, and Titiunik (2012); IK is Imbens and Kalyanaraman (2012); CV is the cross-validation method of Ludwig and Miller (2007). Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

	(1)	(2)	(3)	(4)	(5)	(6)
DST	0.0737	0.0621	0.784**	0.1066***	0.0525*	0.0726**
	(.0502)	(.0386)	(.0391)	(.0343)	(.0308)	(.0299)
Bandwidth	CCT	IK	CV	CCT		