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When the Moon Makes You Drive Like You've Had Too Much Wine: The Lunar Cycle and Fatal Car Crashes

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When the Moon Makes You Drive Like You've Had Too Much Wine: The Lunar Cycle and Fatal Car Crashes*

Abstract

We use variation in nighttime light across the lunar cycle as a novel, plausibly exogenous source of variation in sleep to study the relationship between sleep loss and fatal traffic accidents. Linking over 1.8 million fatal crashes from the Fatality Analysis Reporting System (1975–2023) to the precise timing of 606 full moons, along with nearly 3 million self-reported sleep responses from the Behavioral Risk Factor Surveillance System and the American Time Use Survey, we show that sleep worsens and fatal crashes rise in the days following the full moon. Daily traffic fatalities increase by 0.65% in the four days after the full moon overall, and by 1.78% in states with clearer skies and during non-winter months, when moonlight is less likely to be blocked by cloud cover. These effects vanish during total lunar eclipses, when the Earth blocks the sunlight the moon would otherwise reflect, and are concentrated in daytime hours, when sleep loss can impair driving but moonlight cannot affect road visibility. We estimate that the lunar cycle causes 35–38 traffic fatalities annually, costing approximately half a billion dollars per year using the 2023 Value of a Statistical Life (VSL). By isolating the sleep channel from the visibility channel that complicates studies of daylight saving time, our design provides robust evidence that even small, recurring sleep disruptions impose large social costs.

JEL classification

I12, R41, J22

Keywords

sleep, traffic fatalities, lunar cycle, circadian rhythm

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1. Introduction

Inadequate sleep is a pervasive and widely underappreciated public health burden, linked extensively to elevated risk of cardiovascular disease, metabolic dysfunction, cognitive impairment, and premature mortality,[1] as well as reductions in test scores, human capital accumulation, employment, and productivity.[2] Despite strong evidence of deleterious impacts on health and economic outcomes, credible causal evidence on the consequences of sleep loss remains limited. This is largely due to the fact that exogenous variation in sleep is rare and most of sleep's downstream harms unfold slowly and too diffusely to trace back to a specific night or week of disrupted rest. Fatal traffic accidents are a notable exception, as they are acute, with data that is precisely timed and located. A well-established literature has shown that plausibly exogenous shocks to sleep, such as the transition to daylight saving time (DST), produce measurable increases in fatal crash risk, though the relative contributions of sleep loss versus road visibility remain debated.[3]

In this paper, we utilize a novel, more frequent, and more subtle source of variation in sleep which allows us to measure sleep effects and link them directly to crash risk, while simultaneously addressing the direct and indirect effects of ambient light. We exploit the fact that there is substantial variation in nighttime ambient light across phases of the lunar cycle. The sky during the full moon can be more than ten times brighter than during a 'new moon' (Kyba et al., 2017; Austin et al., 1976), and this variation in ambient light can lead to systematic deficiencies in sleep duration and quality on nights leading up to, during, and immediately after the full moon (Casiraghi et al., 2021; Cajochen et al., 2013; Chaput et al., 2016). We link data from the Fatality Analysis Reporting System (FARS) on the universe of over 1.8 million fatal car accidents that took place in the United States between 1975-2023 with the precise dates of 606 full moons over this same period. Additionally, we utilize more than 2.6 million self-reported sleep survey responses from the Behavioral Risk Factor Surveillance Survey (BRFSS) between 2011-2022 and more than 245,000 time diaries from the American Time Use Survey (2003-2023) in order to investigate how both sleep and fatal car risk vary over the lunar cycle, and how this effect depends on the strength of the moon's ambient light.

Across all three datasets, we find that self-reported sleep and fatal crashes both worsen significantly in the days just after the full moon, and that the effects scale in a similar way with measures of ambient light exposure. Effects are concentrated in states with clearer skies and

[1] Pan et al. (2023), Spiegel, Tasali, et al. (2009), Durmer and Dinges (2005), Cappuccio, D'Elia, et al. (2010), Gibson and Shrader (2018), Lim and Dinges (2010), Cappuccio, Cooper, et al. (2011), Flink et al. (2024), Spiegel, Leproult, et al. (1999), Giuntella and Mazzonna (2019), Hyndych et al. (2025), and Assefa et al. (2015)

[2] Heissel and Norris (2018), Lusher and Yasenov (2018), Groen and Pabilonia (2019), Carrell et al. (2011), Jagnani (2024), Costa-Font et al. (2024), and Gibson and Shrader (2018)

[3] Smith (2016) attributes the increase in fatal crashes following the spring DST transition primarily to sleep deprivation. Coren (1996) and Varughese and Allen (2001) find similar increases in the U.S. consistent with a sleep-based mechanism. However, Laliotis (2023) and James (2023), using Greek and Australian data respectively, attribute DST-related crash effects to ambient light rather than sleep loss, and Fritz et al. (2020) find effects that vary by time of day in ways consistent with both channels operating simultaneously.

during in the non-winter months, where the moon's light is least likely to be blocked by cloud cover. In the ATUS sleep data, we find average reductions of 2.8 minutes per night (p = .000) for each of the four nights following the full moon, though this is driven mainly by reductions of over 4.0 minutes per night (p = .000) in states with clearer skies.[4] Though small, these persistent sleep reductions translate to meaningful risk of fatal traffic accidents. Daily traffic fatalities rise by a marginally insignificant 0.65% (p = .054) in the four days following the full moon across our entire sample, though this effect is similarly driven by increases in clear-sky states during non-winter months, where there is an increase in daily traffic fatalities of 1.8% (p = .000). With 12 to 13 lunar cycles per year, this translates to an estimated 35 to 38 additional fatalities annually, or roughly 1,780 fatalities over our 49-year sample, with an estimated annual cost of roughly $500 million USD using the 2023 Value of a Statistical Life (VSL) (U.S. Department of Transportation, 2023).[5]

We perform multiple additional tests of whether sleep loss due to the additional nighttime ambient light from the full moon is the mechanism behind our traffic fatality results. First, we show that the effects disappear during total lunar eclipses, when the moon's illumination is sharply reduced despite its position in the sky being unchanged. Additionally, we use a solar position algorithm from the National Oceanic and Atmospheric Administration (NOAA) to calculate daily sunrise and sunset times for each county in the US. This allows us to determine whether each crash in our sample happened at nighttime, dawn or dusk, or during the day. If ambient light impacting sleep is the mechanism for our findings, we should find an increase in crashes during the day, when the moon itself is no longer visible, as any mechanism that relies on the full moon impacting visibility for drivers would only predict changes in crash risk at night. We demonstrate that our main effects are driven almost entirely by increases in daytime crashes in the days immediately following the full moon, though we do find evidence of a reduction in nighttime crashes in settings where baseline levels of ambient light are low, such as during the winter and in the states with fewer clear-sky days.

Finally, we test for whether the effect of the lunar cycle on traffic fatalities changes with the introduction of the smartphone, splitting our sample into the periods from 1975-2010 and 2011-2023. Studies have demonstrated that the light from smartphones has impacted our sleep (Bauducco et al., 2024; Billari et al., 2018; Hartstein et al., 2024; Carter et al., 2016), so the effect of the lunar cycle could theoretically be either dampened or intensified in the smartphone era. We find that our main effects are driven by increases in the 'pre-smartphone' era, though with important heterogeneity by time of day. We find that daytime traffic fatalities increase by just as much during the 'smartphone' era, but that there is a significant decrease in nighttime fatalities

[4]Because the BRFSS question asks respondents to report their average sleep rather than their sleep on a specific night, the magnitude of this decline is difficult to interpret directly, where any measured change implies a much larger night-specific effect, since a respondent's stated average will only shift if recent sleep loss is severe enough to alter their overall self-assessment. We therefore focus on the pattern of heterogeneity in these estimates rather than their absolute magnitude.

[5]The 2023 VSL is $13.2 million USD, so the estimated range based on our fatality estimate is between $464-504.2 million.

in this period. This is consistent with the possibility that the light from the full moon could help drivers who are distracted by their phones to spot potential dangers. Taken together, our findings indicate that sleep and crash effects co-move in patterns that scale with independent proxies for ambient light dosage, providing strong evidence that the mechanism linking the lunar cycle to fatal crashes operates through its effect on nighttime light exposure and sleep.

This paper makes several contributions to the literature on the economic causes and consequences of sleep loss and fatal car crashes. A number of papers use sleep as an economic outcome itself and investigate the economic, environmental, and cultural forces which influence sleep. For example, Blanchflower and Bryson (2021) finds that spells of unemployment reduce self-reported sleep, while Niekamp (2019) finds that poor macroeconomic conditions lead to less sleep on weekends, but more sleep on weekdays. Farbmacher et al. (2022) uses variation in SNAP distributions over the course of the month to demonstrate that food insecurity has a negative impact on sleep, while Heyes and Zhu (2019) finds that air pollution also disrupts sleep, with a one standard deviation increase in AQI leading to a 11.6% increase in sleeplessness. Relatedly, Billari et al. (2018) shows that the introduction of broadband internet access reduces sleep duration and satisfaction, driven in part by digital temptations that compete with time for sleep. Recent field experiments have also attempted to increase sleep for various populations. Avery et al. (2025) and Giuntella, Saccardo, et al. (2026) find that commitment devices, monetary incentives, bedtime reminders, and morning feedback can improve sleep outcomes among college students, while Bessone et al. (2021) find that a three-week intervention providing information, encouragement, and improvements to home sleep environments increased sleep by 27 minutes among the urban poor in India. We build on this literature by introducing a new source of variation in sleep, the lunar cycle, which has been investigated with mixed results in the human biology and medical literature, but which to our knowledge has not been studied in the economics literature.

Other papers exploit quasi-exogenous variation in sleep to measure the impact of sleep loss on other health and economic outcomes. Researchers have used the fact that discontinuous jumps in sunset time across timezone boundaries lead to small but chronic differences in sleep to demonstrate that insufficient sleep leads to poor mental and physical health outcomes (Giuntella and Mazzonna, 2019; Argys et al., 2026), impaired cognitive function (Giuntella, Han, et al., 2017), reduced human capital accumulation (Jagnani, 2024), and worsening labor market outcomes (Costa-Font et al., 2024; Gibson and Shrader, 2018). Others take the fact that when schools start earlier, adolescents tend not to respond by going to bed earlier and subsequently get less total sleep, leading to lower test scores and worse academic performance (Carrell et al., 2011; Heissel and Norris, 2018; Groen and Pabilonia, 2019; Edwards, 2012; Hinrichs, 2011). While these papers all examine the effect of small but chronic sleep deficits, another strand of the literature looks specifically at the effect of sleep loss related to the springtime DST transition, where the vast majority of the population receives a single, acute, contemporaneous shock to sleep. Research has demonstrated that DST-related sleep loss leads to increased workplace accidents (Barnes and Wagner,

2009), lower self-reported well-being (Kountouris and Remoundou, 2014), and that it reduces stock market returns on the Monday after trading reopens (Kamstra et al., 2000). Symmetrically, (Jin and Ziebarth, 2020) find that the increased sleep from the fall DST transition reduces hospital admissions related to cardiac events. We contribute to this literature by demonstrating that sleep loss from the lunar cycle leads directly to a large, persistent, and extremely costly increase in fatal car crashes.

There is also a literature which focuses specifically on the link between DST and the risk of fatal car crashes, going back to at least the 1990s.[6] This literature is complicated by the fact that the DST transition impacts sleep, but also shifts the timing of daylight hours during the day to the later evening hours, which are generally more dangerous on the road, which explains the mixed findings in the literature. Smith (2016) is one of the the most well-identified papers in this literature, using both an RD-in-time approach around the day of the transition while also using the fact that the U.S. changed the dates when the spring and fall DST transitions occurred in 2007 as a source of identifying variation. He compares the days before and after the actual transition from 2007-2011 with the days which would have followed the transition in 2002-2006 but did not due to the policy change, finding that the spring DST transition caused around 30 traffic fatalities annually from 2002-2011, with sleep-loss as the driving mechanism. Fritz et al. (2020) builds on Smith (2016)'s findings by demonstrating that the effects are concentrated in the morning time and in the western half of timezones, which have later average sunset times and thus experience a more extreme disruption to circadian rhythm. Conversely, Laliotis (2023) and James (2023) use Greek and Australian data, respectively, and find the DST transition reduces fatal crashes in these settings due to the additional visibility in the peak-driving evening hours. This back and forth highlights the major challenge of using DST to identify the effect of sleep loss on fatal crash risk, which is that DST has the dual effect of impacting sleep while also creating a large shock to daylight hours and sunset time.

We build on this literature by analyzing a mechanism which impacts sleep, but which crucially does not impact sunset times or have any other major impact on the daylight hours. By assigning crashes to daytime, dawn/dusk, or nighttime and analyzing a sleep shock which does not impact sunset times, we can isolate the effect of sleep on fatal crashes while holding the visibility channel constant. We find the largest increase in crash risk during daytime hours, which can only realistically be attributed to the sleep-loss mechanism. Our approach further allows us

[6] Vincent (1998) and Lahti et al. (2010) find no significant effect of the DST transition on collision rates, while Ferguson et al. (1995) estimated that switching to permanent DST would have prevented roughly 900 fatal crashes due to the reallocation of daylight into the relatively more dangerous evening commute hours. Coren (1996) used data from Canadian traffic accidents and focused specifically on the Mondays before, immediately following, and one week after the spring transition and found an increase in fatal accidents. Varughese and Allen (2001) looked across a longer US time series (1975-1995) and also found a significant increase in fatal accidents in the days following the spring transition, reinforcing the sleep-based interpretation. On the other hand, Coate and Markowitz (2004), Broughton et al. (1999), and Sood and Ghosh (2007) all conclude that DST reduces crashes, primarily through the evening-time ambient light mechanism. Aries and Newsham (2008) conducted a broader review of this literature and concluded that results were decidedly mixed and highly sensitive to methodology, data source, and geography, offering little basis for a confident consensus on DST's net effects.

to disentangle the sleep-visibility tradeoff by looking at how the lunar cycle impacts nighttime crashes, where the sleep loss mechanism may be counteracted by improved visibility. Here, we generally find null effects, which suggests the two mechanisms may be canceling each other out. Crucially, in settings with low baseline levels of nighttime ambient light, such as in states with cloudier skies and during the winter months, we find a significant reduction in traffic fatalities, suggesting that the protective effect of improved visibility at night may outweigh the harmful effect of sleep loss.

2. Background/Review of Relevant Literature

2.1. Light, Sleep, and Driving Impairment

Light is the primary signal that keeps the human circadian rhythm aligned with the solar day, and that system is quite sensitive to evening and nighttime light. Gooley et al. (2011) demonstrate that exposure to room light in the hours before bedtime substantially delays melatonin onset and shortens melatonin duration, and Zeitzer et al. (2000) show that the response to nocturnal light rises steeply at low intensities before flattening out at higher ones. Importantly, natural moonlight in our setting is much dimmer than the light levels tested in these laboratory studies, so whether it is bright enough to meaningfully disrupt sleep is ultimately an empirical question. Other work finds that the costs of small sleep losses do not reset each night, but can compound and accumulate.Van Dongen et al. (2003) restricted participants to six or four hours of sleep per night for two weeks and found that cognitive deficits accumulate in a dose-dependent manner, with lapses in alertness rising nearly linearly with cumulative excess wakefulness. This suggests that repeated disruptions to sleep sustained over several consecutive nights can compound into substantial impairment.

Sleep loss is particularly consequential for driving, which depends on sustained attention and rapid reaction times. Dawson and Reid (1997) demonstrate that moderate levels of fatigue impair performance by more than the legal limit of alcohol intoxication, and Williamson and Feyer (2000) find that after 17 to 19 hours without sleep, performance on several cognitive and motor tasks can be worse than performance at a blood alcohol concentration of 0.05%. Drowsiness is also likely a more common contributor to fatal crashes than official statistics suggest, with Tefft (2014) using in-depth crash investigations to estimate that roughly 21% of fatal crashes involve a drowsy driver. The relationship between sleep and crash risk is also not confined to extreme deprivation. While Tefft (2018) finds that culpability for crashes rises nearly exponentially with additional sleep deprivation, he still finds that drivers who slept six hours in the prior 24 hours had roughly 1.3 times the odds of being culpable for their crashes relative to drivers who slept at least seven hours. Taken together, this evidence implies that even modest population-wide reductions in sleep will likely translate into measurable changes in fatal crash risk, including during daylight hours, when the moon has no direct effect on road visibility.

2.2. *Science of the Full Moon and Ambient Light*

The amount of light that reaches the Earth from the moon changes drastically across the phases of the lunar cycle. Moonlight is light from the sun that reflects off of the moon, and it is significantly more dim than sunlight. The half of the moon that is facing the sun is illuminated at all times, but since the moon's position relative to the Earth is continually shifting, the portion of the illuminated side of the moon that we can see is also varying cyclically, creating the phases of the lunar cycle (NASA Space Place, 2023).

The luminosity from the moon peaks in the full moon phase, as this is the point in the cycle in which the entire face of the moon is visible from Earth. The ground illuminance from the full moon is over double that of three days prior and more than ten times the levels during the 'new moon' phase (Poon et al., 2024; Kyba et al., 2017; Austin et al., 1976). Subsequently, ground illumination begins to decrease in the days after the full moon as more of the moon is gradually shadowed. The rapid increase of ambient light from the moon in the days immediately before and after the full moon has been documented in the Biological Sciences to have impacts on ecology (Kronfeld-Schor et al. (2013), Sergeyev et al. (2023), Prinz et al. (2025)). This means that any impact of the lunar cycle which operates through exposure to ambient light should operate like a sine wave, which rises to a crest and then falls. If the effect of ambient light dosage is cumulative, we would therefore expect effects to be largest in the days just after the full moon, where the population has been exposed to higher-than-average levels of additional ambient light for several days in a row.[7]

Besides the changing light levels throughout the lunar cycle, there is some linkage of the lunar cycle to the gravitational pull from the moon. During the full moon, the moon's orbit is closest to the Earth, causing the gravitational pull of the moon to be the strongest during this time. However, the phases of the moon are not directly linked to the location of the moon in its orbit, and there is significant variation between cycles (National Ocean Service, n.d.). Additionally, any impacts on the Earth that have been linked to the gravity of the moon, particularly tides, are actually the result of both the gravitational pull of the moon and the sun. The gravitational pull of the sun is significantly stronger than that of the moon, and the two work in tandem to create effects (NASA Science, 2026). At most points in the moon's orbit, any effects from the gravitational pull of the moon are overpowered by the gravitational pull of the Earth, as discussed in Mayoral et al. (2020).

2.3. *Scientific Literature on the Lunar Cycle*

Humans have been fascinated by the lunar cycle for as long as history has been recorded. The ancient Japanese had mythology portraying the sun and moon as 'sibling spouses' (Philippi, 1969),

[7] This idea of cumulative exposure relies on there being persistent effects of impacted sleep from previous days, which is in line with the findings from Smith (2016), where the effect of the spring DST transition lasts for six days following the initial sleep shock.

while the Greeks and Romans both had goddesses of the moon (Hansen, 2004; Hard, 2004). References to the full moon appear in The Epic of Gilgamesh, which gives us the first known reference to the idea of a 'werewolf' (Sconduto, 2008), as well as in both The Iliad and The Odyssey. In addition to werewolf mythology, it was Balkan/Slavic folklore that a corpse could rise as a vampire if the full moon shone on it before burial (Barber, 1988; Perkowski, 2006). Even Shakespeare was fascinated by the moon, referencing it over 50 times in his work, particularly in 'A Midsummer Night's Dream' where moonlight features prominently (Schanzer, 1951; Schanzer, 1955).

Given our ancient obsession with the moon and the lunar cycle, it is unsurprising that many attribute the outcomes of events on Earth to lunar positioning or activity. A massive literature has looked at whether crime,[8] anxiety,[9] suicidality,[10] births,[11] and even emergency hospital admissions[12] are impacted by the lunar cycle, with the overwhelming majority of these studies finding null effects.

One area where results are substantially more mixed is in looking at how sleep quantity and quality varies with the lunar cycle. Röösli et al. (2006) used sleep diaries of 31 adults over a six week period and found that respondents reported 19 minutes shorter sleep around the full moon. Similarly, Cajochen et al. (2013) analyzed data from 33 healthy volunteers in a circadian sleep laboratory over a three year period and found worsened sleep quantity and quality (as measured by delta EEG activity) around the full moon. As a rebuttal, Cordi et al. (2014) reanalyzed data from three large scale sleep-lab EEG datasets, including over 23,000 nights worth of observations, and found no effect of the lunar cycle on sleep. Turányi et al. (2014) analyzed lab-based sleep data of 224 patients referred for polysomnography at a hospital-based sleep laboratory and found lower sleep efficiency, less deep sleep, and increased sleep latency on full-moon nights compared to new-moon nights. Smith et al. (2017) analyzed data on 1,411 German adolescents over 8,332

[8] Lieber (1978a), Karan et al. (2010), Tasso and Miller (1976), Forbes and Lebo (1977), Templer et al. (1983), Sheldon and Prunckun (2017), Owen et al. (1998), Calver et al. (2009), Cohen-Mansfield et al. (1989), Simon (1998), Schafer et al. (2010), Atlas (1984), Pokorny (1964a), Lester (1979a), Näyhä (2019), Salafranca Barreda and González (2026), and Yeung et al. (2021) all study whether crime varies over the lunar cycle, with only Lieber (1978a), Tasso and Miller (1976), and Calver et al. (2009) finding an increase in crime around the full moon, while Näyhä (2019) actually found that homicides were 15% *lower* during the full moon phase.

[9] Wilkinson et al. (1997), Climent and Plutchik (1977), Laprérie et al. (2026), McLay et al. (2006), Amaddeo et al. (1997), Wang et al. (2020), Demler et al. (2019), Alhumoud and Alhemoud (2013), Kamat et al. (2014), Francis et al. (2017), Kaufmann (2023), DeVoge and Mikawa (1977), Wilson and Tobacyk (1990), Michelson et al. (1979), Kollerstrom and Steffert (2003), Weiskott (1974), Gorvin and Roberts (1994), Kung and Mrazek (2005), and Belleville et al. (2013) all study whether episodes of anxiety and depression vary over the lunar cycle, with only Wang et al. (2020) and Kollerstrom and Steffert (2003) finding any evidence of a statistical relationship.

[10] Jones and Jones (1977), Gutiérrez-García and Tusell (1997), Garth and Lester (1978), Mathew et al. (1991), Lieber (1978b), Maldonado and Kraus (1991), Biermann et al. (2005), Koyuncu et al. (2019), Jacobsen et al. (1986), Thakur et al. (1980), Rashid and Gowar (2004), Pokorny (1964b), Lester (1979b), Chaudhari et al. (2018), Voracek et al. (2008), Plöderl et al. (2022), Bhagar et al. (2023), Bourdin et al. (2023), and Cumin et al. (2025) all study whether suicide or other self-harm increases during the full moon, with only Bhagar et al. (2023) and Thakur et al. (1980) finding any evidence of a correlation.

[11] Joshi et al. (1998), Abell and Greenspan (1979), Kuss and Kuehn (2008), Staboulidou et al. (2008), Arliss et al. (2005), Morton-Pradhan et al. (2005), Smith et al. (2022), and Windsperger et al. (2026) all fail to find a relationship between the lunar cycle and births.

[12] Coates et al. (1989), Stomp et al. (2009), Bundi et al. (2018), Migliorini et al. (2025), Kong et al. (2021), Thompson and Adams (1996), Wende et al. (2013), Alves et al. (2003), Zargar et al. (2004), Ruuskanen et al. (2018), and Wang et al. (2020) all look at how emergency hospitalizations vary over the lunar cycle, with only Stomp et al. (2009) finding a significant effects, though they found that trauma cases were actually lower during the full moon.

nights and Haba-Rubio et al. (2015) looked at 2,125 records of home polysomnography of Swiss patients, both failing to find any link between the lunar cycle and sleep. Meanwhile, Casiraghi et al. (2021) analyzed data from 98 indigenous Argentinians and found significantly worse sleep around the full moon, while Chaput et al. (2016) looked at data for 5,812 children aged 9-11 across five continents and found they slept five minutes less during the full moon phase.

While there is a great deal of variation in the methodology and statistical precision of the various studies in the scientific literature on the effects of the lunar cycle, many of these studies have common strengths and weaknesses. The data on sleep quality is typically very high, often coming from lab-based sleep studies measuring time actually spent asleep as well as multiple measures of sleep quality using precise medical instruments. On the other hand, one concern with some of these lab based studies is that they may not be generalizable to typical sleep conditions. Tightly controlled sleep environments in laboratory settings may be protected from the additional ambient light the full moon provides, which could explain why lab-based studies often find no effect while many of the studies based on more natural sleep conditions do find worsening sleep around the full moon. All of the studies mentioned above suffer from relatively small sample sizes, and many of them only look for effects of over relatively small time periods of a couple of months or even a few years. Additionally, they often look for effects in only one particular geographic area, which overlooks how the effect of the lunar cycle may vary in its impact based on how much ambient light is actually reaching the Earth.

We build on all of these challenges by analyzing datasets that include nearly 3 million self-reported sleep observations and 1.8 million fatal traffic accidents, with sleep data spanning across 21 years (2003-2023) and accident data spanning 49 years (1975-2023). These massive datasets over many years allow us to look over hundreds of lunar cycles across different regions in order to precisely estimate even relatively small effects that show up consistently, and to unpack how these effects vary by region of the country and season of the year. This also allows us to look across the entire lunar cycle to see how our outcomes evolve in the period leading up, on, and after the full moon in order to get a complete picture of how the lunar cycle affects both sleep and fatal crash risk.

3. Data and Methods

3.1. Data Sources

To examine the effect of the full moon on sleep, we use data from two different but complementary data sources. First, we use data from the American Time Use Survey (ATUS), an annual survey conducted by the US Census Bureau based on a random sample drawn from households that recently completed the Current Population Survey (CPS). From every household, one member aged 15 or older is randomly selected to keep a 24-hour time diary. ATUS diaries record how respondents allocate their time across a 24-hour period beginning at 4:00 a.m., with each activity

coded by type, duration, and timing. We use these time diaries to construct a measure of total sleep duration for each respondent-day by summing the minutes classified under the sleep activity code within the 4a.m.-to-4a.m. window. There are approximately 10,000 time diaries collected each year, and we use every year of data from 2003-2023, giving us a total of 245,139 observations. Crucially, the time diaries include the precise date the diary was recorded, which we link to our data on the lunar cycle to estimate how sleep evolves over the lunar cycle.

We supplement this analysis by also using the CDC's Behavioral Risk Factor Surveillance System (BRFSS) survey, which surveys 400,000 American adults every year. BRFSS began in 1984 with a limited number of states, and has expanded to survey all 50 states, plus the District of Columbia. BRFSS is conducted by surveyors randomly calling non-institutionalized adult Americans and asking them a variety of questions pertaining to health, including risky behaviors, healthcare utilization, and daily habits. Beginning in 2011, the survey irregularly asks participants the question "On average, how many hours of sleep do you get in a 24-hour period?" The responses are measured in whole hours, meaning respondents are asked round their response to the nearest hour, which will naturally induce some measurement error. This question appears in the years 2011, 2013, 2014, 2016, 2018, 2020, 2022, leading to just under 2.7 million non-missing observations. Like ATUS, each survey response crucially includes the precise date the interview was conducted, which allows us to link each response to where in the lunar cycle the interview took place.

For our identification strategy, the survey would ideally ask for how much each respondent slept the previous night, but the BRFSS question asks how much people sleep "on average." This means that responses theoretically should not change across the lunar cycle. The only way that we would observe changes are if people are sleeping so much less around the full moon that they feel tired enough that they perceive that they sleep less on average than they really do. This also suggests that if we do find any impact of the lunar cycle on self-reported average sleep, it is likely only a small fraction of the effect of the lunar cycle on sleep for the individual days around the full moon. While BRFSS likely suffers from measurement error due to these concerns, it provides a much larger sample with greater statistical power than ATUS, and thus complements the data from time diaries.

Summary statistics for our two sleep datasets are displayed in Table 1. BRFSS has over 10 times the number of observations as ATUS, though over a considerably shorter time window. BRFSS has six years of data between 2013 and 2022, whereas ATUS includes data from each year from 2003-2023. This means that we can only link the BRFSS data to about 40% as many lunar cycles as the ATUS data, though each lunar cycle that is linked has many more observations in BRFSS.[13] Self-reported sleep duration in ATUS is generally higher than in BRFSS, a discrepancy documented in the time-use literature as the 'sleep gap' between diary-based and stylized-question

[13]The BRFSS interview cycle often spills over into the following year, meaning the 2013 cycle has interviews in January and February of 2014. This means that even though we only have data from six waves of BRFSS, we are able to link the data to more lunar cycles than would be possible if it only included observations from January through December of that year.

sleep measures (Kaplan et al., 2016; Basner, Fomberstein, et al., 2007; Basner and Dinges, 2014). One proposed explanation is that time diaries may capture time in bed rather than time actually asleep, though the BLS validation work points to broader measurement differences between diary and recall-based question formats as well. If our mechanism operates by disrupting sleep quality and making it take longer to fall asleep once in bed, this suggests that our estimates using ATUS may be biased toward zero. Appendix Figure A.1 further highlights this by displaying the distribution of the sleep variable across the two datasets.

Utilizing survey data has several limitations when attempting to measures impacts on sleep, particularly in this setting. Ideally, we would be able to utilize biologic data with precise estimates of sleep duration and quality from a smart watch or ring, as these sources would not be as prone to measurement error as our survey responses. However, for all of their limitations, these datasets do have one advantage over lab-based studies in that they estimate sleep as people experience it in the real world and not in tightly controlled experimental settings, which are valuable for isolating the effect of one specific intervention, but may have less external validity when estimating the effects of real world phenomena like the lunar cycle.

We supplement our sleep data with accident data from the Fatality Analysis Reporting System (FARS). FARS is publicly available data compiled by the National Highway Traffic and Safety Administration (NHTSA), which reports every fatal car accident from 1975 to 2023. As the name suggests, all accidents reported within must have resulted in at least one death within 30 days of the accident, and must have involved a motor vehicle on a public roadway. The data provides general information including location, date, and time of day, but also reports whether law enforcement suspected that alcohol was involved in the crash, weather conditions, and if the location of the accident was on a rural or urban road. We use this to construct a dataset that tells us the total number of crashes and fatalities every day in the US from 1975-2023. We proceed to construct additional versions where we restrict the data by non-winter months, sunny states, etc.

In order to link our sleep and accident data with the lunar cycle, we used data from fullmoon.info to compile a listing of every full moon which took place from 1975-2023. This website has annual tables listing the dates of every full moon going back to 1900. We then link this data to our BRFSS and ATUS sleep data and FARS crash data in order to determine when during the lunar cycle each response or accident took place. In addition to reporting the date and precise time of the full moon, there is also an indicator of whether the full moon is a total lunar eclipse, which we will use as a test of the ambient light hypothesis outlined below.[14]

3.2. Empirical Strategy

Our main empirical strategy will be to estimate event-study specifications that track the evolution of sleep and traffic accidents for the six days leading up to the full moon, on the date of the full

[14]The data presented on this website is reported in Central European Time (CET), which we adjusted for the difference in time zones by adjusting any full moon that occurred before 6:00 AM in the dataset to be the day before, as 6 hours is the difference between CET and Eastern Standard Time (EST).

moon itself, and then for the six days following the full moon. Although we follow the same general strategy across both datasets, the format of each dataset requires us to estimate slightly different models for each of our two main data sources. First, to estimate the effect of the lunar cycle on self-reported sleep, we estimate functions of the following form:

$$Sleep_{idmyw} = \sum_{\tau=-6}^{6} \alpha^{\tau}(\mathbf{1}[FullMoon_{dmyw} + \tau = d]) + \delta X_i + \gamma_y + \eta_m + \mu_w$$

Where $Sleep_{idmyw}$ represents the self-reported sleep for individual i, surveyed on date d during month m of year y on day-of-week w. The coefficients of interest, the α^{τ}'s, compare the evolution of self-reported sleep for the six days leading up to the full moon, the night of the full moon itself, and the six days following the full moon to the rest of the lunar cycle. δX_i is a vector of individual controls that predict self-reported sleep, including indicator variables for age, gender, race, education, and state of residence. There is also an indicator variable for whether the day is a national holiday. γ_y is a year fixed effect, which controls for variation in self-reported sleep across survey years which is constant across the lunar cycle. η_m is a month fixed effect, which controls for seasonal variation in sleep throughout the year. Finally, μ_w is a day-of-week fixed effect, which controls for differences in self-reported sleep based on the day of the week in which the survey is asked.

When we replace sleep on the left-hand side with our FARS data on fatal car accidents, we estimate models of the following form:

$$ln(Fatalities)_{dmyw} = \sum_{\tau=-6}^{6} \alpha^{\tau}(\mathbf{1}[FullMoon_{myd} + \tau = d]) + \delta_d + \mu_w + \eta_{ym}$$

Where now the log of the number of daily traffic fatalities on date d in month m and year y on day-of-week w is the dependent variable. In this dataset, there is only one observation per day instead of for each survey response, so there are no longer any individual controls, but because our FARS data span the 49 years from 1975-2023, we are able to include a richer set of fixed effects to control for possible confounding variation across years. δ_d is a date fixed effect, which includes a separate intercept for each day of the year. As above, we include our day-of-week fixed effect μ_w to control for variation in fatal accidents throughout the week. Finally, η_{ym} is our year-month fixed effect which controls for both general trends over time and idiosyncratic seasonal variation from year-to-year that impacts days near the full moon and far from the full moon equally. With this set of controls, we are effectively comparing fatal accidents on a Tuesday, March 12, in a year where it is near the full moon to another Tuesday, March 12, in another year where it is not near the full moon, after controlling for general differences in fatalities from March in one year to March in the other.

In this framework, causal identification of the lunar cycle on self-reported sleep and fatal car accidents relies on treatment days being as good as randomly assigned. Any threat to identifi-

cation would have to be from some other driver of both of these outcomes that is consistently correlated with the phase of the lunar cycle across different years and even decades. Full moons occur roughly every 29.5 days, which means that it happens on a different day each month and eventually cycles through all days of the year. Figure A.4 supports our identifying assumption by displaying the distribution of full moon dates by month, day of month, day of week, and year. There is roughly an equal distribution of full moons across the days of the week. There are slightly more full moons on months with 31 days and slightly fewer full moons in February, which only has 28 or 29 days, as expected. There is a nearly equal distribution across the days of the month, with days 29-31 being less due to different lengths in months. Additionally, every year has 12 or 13 full moons. The threat to identification mentioned above seems unlikely due to the relatively random assignment of full moons to dates within months and years.

3.3. Tests of the Ambient Light Hypothesis

The main mechanism we consider for this research design is that ambient light from the full moon causes people to stay up later and sleep less in total. This proposed mechanism leads to a number of testable predictions, which we will be able to validate or falsify. First, since this mechanism depends on ambient light from the moon reaching people on the Earth's surface, this suggests that the effects will be most pronounced when the sky is clear. To test this, we take advantage of both geographic variation in weather across U.S. states, as well as temporal variation throughout the course of the year. We gathered data from the World Population Review,[15] which keeps track of the number of days per year in each state with clear skies. We use their data to split the U.S. into the 25 states with the most clear sky days, which we label 'Sunny States', and the 25 states with the fewest clear sky days, our 'Non-Sunny States'. A map of our assignment is in Appendix Figure A.2. The 'Sunny States' are predominantly in the southern and southwestern portions of the U.S., while the 'Non-Sunny' states include most of the states on the northern border with Canada, as well as the 'rust belt' states of Pennsylvania, Ohio, Michigan, Wisconsin, Indiana, Illinois, Kentucky, Virginia, West Virginia, Delaware, New York, and most of New England with the exception of Maine. The ambient light hypothesis would predict that any effects on sleep and car crashes would be larger in the 'Sunny States'.

In addition to exploiting geographic variation in clear skies, we also take advantage of the fact that different seasons of the year have different propensities for clear versus cloudy skies. Appendix Figure A.3 uses data from the National Oceanic and Atmospheric Administration to plot the percentage of days in each month that are considered 'cloudy' for the ten most populous cities in the United States. These cities span the entirely of the U.S. geographically and have a good deal of baseline variation in levels of cloudy days, but all ten cities display a similar pattern in that cloudy days peak in the winter months, usually starting in November and lasting through at least February. Then, days get markedly clearer throughout the spring, with the fewest cloudy

[15] https://worldpopulationreview.com/state-rankings/sunniest-states

days in the summer months. The ambient light hypothesis would thus predict that we would find the smallest effects in the winter months. Since we have data on both the location and date for both our sleep and traffic fatality data, we are able to test these predictions across both data sources.

Next, there are three additional tests of the ambient light hypothesis that we are only able to adequately test using the FARS data. Our next approach takes advantage of the fact that not all full moons cast the same intensity of ambient light. Roughly one out of every 12-13 full moons is also a lunar eclipse, when the Earth passes directly between the Sun and the Moon, causing Earth's shadow to fall on the Moon's surface. Since the light from the moon is reflected from the sun, this means that when this happens, the ambient light from the full moon is severely diminished. Estimates suggest that ambient light from regular full moons is thousands of times brighter than the light from total lunar eclipses (Hernitschek et al., 2008). This provides us with a clean falsification exercise, since the ambient light hypothesis suggests that while typical full moons might lead to sleep loss and increased risk for fatal crashes, that these effects should not show up, or at least be severely diminished during total lunar eclipses. In our data spanning from 1975-2023, we have 606 total full moons, of which 44 are total lunar eclipses, which means we should have power to distinguish between the two types of full moons.

Next, we use the fact that the introduction of smartphones has increased the amount of ambient light we are exposed to at home. For example, Billari et al. (2018) uses historical differences in telephone infrastructure in Germany to demonstrate that exposure to broadband internet reduced both sleep duration and sleep satisfaction. Other research, both experimental and associational, shows that blue light emitted by smartphone screens disrupts circadian rhythms and suppresses the production of melatonin, delaying sleep onset.[16] Helfrich-Förster et al. (2025) reports that since 2010, synchronization of menstrual cycles with the lunar cycle has diminished, which is driven by the widespread use of smart phones. Since we are voluntarily exposing ourselves to light which is keeping us awake and harming our sleep quality, this suggests that the effects of the ambient light of the full moon may not have as much of a roll to play. To address this, we split our FARS data into a 'pre-smartphone' era of 1975-2010, and a 'smartphone era' of 2011-2023. We choose 2010 for the split because although the first iPhone was introduced in 2007, smartphones did not become ubiquitous until the early 2010s. We therefore predict that our effects will be larger in the 'pre-smartphone' era.

Finally, in order to disentangle the effects of ambient light from other potential mechanisms through which the full moon could affect driving, like visibility on the roads, we take advantage of the fact that our FARS data give us the precise time that each accident was reported, in addition to the location. We further wanted to sort accidents based on whether they occurred at nighttime, during dawn or dusk, or during the daytime hours. To do this we use the latitude and longitude of each county centroid, obtained from the U.S. Census Bureau's Gazetteer Files, as inputs to

[16] Amalakanti et al. (2024), Meijden et al. (2019), Cheng et al. (2025), and Bauducco et al. (2024)

the solar position algorithm described by the National Oceanic and Atmospheric Administration (NOAA), which is based on equations from Meeus (1998) to calculate the sunrise and sunset time for each county on each day of the year.[17]

Appendix Figures A.15 and A.16 highlight the strengths of this data, and demonstrate why we could not split the data by a particular time of day to separate the FARS data into daytime and nighttime accidents. Figure A.15 displays the sunset times throughout the course of the year for Boston, Phoenix, and Anchorage, cities with very different evolutions throughout the course the of year. Boston starts the year with sunset times just after 4pm, and these gradually move later in the day until the daylight savings time transition in March, where sunset time increases abruptly by an hour, before continuing to increase nonlinearly until the summer time, before then declining in an almost symmetric pattern. Phoenix, on the other hand, starts with later sunset times and experiences less overall variation throughout the year, particularly due to the fact that the state of Arizona does not observe daylight savings time. Finally, Anchorage has a much more aggressive arc, with sunset times as low as between 3-4pm in December after being as late as 11pm in during the summer. Appendix Figure A.16 displays both sunrise and sunset times for Los Angeles County for the year of 2023, with every single fatal car accident plotted on the precise date and time. This figure highlights the importance of accurately categorizing accidents into daytime, nighttime, or dawn and dusk throughout the year as there is a clear increase in fatal accidents just after sunset that varies throughout the year with local sunset times.

If the effect of the full moon on fatal accidents was operating through changes in visibility, we would expect these crashes to predominantly show up either at nighttime, or during dawn or dusk, where the full moon could either improve visibility by increasing light, or serve as a distraction. On the other hand, if the ambient light hypothesis is the main mechanism, we would expect to see an increase of daytime crashes as well. It is also possible that the increased light from the full moon at nighttime could serve as a countervailing force, helping sleepy drivers navigate roads more safely. In this case, we might expect the effects of ambient light to only show up during the daytime.

[17] This algorithm computes sunrise and sunset times in three steps. First, it calculates the sun's apparent position in the sky for a given date by computing the Julian century, the sun's geometric mean longitude and mean anomaly, the equation of center, and corrections for the obliquity of the ecliptic. Second, it uses these quantities to derive the equation of time and the sun's declination. Third, it computes the hour angle at sunrise and sunset, defined as the point at which the sun's center is 90.833 degrees from the zenith (the additional 0.833 degrees accounting for atmospheric refraction and the angular diameter of the sun), and converts this to clock times in UTC. All times are expressed in minutes elapsed since midnight UTC. This procedure is accurate to within approximately one to two minutes for locations outside of polar latitudes, where the assumption that the sun rises and sets each day breaks down.

4. Results

4.1. The Lunar Cycle and Self-Reported Sleep

Figure 1 previews our main results by displaying the time-series of self-reported sleep in hours for the 12 days before and after each full moon in our BRFSS sample. The ambient light hypothesis would suggest that we might expect self-reported sleep to decline in the days leading up to and immediately following the full moon as there is a buildup of sleep loss as people are exposed to increasing amounts of ambient light from the full moon. If the impacts of ambient light are cumulative across days, we might even expect sleep loss to be maximized in the days after the full moon, after people are exposed to several consecutive days of above average levels of ambient light. On the other hand, if there is not a direct effect of the lunar cycle on sleep loss, we would expect there to be no distinguishable pattern in the time series. In the top left graph of the figure, there is some suggestive evidence of lower levels of self-reported sleep from two days before the full moon through the two days following it, but there is no clear trend. In the top right graph, we restrict the sample to the 25 'clear sky states'. There is quite a bit of noise in the days leading up to the full moon, but there does appear to be more of a pattern with lower levels of sleep in the days around the full moon, before the graph starts trending upward again.

In the bottom left graph of Figure 1, we again restrict the sample to the 25 'clear sky' states, and we also drop the 'winter months' of November through February. Here, a clearer downward trajectory emerges in the days leading up to the full moon, with self-reported sleep reaching its lowest point the day after the full moon and remaining low all the way through the sixth day following the full moon. Finally, in the bottom right graph of the figure, we further restrict the sample by dropping two additional months on either side of the previous sample, now only including the four 'summer months' of May through August. Once again, there is a clear downward trajectory throughout the period leading up to the full moon, now reaching a local minima on the day after the full moon before rising again in the days following the full moon. Though anecdotal, the trends in the bottom right graph of Figure 1 are precisely what would be predicted by the ambient light hypothesis.

Figure 2 displays results from estimating equation (1) on both our BRFSS and ATUS sleep data. Coefficients are plotted together and represent hours of sleep, but note that the y-axes are scaled differently due to the fact that the ATUS data varies considerably more. This is likely due to the framing of the BRFSS question, which asks how much respondents sleep *on average*, as opposed to ATUS which has respondents record the precise amount of time they sleep the previous night. In the days leading up to the full moon, there is no clear trend across the two sources. All of the ATUS coefficients are insignificant, with both positive and negative coefficients. The BRFSS coefficients are all negative, with significant reductions on days six and two before the full moon. Both data sources display downward trends from the day before the full moon to the second day after the full moon, with self-reported sleep deteriorating. The BRFSS coefficients are negative and

significant for the day of the full moon and the two subsequent days, while the ATUS coefficient is only significant on day two following the full moon. This coefficient is consistent with an average reduction of 5.16 minutes of sleep per respondent ($p = .001$). Both sets of coefficients attenuate, though the BRFSS coefficient is once again negative and significant on day four after the full moon. The largest BRFSS coefficients following the full moon occur on days 1 and 2, where the coefficients are consistent with reductions of sleep of about one minute, on average. If the data generating process across the two datasets is similar, this would suggest that a recent reduction in sleep would generate perceived average sleep deprivation of about $\frac{1}{5}$ the magnitude of the actual sleep shock.

Figure 3 displays event study estimates which explore heterogeneity in our main sleep effects related to our predictions from the ambient light hypothesis. The top row of the figure splits the data by the time of year. Specifically, the top left graph drops the cloudier, winter months of November through February, while the top right graph includes only these months. The reduction in sleep during and in the nights following the full moon are significantly larger than the effects during the winter months, as predicted by the ambient light hypothesis. For the ATUS data, there is little happening in the days leading up to the full moon, followed by a marginally insignificant reduction of about 2.85 minutes on the night following the full moon ($p = .111$) and a significant reduction of 6.67 minutes on night two ($p = .002$). For the BRFSS data, there are significant reductions reported on the day of the full moon and the two days after, all of which are consistent with reductions of between 0.75-.95 minutes, on average. Meanwhile, when we look only at the winter months, the reduction during this period virtually disappears, with smaller coefficients that are no longer statistically significant in most cases. The only exception is for day two following the full moon in the ATUS data, which displays a reduction in sleep of 4.45 minutes ($p = .030$).

The bottom row of Figure 3 splits the data by whether each respondent was in our 25 'sunny states' or not. When we focus on the sunny states, all of the coefficients across the datasets are negative from the day before the full moon through the end of the period window, with several individually significant reductions. From the day before the full moon to the fourth day after, all the coefficients are negative and five of the six are significant at least at the 10% level. The average magnitude across this period is consistent with average sleep loss of about 4.6 minutes per night over this period. We similarly see reductions on days -1, 1, and 4 for the BRFSS data. The coefficients for the non-sunny states are mostly flat across the board, with the exception of the second day following the full moon, where there is a significant reduction in both datasets which quickly reverts to zero on day three.

Finally, Figure 4 combines our two restrictions, with the left graph displaying effects for the sunny states during the non-winter months, while the right graph displays effects for the non-sunny states during the winter months. Once again, the effects are much larger and more consistent for the group which the ambient light hypothesis predicts would be more exposed to the

effects of the full moon. The left graph displays consistent declines from day -1 to day 4 which are significant at 10% in both datasets for days 1, 2, and 4, while no clear pattern emerges on the graph for the winter months in the non-sunny states, with coefficients bouncing around apparently at random and mostly insignificant.

Taken together, these results suggest that there is substantial self-reported sleep loss on the days surrounding the full moon, with the largest effects in states and during times of the year where the light from the full moon is less likely to be blocked by cloud cover. Effects also show up most consistently in the four days which follow the full moon. We now turn to look at whether the lunar cycle also has an impact on fatal car crashes, which are known to be impacted by population-level sleep loss.

4.2. The Lunar Cycle and Fatal Car Crashes

Figure 5 displays results from our event-study specification from equation (2), where the log of the daily nationwide number of traffic fatalities from 1975-2023 replaces self-reported sleep on the left-hand side. While the figure broadly shows the inverse pattern to the sleep event-studies, with coefficients generally rising leading up to and following the full moon, none of the individual coefficients our statistically significant at the 5% level. Figure 6 builds on this by displaying results using the same heterogeneity in sample construction from Figure 3. In the top left graph, which excludes the months of November through February, the coefficients are all insignificant leading up to and including the day of the full moon, before we see large increases in days one through four following the full moon. The coefficients are individually significant at the 10% level on days one, three, and four, and a joint t-test for whether the coefficients across these four days are significant returns a p-value of .0111. The average coefficient estimate across these days is .01291, which roughly translates to a 1.3% increase in traffic fatalities on the four days following the full moon. On average, there are about 113 fatalities per day in our sample, so this translates to an increase of about 1.5 fatalities per day for the four days following each full moon. There are 408 non-winter full moons in our sample, which means our estimates imply a total of over 600 traffic fatalities attributable to the lunar cycle from 1975-2023.

In the top right panel of Figure 6, we focus only on the cloudier, winter months of November through February, and the effect once again virtually disappears. In fact, there are negative and borderline significant *reductions* in fatal car crashes on days zero and one. This is consistent with the extra ambient light from the full moon serving a protective effect by making it easier to drive at nighttime during the darker winter months, which we will explore further in the next section.

The second row of Figure 6 splits our data into the sunny and non-sunny states, and the results are once again similar. In the sunny states, there is surprisingly a negative and significant coefficient on the night of the full moon, followed by positive coefficients for the next four nights. The coefficient on day three is individually significant ($p = .007$) and a joint test for whether days one through four are different from zero returns a p-value of .0696. In the middle-right graph,

we restrict our sample to the non-sunny states, and there is no similar pattern. All thirteen of the coefficients are individually insignificant and oscillate above and below zero apparently at random. A joint t-test for whether days one through four are significantly different than zero returns a p-value of .5076.

Finally, the bottom row of the figure combines our two exposure measures. In the bottom-left, which includes only our sunny states during the non-winter months, all of the coefficients leading up to the moon are small and insignificant, while the four days following the full moon are all large in magnitude and significant at least at the 10% level. The average coefficient estimate across this period is .0171, and a joint test for significance across these four days yields a p-value of 0.004. The bottom right portion of the figure restricts the sample to the non-sunny states during the winter months, and the effect once again vanishes, with mostly insignificant coefficients oscillating back and forth across zero, with the exception of one negative and significant coefficient appearing on the day following the full moon.

So far, our results on fatal car crashes closely mirror those for self-reported sleep loss on the days around the full moon. Table 3 and Figure 7 explores this further by displaying regression results where we replace the individual leads and lags with a single treatment indicator for whether an observation falls on the four days following the full moon, where our largest effects show up for all three datasets. For each cut of the data in Figure 7, we display regression coefficients for the ATUS sleep data in light gray, coefficients for the BRFSS sleep data in dark gray, and coefficients for the FARS fatality data in black. Because the ATUS data has more variation overall, we scale down the ATUS coefficients and confidence intervals by a factor of five so that they are comparable with the BRFSS coefficients. Both the ATUS and BRFSS coefficients are measured in hours of sleep, while the FARS coefficients represent the log of the number of daily traffic fatalities.

In the first row, we impose no restrictions on our data. For both of the sleep variables, this model returns negative and significant coefficient estimates, while the FARS data returns a positive but borderline significant coefficient. We then iteratively impose the same restrictions that we added to our event-study specifications. When we focus on only the sunny states, all three coefficients get larger, with FARS coefficient now significant at 5%. Alternatively, when we focus on the non-sunny states, all three coefficients are now smaller and statistically insignificant. The BRFSS and FARS coefficients both attenuate substantially, while the ATUS coefficient is mostly unchanged aside from being slightly smaller with a confidence interval that now barely crosses zero. When we once again include all states but drop the cloudier winter months of November through February, all three coefficient are once again larger than the main specification and are significant at 5%. We then reverse this, and focus exclusively on the cloudier winter months, and all three coefficients again attenuate and now all have p-values greater than .2. In the final two columns, we combine our data restrictions and the results are similar. For the sunny states and non-winter months, both BRFSS and ATUS show large, significant reductions in sleep, while FARS displays a large, significant increase in traffic fatalities. Conversely, when we focus on the

non-sunny states during the winter months, the coefficients again attenuate towards zero and are all no longer significant at even 10%. Since the coefficients consistently exhibit similar, though opposite patterns, this suggests that any threat to our identification would have to be something that somehow impacts both sleep loss and fatal crashes in a way that is correlated with the lunar cycle over the period our datasets cover, which seems vanishingly unlikely. We now move on to implementing additional tests of the ambient light hypothesis which can only be executed on our traffic fatality data.

4.3. Additional Tests of the Ambient Light Hypothesis

As mentioned above, the ambient light hypothesis would predict that the impact of the lunar cycle on fatal crashes should be muted on full moons which are also total lunar eclipses, as the Earth is blocking the sun's light from reaching the moon and then reflecting back to the Earth. Figure 8 displays coefficient estimates from the same model used in Table 3 and Figure 7, with each row further split by whether each full moon is also a total lunar eclipse. Event-study versions of each of these specifications are display in Appendix Figures A.6 through A.8. Across the board, our main effects are driven entirely by full moons which are not also total lunar eclipses. All seven coefficients for total lunar eclipses are negative, and although they have much wider confidence intervals due to the smaller sample sizes, we can statistically rule out that the effect on total lunar eclipses and non-eclipses are equal on the main specification, the 'sunny state' specification, and the 'non-winter' specification. For both the 'non-sunny' and 'only winter' specifications, the coefficient on the total lunar eclipse full moons are negative and significant, indicating that these full moons may actually have a protective effect.

Next, we investigate whether our main effects differ during the post-2010 'smartphone era', where we now have abundant blue light at our fingertips, which has been extensively shown to disrupt sleep. Here, the ambient light hypothesis predicts that we might find smaller effects in the period after 2010, as light from smartphones may dwarf the consistent but relatively low doses of ambient light coming from the full moon. Figure 9 displays each of the coefficients from our main specification, as well as separately-estimated coefficients looking only at the 1975-2010 period and then the 2011-2023 period. Figure 9 demonstrates that our entire effect is coming from the 'pre-smartphone' era of 1975-2010. In each case, the coefficient estimate gets larger in magnitude and more statistically significant as we focus on the earlier period. Conversely, in all seven rows of the figure, the coefficient on the later period includes zero in its confidence interval, with each of the estimates on the more exposed samples being much smaller in magnitude than the corresponding estimate on the earlier period.

In our final test of the ambient light hypothesis, we re-estimate each of our main specifications separately for crashes that took place in the nighttime hours, during dawn or dusk, or during the daytime hours. As mentioned in the data section, we assigned crashes to periods of the day by first calculating sunrise and sunset times for every time of the year, using the equations derived

in Meeus (1998). We then assign all crashes in the hour before sunrise and the hour after sunset to the dawn/dusk group, while all crashes occurring between dawn and dusk are assigned to the daytime group, and all crashes occurring between the period beginning one hour after dusk until one hour before dawn in the morning are assigned to the nighttime group. Due to the fact that the proposed mechanism operates through sleep loss and impaired driving, the ambient light hypothesis would predict that at least some of the effects we find would be coming from daytime crashes. Alternative hypotheses that operate through the light from the full moon being a distraction for drivers on the road would predict that the entire increase would come from nighttime crashes. Figure 10 displays our main specifications, this time broken out by time of day the crashes took place, and also includes rows for our 'pre-post smartphone era' split of the data. Corresponding event-study figures are display in Appendix Figures A.9 through A.11.

Interestingly, our main effect is driven entirely by crashes occurring in the well-lit daytime hours, with both the nighttime and dawn/dusk coefficients being relatively precisely estimated null effects. This rules out any explanation of our findings that suggest that the full moon, which is typically either not visible or much less prominently visible during the daytime, serves as a distraction for drivers. Looking at the 'pre-smartphone' period, the coefficient estimate is again largest in the daytime, though the coefficient estimates are both positive and not statistically distinguishable from the daytime estimate for both nighttime and dawn/dusk crashes. Looking at the later period including post 2010 years, a dichotomy emerges from the daytime and nighttime estimates. After 2010, nighttime crashes are significantly *lower* during the days just after the full moon. While we do not have any direct evidence, one possible explanation for this could be that the light from the full moon could help drivers who are distracted by their phones. Furthermore, the effect on daytime crashes actually persists during this later period, and is actually of similar size in magnitude to the main effect and the pre-2011 effect.

In our sunny states, we see an effect on both daytime and nighttime crashes that are nearly identical, though no effect on crashes occurring at dawn or dusk. In the non-sunny states, a similar dichotomy to the post-2010 period emerges, where we see a decline in nighttime crashes, and an increase in daytime crashes, with no effect on crashes at dawn/dusk. When we exclude the winter months, the daytime coefficient is even larger in magnitude, while both the other coefficients are statistically indistinguishable from zero. In the period only including winter, we see precise nulls for daytime and dawn/dusk crashes, but a suggestive decline in nighttime crashes, which again could suggest that the extra nighttime light from the full moon could have a protective effect in otherwise cloudier skies. In the final column, we estimate effects on the intersection of the sunny states, excluding winter, in the pre-2011 period, and we see large and significant increases that are similar in magnitude for both daytime and nighttime crashes, with little impact on crashes at dawn and dusk.

4.4. *Additional Heterogeneity*

Figure 11 displays estimates of the heterogeneity in our treatment effect. We start with our most significant baseline finding, which includes the sample restricted to daytime crashes in our 'clear-sky' states during non-winter months, following non-eclipse full moons prior to 2011. We then explore how our treatment varies across a number of other dimensions by further splitting our sample based on other metrics before estimating equation (2). The top row of the figure displays the baseline estimate mentioned above, an increase of .023 log points (p = .000). We first test whether this effect varies by local sunset time. We know from prior work that later sunset times lead to later bedtimes and less overall sleep. Lower baseline levels of sleep could theoretically make counties more or less vulnerable to additional sleep disruptions from the lunar cycle. For each county, we take the mean sunset time between March and October. We then label counties as 'early sunset' or 'late sunset' counties based on whether their average sunset time is later than the median sunset time of 7:52pm. Figure A.17 displays the results of this sorting procedure. For the most part, 'late sunset' counties are the ones in the western half of each timezone, though no counties in Arizona are counted since Arizona does not observe DST. We then estimate our preferred specification above on both the early and late sunset counties in the second and third rows of figure 11. If anything, the effect is slightly largely and more precisely estimated on 'early sunset' counties, though the two estimates are both positive and significant and not statistically distinguishable from one another.

In rows four and five, we split the data based on whether the crashes took place in urban or rural roads. We might expect bigger effects in more rural settings, since urban areas have lots of nighttime ambient light throughout the lunar cycle. We find some suggestive evidence of bigger effects on urban roads, but we are unable to statistically distinguish between the two estimates. The same is true when we split accidents by whether alcohol was suspected to be involved in the crash, where we find significant increases for both crashes which do and do not involved alcohol. We next look for heterogeneity by gender of the drivers involved in the crash. Since about 75% of drivers in fatal car crashes are male, we split the data based on whether there was any female driver involved. In row eight, we see that the increase in crashes involving female drivers is about 40% smaller than the main effect and is no longer statistically significant (p = .121), while the coefficient on crashes not involving any female drivers is similar to the baseline effect for this exercise in magnitude (.024 log points) and significance (p = .000).

Rows 10 and 11 split the data by whether there was any adverse weather at the time of the accident. Approximately 92% of all accidents in our dataset happened under clear driving conditions, so it is little surprise that our main effects are driven entirely by accidents happening without adverse weather conditions, but this rules out any potential weather confounding with the lunar cycle. We also split our data by whether each accident took place on an interstate highway or not. Only about 12% of accidents in our data take place on interstate highways, which explains the wider confidence intervals and lack of significance for these accidents, though we

cannot rule out that the coefficients on the two types of accidents are equal. Finally, we split our dataset by whether there was a pedestrian involved in each accident, and the coefficients are once again similar though with wider confidence intervals for accidents that do involve a pedestrian

4.5. Robustness Checks and Simulations

One possible concern with our main findings is that we have a large sample size of almost 18,000 daily observations spanning 49 years of crash data. With such a well-powered sample, it becomes possible for a single anomalous result to stand out. In order to assess the likelihood that our results are simply a statistical irregularity and not a causal effect of the lunar cycle on traffic fatalities, we run placebo simulations designed to test how frequently results as large as the ones we find show up in our dataset. For each simulation, we sort our entire 49-year sample into consecutive 29-day increments, similar to the lunar cycle. Then, within each lunar cycle, we randomly select one of the 29 days to be the day of the full moon. Then, just as in our main specifications, we assign treatment status to the four days following our placebo full moon and run our main specification from equation (2). Since these placebo full moons are assigned randomly and uncorrelated with the actual lunar cycle, they should not return large coefficient estimates if our hypothesized mechanism is in fact causal. We therefore run 10,000 simulations of this form, and compare the distribution of the resulting estimates with our actual regression coefficients in order to determine how frequently this random process generates effect-sizes which are larger in magnitude than our true estimates. We calculate p-values for inference using the formula $\frac{N+1}{10,000}$, where N is the number of estimates that are larger in magnitude than our estimated coefficient from our main empirical analysis.

Appendix Figure A.18 displays the results of this process for our main specification. Of the 10,000 estimates, 544 of them are larger in magnitude than our actual estimate of 0.0065, consistent with a p-value of .0545. Interestingly, this is almost identical to the p-value from our main estimate, which was .054. This suggests that the standard errors from our main analysis are unlikely to be biased downward. Appendix Figure A.19 repeats this process for our four main sample restrictions. In the top left graph, we restrict the sample to our 25 'sunny states'. Now, only 47 of the 10,000 placebo estimates are larger in magnitude than our estimate of 0.0108, consistent with a p-value of .0048. Once again, this is almost identical to the p-value from our earlier specification of .004. In the top right graph, we drop the months of November through February before running our specifications. Here, only 7 of the 10,000 placebo estimates are larger than our estimate of .0134, for a p-value of .0008 (compared with $p = .000$ for our estimate). In the bottom left, we restrict the sample by dropping all observations after 2010, where smartphones became popular. Now, our estimate of 0.0092 is larger than all but 179 of the placebo estimates, for a p-value of .0180 (compared with $p = .021$ above). Finally, when we restrict the placebo estimates to daytime crashes, our estimate of 0.0130 is larger than all but 23 of the placebo estimates, consistent with a p-value of .0024 (compared with $p = .002$ above). Together, these figures suggest that it is highly

unlikely that the results presented above are merely a statistical artifact of our data.

Another concern is that we might find similar effects by looking at other phases of the lunar cycle. In other words, it might be that there is enough variation in crashes that we could find significant increases at other parts of the lunar cycle, but that we happened to only look specifically around the full moon. In order to address that, Appendix Figure A.20 runs placebo specifications where we assume other days in the lunar cycle are actually the full moon. We then mark the subsequent four days as 'treated' and run our preferred specification, where we restrict the sample to clear sky states in non-winter months, and focus only on non-lunar eclipses. We do this for every possible start date, from 14 days before the full moon to 14 days after. The only dates which return a significant increase in fatal crashes are when the full moon date is assigned to be the day before the full moon, the actual full moon, and the two days after the full moon. A few days earlier in the cycle return negative and significant estimates, but this could partially be due to the fact that the true full moon dates, where we see large increases in accidents, are included in the control group for these specifications.

Another potential concern is that perhaps our results are driven by some extreme outlier. For example, if there was one particular full moon where there happened to be an extremely violent crash or set of crashes, where many people died, this could potentially explain our findings. At baseline, this seems quite unlikely since we are looking at over 600 hundred full moons spanning 49 years of crash data. For such an event to explain our findings, it would have to involve hundreds of fatalities, while the deadliest crash in our entire dataset was a 1976 crash in Los Angeles that took the lives of 29 people. Still, it is important to demonstrate that our results do not depend on any single full moon period or even calendar year. To do this, we conduct a 'leave-one-out' analysis, where we iteratively drop each year or full moon and then reestimate our main specifications, saving both the coefficient estimate and the lower bound of the 95% confidence interval.

Figure A.21 displays the distributions of estimates and lower confidence bounds for our six specifications where we found increases in fatal car crashes in the days just following the full moon. In each graph, the main estimates are displayed in black, while the lower confidence bounds are in gray. A vertical line is displayed at zero in each graph to help the reader see whether the significance of the estimates hinges upon the inclusion of any particular year. In the top left, we display results for our main specification, with no data restrictions. There is some variation in the coefficients, but they are always positive and between .0052 and .0080. This specification was not significant at 5% in Panel C of Table 3, so it is no surprise that about half of the lower bounds are below zero.

As we cycle through the other specifications, the distributions of coefficient estimates are all tightly centered, indicating that they do not change much when a single year is excluded. For the specifications on the sunnier states, the ones excluding winter months, the ones excluding total lunar eclipses, and the ones focusing on daytime crashes, all 49 coefficient estimates are positive and remain significant at 5%. The only other specifications that are no longer significant

are in the sample which focuses on the pre-2011 period. Here, when we drop 1986 or 1987, the lower confidence bound crosses over zero, but both estimates are still greater than .007 and have p-values less than .06.

Appendix Figure A.22 repeats this process for every one of the 606 full moons in our sample, to assess whether our results are dependent on any particular lunar cycle. On the main specification, with no data restrictions, once again about half of the lower bounds cross zero, though all of the estimates are clustered between .0057 and .0070. When we cycle through our sample restrictions, every one of the 3,480 estimates[18] are positive and significant at 5%, again suggesting that our main results are not driven by the inclusion of any particular full moon or year of data.

5. Discussion and Conclusion

5.1. Back-of-the-Envelope Calculation

We now turn to an attempt to quantify the burden of traffic fatalities related to the lunar cycle. We calculate the implied daily number of excess traffic fatalities in the four days following the full moon by taking our coefficient estimate, converting it to a percentage change, and then multiplying that by the baseline number of traffic fatalities in our sample. This procedure gives us the daily increase in fatalities, which we then multiply by the number of 'full moon treated' days in that subsample to arrive at the annual and total burden. Our main estimate with no sample restrictions implies that in the days immediately following the full moon there is an increase of .0065 log points in daily nationwide traffic fatalities. This is consistent with a 0.621% increase.[19] On average, there were 112.8 daily traffic fatalities across our sample, so our coefficient estimate implies a daily increase of $112.8 * .00652 = 0.735$ fatalities attributable to the lunar cycle on the four days following the full moon. With 12 or 13 full moons each year, and four 'treated' days per full moon, this translates to an additional 35.3-38.2 fatalities per year, and an additional 1,780 fatalities over the course of our 49-year sample window. Using the 2023 Value of a Statistical Life, this translates to an estimated cost of approximately half a billion dollars each year. Interestingly, this annual burden is comparable in magnitude to Smith (2016)'s estimate of about 30 annual deaths attributable to the spring daylight saving time transition, even though the mechanisms differ meaningfully: where DST imposes a single, acute, semiannual shock to sleep, the lunar cycle operates through smaller, consistent, recurring disruptions that repeat twelve to thirteen times a year.

While we are only able to directly measure fatal car accidents, it is likely that the lunar cycle has a similar effect on non-fatal crashes, which make up the vast majority of all traffic accidents. According to the National Highway Traffic Safety Association (NHSTA) publicly available annual

[18] This is made up of 606 estimates for each of the specifications on the sunnier states, the ones excluding winter months, the ones excluding total lunar eclipses, and the ones focusing on daytime crashes, as well as 450 estimates from the pre-2011 period, where we stop iterating through full moons once we reach 2011.

[19] We calculate this using the formula $\Delta\% = e^x - 1$ where x is the coefficient estimate from our regression

Traffic Safety Reports from 2018-2023, only about 0.6% of all traffic accidents result in a fatality. If the lunar cycle has the same effect on non-fatal crashes as it does on fatal crashes, this would suggest that 5,883 to 6,367 accidents are caused by the full moon annually.[20] Using estimates from Blincoe et al. (2023), the estimated costs of motor vehicle accidents in 2019 were $339.8 billion. Of this, medical costs accounted for $30.9 billion, $115.3 billion from property damages, lost productivity accounted for $106.3 billion, and $36 billion from congestion and the remaining went to other costs. Considering that there were 6,756,084 crashes in 2019, this equates to $50,295 per crash. Applying this number to our estimated increase in total crashes means an additional economic burden of $295-320 million due to accidents caused by the lunar cycle. In addition to costs borne onto the victims of the accidents, costs are imposed onto others. According to Blincoe et al., 2023, 9% of all vehicle crashes are paid for by public revenues. Further, an estimated 54% of all costs are paid by private insurers and 15% are paid for by uninvolved people. Therefore, about 70% of the costs of accidents are placed onto those not involved.

5.2. Conclusion

This paper introduces the lunar cycle as a novel, recurring, and plausibly exogenous source of variation in sleep, allowing us to study the causal relationship between sleep loss and fatal traffic accidents while circumventing the confounding role of ambient light that has long complicated the daylight savings time literature. Using over 1.8 million fatal crashes from FARS and over 2.6 million self-reported sleep responses from BRFSS, supplemented by 245,000 time diaries from ATUS, we show that both self-reported sleep and fatal crashes deteriorate in the days following the full moon, with effects that scale consistently with independent proxies for ambient light exposure. Effects are more than twice as large in states with clearer skies and during non-winter months, vanish during total lunar eclipses when the moon's illumination is blocked by the Earth's shadow, and are strongest in the pre-smartphone era, when alternative nighttime ambient light was scarcer and thus potentially more likely to meaningfully disrupt sleep. Critically, our effects are driven by daytime crashes rather than crashes at night, ruling out a simple visibility or distraction-based explanation and pointing instead to sleep loss as the operative mechanism.

Our results imply that the lunar cycle is responsible for approximately 35 to 38 additional traffic fatalities each year, or roughly 1,780 deaths over our 49-year sample period. Extensive robustness checks, including simulations using randomly assigned placebo full moons and leave-one-out analyses dropping each year and each lunar cycle in turn, indicate that our findings are not driven by any single full moon, year, or idiosyncratic cluster of crashes, and that our standard errors are unlikely to be meaningfully understated.

Taken together, our findings underscore that even small, frequent and easily overlooked sleep disruptions can accumulate into large and measurable social costs. Although a single night of lost

[20] This is calculated by taking the inverse of 0.06% and multiplying it by the estimated increase in fatal accidents caused by the full moon, e.g. $\frac{1}{0.006} \times 35.3$.

sleep tied to lunar brightness may seem trivial at the individual level, its population-wide and recurring nature makes it a meaningful contributor to traffic mortality nationally. More broadly, our findings add to the growing literature that shows that ambient environmental conditions can meaningfully shape health and safety outcomes through channels that are easy to miss without a research design capable of isolating them. Future work might explore whether targeted public health messaging around the full moon could meaningfully reduce this modest but persistent source of preventable death.

Table 1 — Summary Statistics for Sleep Data from the Behavioral Risk Factor Surveillance System (BRFSS) and American Time Use Survey (ATUS)

	BRFSS	ATUS
Dataset Outline		
Total # of Observations	2,694,255	245,139
Range of Years	2013-2022	2003-2023
Unique Years	6	21
# of Lunar Cycles Linked	95	250
Sleep Variable		
Output Format	Hours	Minutes
Mean	7.05	527.44
Median	7	515
Standard Deviation	1.47	136.22
Min	1	0
Max	24	1436
Share < 4 hrs	1.14%	1.47%
Share > 12 hrs	0.35%	6.52%

Notes: This table displays summary statistics on self-reported sleep from the Behavioral Risk Factor Surveillance System (BRFSS) and American Time Use Survey (ATUS). BRFSS data contains the response to the question 'On average, how many hours of sleep do you get in a 24-hour period?'. BRFSS asked this question in the 2013, 2014, 2016, 2018, 2020, and 2022 cycles. ATUS contains the results of a time diary, where respondents tracked what they did and for how long over a 24-hour period. We used these time diaries to construct a variable which measures how much time each respondent reported using the code for 'sleep'.

Table 2 — Summary Statistics for Fatality Analysis Reporting System (FARS) Data - 1975-2023

	All	Sunny	Non-Sunny	Non-Winter	Winter
Avg. Daily Crashes	102.31	60.98	40.77	105.56	95.75
Avg. Daily Fatalities	112.83	68.10	45.04	117.46	103.47
% of Crashes Involving					
Drunk Driver	0.32	0.31	0.32	0.32	0.30
Pedestrian	0.18	0.19	0.18	0.17	0.20
Rural Area	0.54	0.55	0.53	0.55	0.53
Urban Area	0.45	0.45	0.46	0.45	0.47
Interstate Highway	0.11	0.12	0.09	0.11	0.11
No Adverse Weather	0.88	0.90	0.86	0.91	0.81
Driver Under 30	0.41	0.41	0.42	0.42	0.39
Driver Over 40	0.39	0.39	0.38	0.38	0.40
Any Female Driver	0.31	0.32	0.31	0.31	0.32
% of Crashes by Time of Day					
Dawn	0.03	0.03	0.03	0.03	0.04
Daytime	0.48	0.47	0.49	0.52	0.38
Dusk	0.06	0.07	0.06	0.06	0.07
Nighttime	0.42	0.43	0.42	0.39	0.51

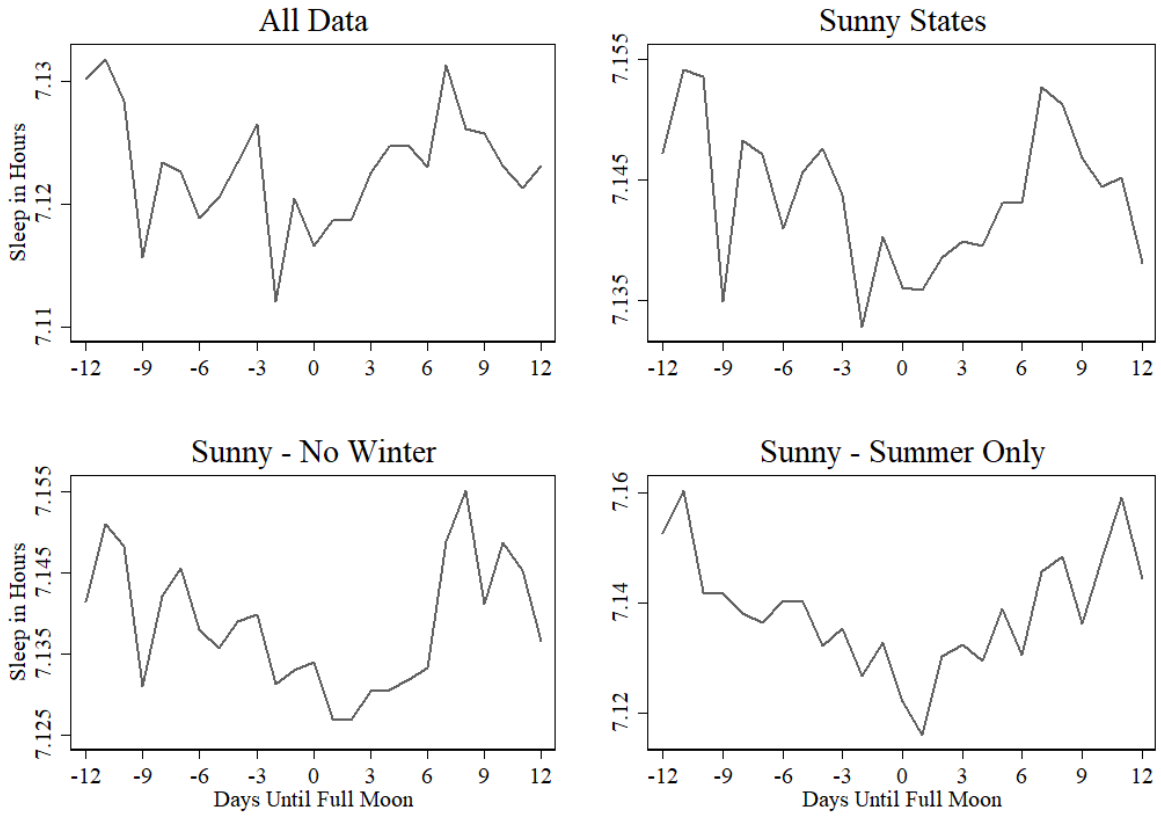
Notes: This table displays summary statistics on daily fatal car crashes and total fatalities using data are from the Fatality Analysis Reporting System (FARS). The first column displays statistics for our entire sample from 1975-2023 with no data restrictions. The second and third columns split our data into the 25 states with the most 'clear sky' days and the 25 states with the least 'clear sky days'. The fourth column looks at all states pooled together, but focuses only on crashes taking place between March and October, while the fifth column focuses only on crashes taking place between November and February. We report the average daily number of crashes and fatalities in the first two rows. The next nine rows display the share of total crashes that involve a drunk driver, a pedestrian, rural or urban roads, and interstate highway, clear weather, a driver younger than 30, a driver older than 40, or a female driver. The last four rows display the share of crashes that happen in the hour before sunrise (dawn), between sunrise and sunset (daytime), in the hour following sunset (dusk), and more than an hour after sunset and more than an hour before the following sunrise (nighttime).

Table 3 — Regression Estimates of the Effect of the Lunar Cycle on Self-Reported Sleep and Fatal Car Crashes

	All	Sunny	Non-Sny	Drop Winter	Only Winter	Sun/No Wntr.	Non-Sny/Winter
Panel A: ATUS - Self-Reported Sleep (Minutes)							
Full Moon	-2.826***	-4.010***	-1.481	-3.0001***	-1.6239	-3.9568**	0.2162
	(0.6285)	(0.7897)	(1.0915)	(1.0833)	(1.3714)	(1.7289)	(1.6853)
Dep Mean							
Observations	245,137	129,528	115,607	162,137	82,998	85,667	39,138
Panel B: BRFSS - Average Self-Reported Sleep (Hours)							
Full Moon	-0.0050*	-0.0079*	-0.0020	-.0074**	-.0003	-0.0128***	-0.0024
	(0.0023)	(0.0033)	(0.0032)	(0.0025)	(0.0035)	(0.0035)	(0.0051)
Dep Mean	7.124	7.145	7.102	7.120	7.132	7.140	7.109
Observations	2,554,468	1,332,835	1,195,822	1,725,559	828,509	903,863	389,579
Panel c: Log of Daily Traffic Fatalities (FARS)							
Full Moon	0.0065	0.0108*	-0.0012	0.0134***	-0.0085	0.0179***	-0.0176
	(0.0033)	(0.0037)	(0.0051)	(0.0038)	(0.0062)	(0.0043)	(0.0096)
Dep Mean	4.698	4.191	3.751	4.735	4.621	4.222	3.651
Observations	17,897	17,897	17,897	12,005	5,892	12,005	5,892

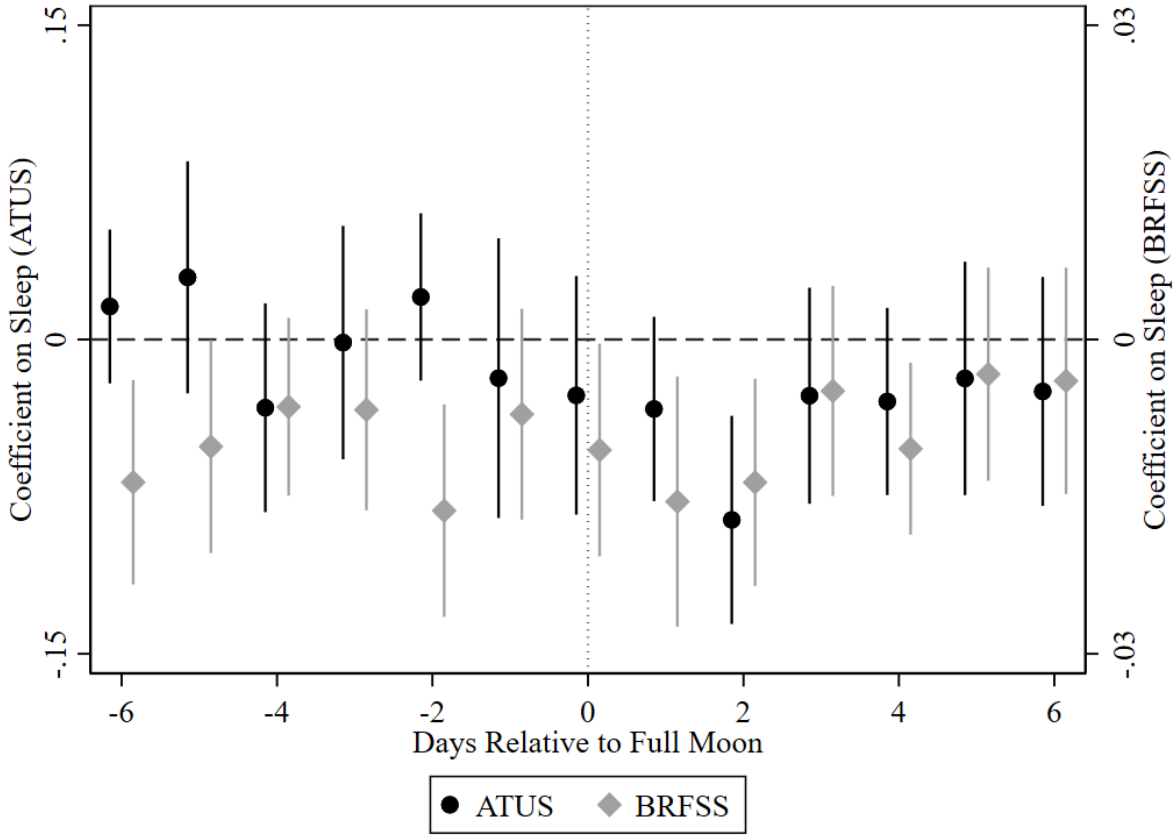
This table displays regression results of the effect of the lunar cycle on self-reported sleep from the American Time Use Survey (ATUS) and the Behavioral Risk Factor Surveillance System (BRFSS) as well as fatal car accidents using data from the Fatality Analysis Reporting System (FARS). Each regression measures whether the outcome was different on the four days following the full moon compared with the rest of the lunar cycle. The first column includes all data, while the subsequent columns restrict the data in various ways to test whether ambient light is the key mechanism through which the effect operates. The second column restricts the sample to the 25 states with the most 'clear sky' days, while the third column restricts the sample to the 25 states with the fewest 'clear sky' days. The third and fourth columns drop the months of November through February and then estimate our specifications exclusively on these months. The sixth columns restricts the sample to the 'clear sky' states and excludes the winter months, while the seventh column restricts the sample to 'non-clear sky states' and includes only the winter months. Panel A estimates the effect on self-reported sleep in minutes from ATUS. Panel B estimates the effect on average self-reported sleep from BRFSS. Panel C estimates the effect on the log of the number of daily traffic fatalities. *Note:* $^{*}\ p < .05$, $^{**}\ p < .01$, $^{***}\ p < .001$.

Figure 1 — Hours of Sleep Reported in the Days Surrounding the Full Moon



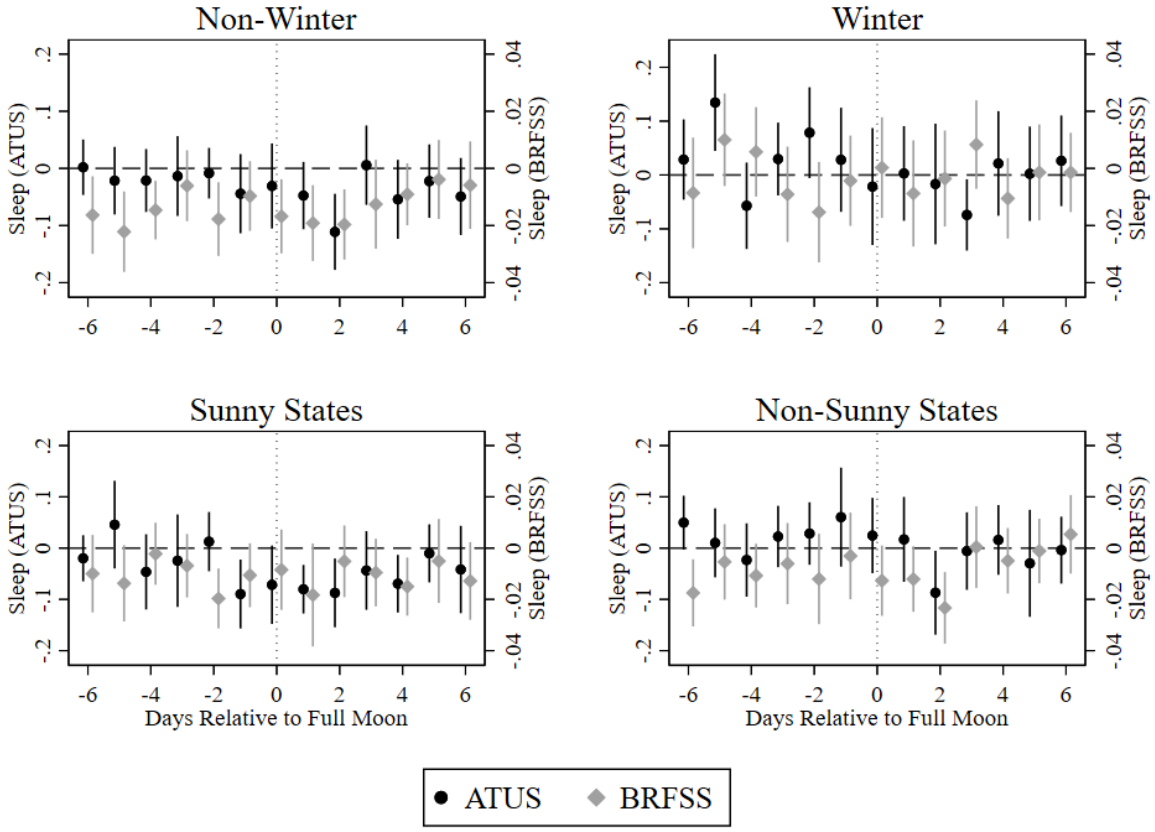
Note: This figure displays the reported sleep from the 12 days leading up to the full moon, the day of the full moon, and the 12 days following the full moon using data from the Behavioral Risk Factor Surveillance System (BRFSS). The top left panel includes data from all respondents. The top right restricts our sample to only observations from the 25 sunniest states according to the National Oceanic and Atmospheric Administration. The bottom lest panel further restricts our data to exclude observations from November through February, while the bottom right panel includes only observations from May through August.

Figure 2 — Event-Study Estimates of the Effect of the Lunar Cycle on Self-Reported Sleep - BRFSS and ATUS



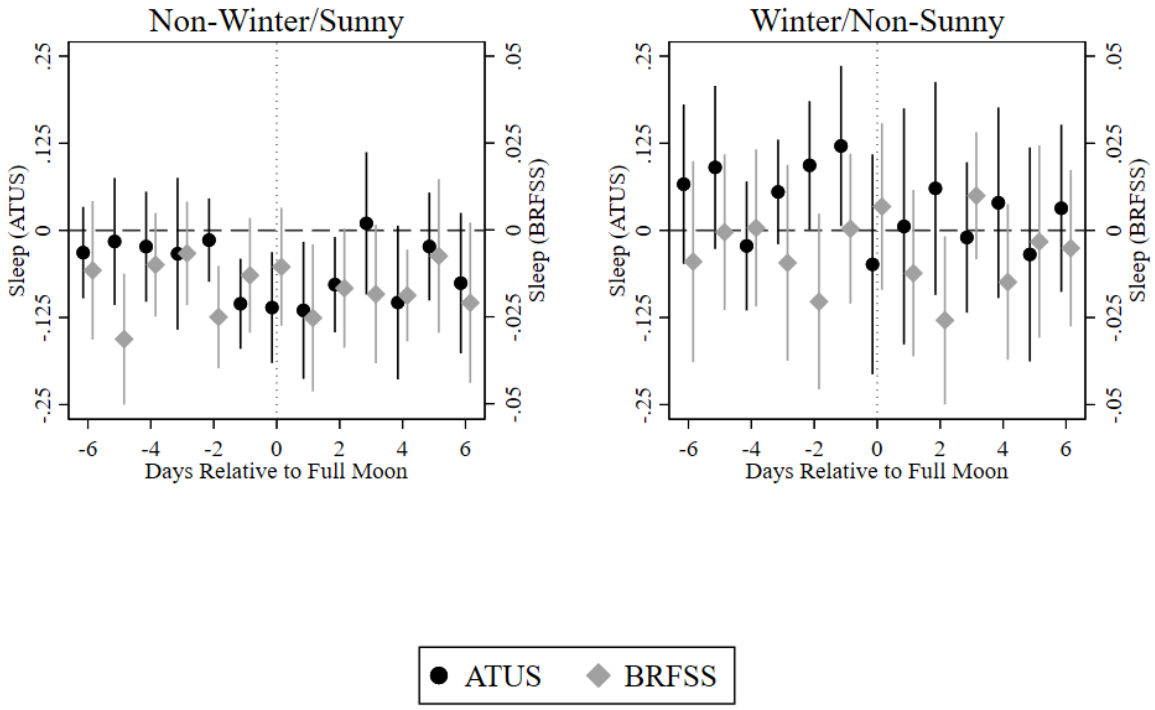
Note: This figure displays event-study estimates of the effect of the lunar cycle on self-reported sleep using data from the Behavioral Risk Factor Surveillance System (BRFSS) and the American Time Use Survey (ATUS). The graph shows the evolution of self-reported sleep for the six days leading up to the full moon, the date of the full moon, and the six days following the full moon, compared with the rest of the lunar cycle. Each specification includes controls for month, year, and day of week, along with individual controls for sex, age, race, and education, and an indicator for whether the day of observation was a holiday. Standard errors are clustered at the state level.

Figure 3 — Event-Study Estimates of the Variation in the Effect of the Lunar Cycle on Self-Reported Sleep Based on Time of Year and Average Number of Cloudy Days in Each State - BRFSS and ATUS



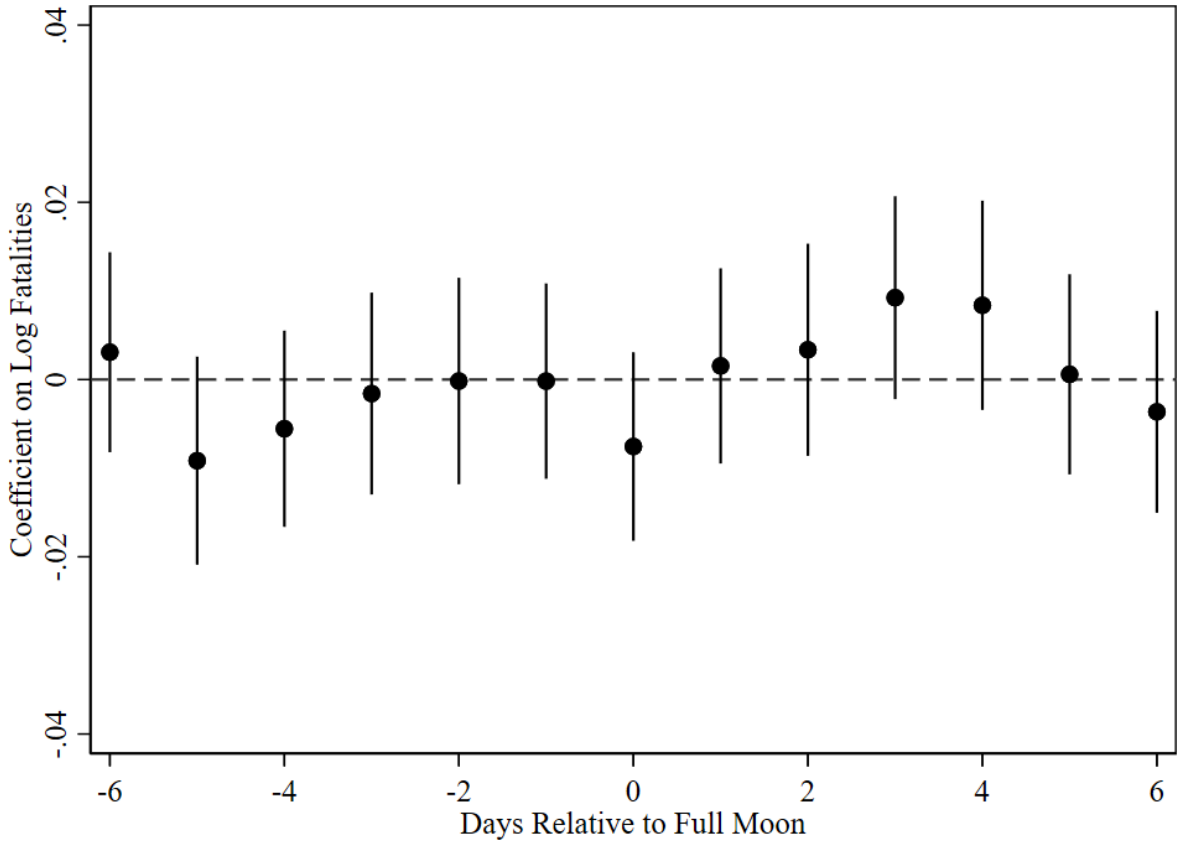
Note: This figure displays event-study estimates of the effect of the lunar cycle on self-reported sleep using data from the Behavioral Risk Factor Surveillance System (BRFSS) and the American Time Use Survey (ATUS). Each graph shows the evolution of self-reported sleep for the six days leading up to the full moon, the date of the full moon, and the six days following the full moon, compared with the rest of the lunar cycle. The top left graph displays the effect when the sample is restricted to the 25 states with the most 'clear sky' days per year. The top right graph displays the effect when the sample is restricted to the 25 states with the fewest 'clear sky' days per year. The bottom left graph displays the effect when excluding the months of November through February. The bottom right graph displays the effect when excluding all months except for November through February. Each specification includes controls for month, year, and day of week, along with individual controls for sex, age, race, and education, and an indicator for whether the day of observation was a holiday. Standard errors are clustered at the state level.

Figure 4 — Event-Study Estimates of the Variation in the Effect of the Lunar Cycle on Self-Reported Sleep Based on Time of Year and Number of Cloudy Days in Each State - BRFSS and ATUS



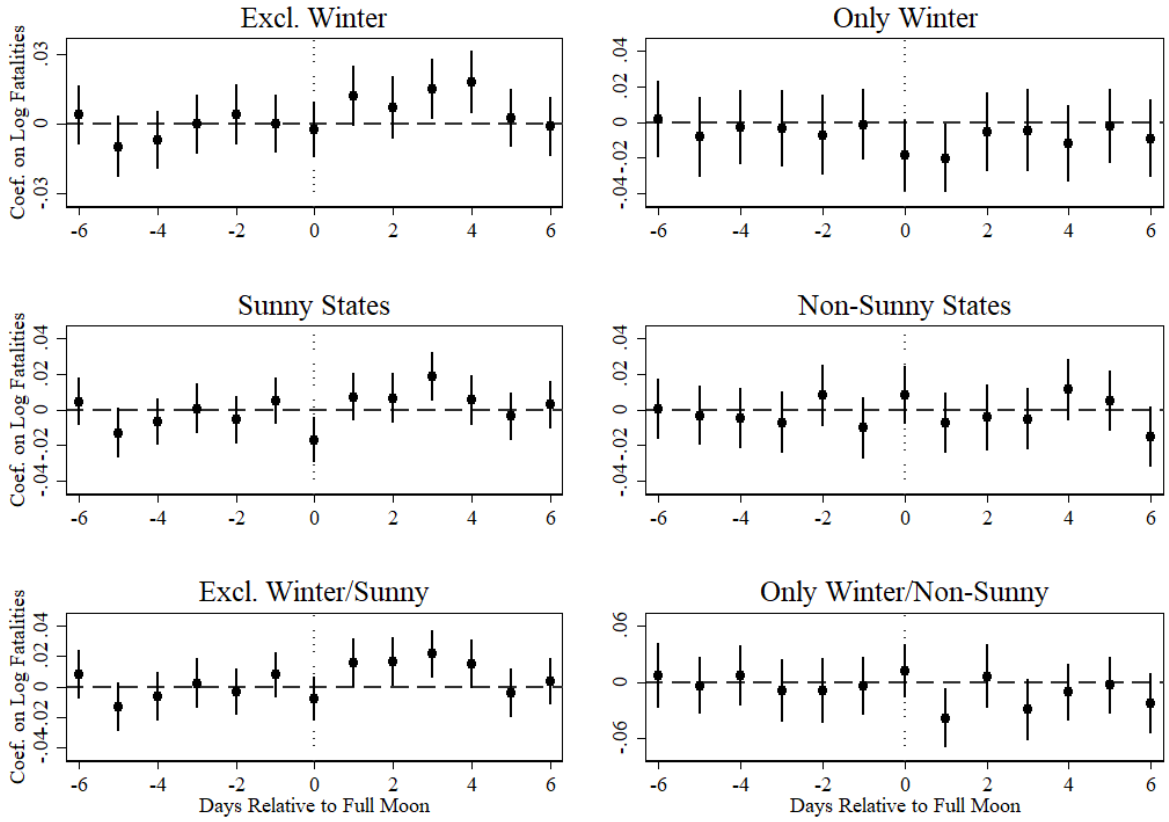
Note: This figure displays event-study estimates of the effect of the lunar cycle on self-reported sleep using data from the Behavioral Risk Factor Surveillance System (BRFSS) and the American Time Use Survey (ATUS). Each graph shows the evolution of self-reported sleep for the six days leading up to the full moon, the date of the full moon, and the six days following the full moon, compared with the rest of the lunar cycle. The left graph displays the effect when the sample is restricted to the 25 states with the most 'clear sky' days per year and the non-winter months. The right graph displays the effect when the sample is restricted to the 25 states with the fewest 'clear sky' days per year and the winter months. Each specification includes controls for month, year, and day of week, along with individual controls for sex, age, race, and education, and an indicator for whether the day of observation was a holiday. Standard errors are clustered at the state level.

Figure 5 — Event-Study Estimates of the Effect of the Lunar Cycle on the Log of Daily Traffic Fatalities - FARS



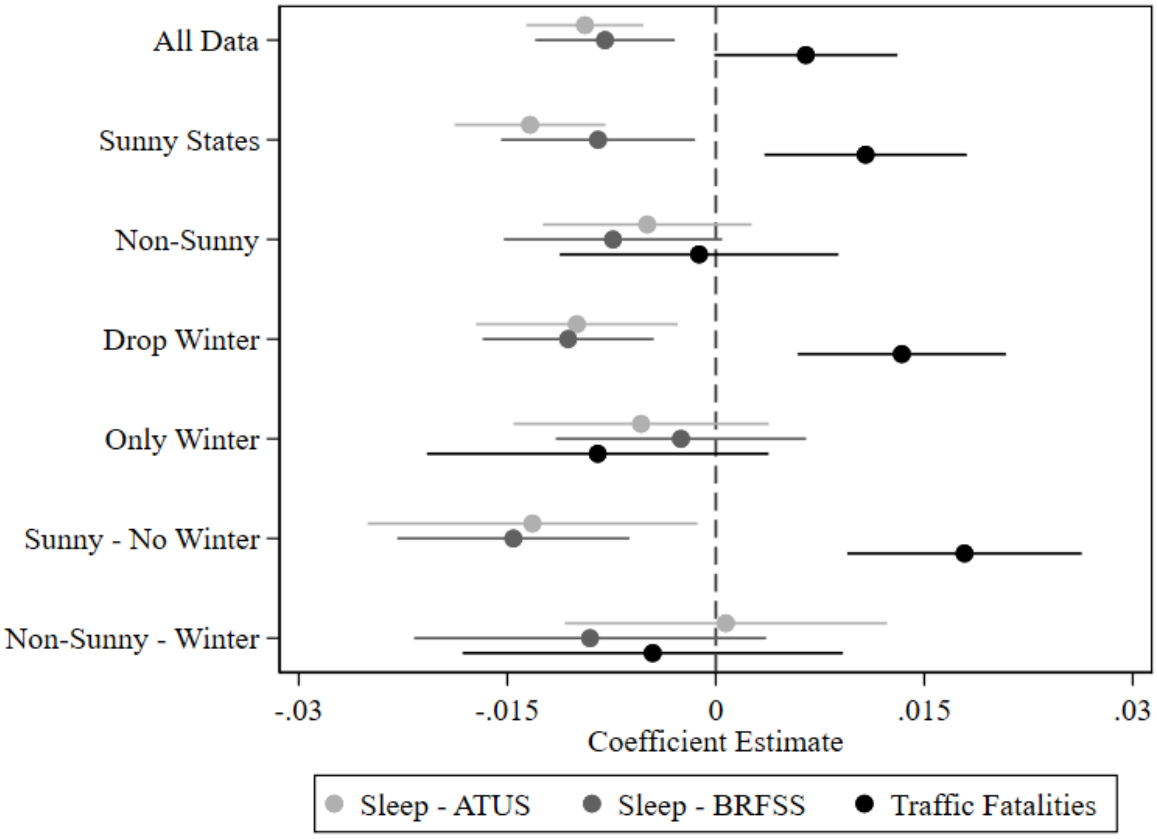
Note: This figure displays event-study estimates of the effect of the lunar cycle on fatalities from car crashes using data from the Fatality Analysis Reporting System (FARS) from 1975-2023. The graph shows the evolution of traffic fatalities for the six days leading up to the full moon, the date of the full moon, and the six days following the full moon, compared with the rest of the lunar cycle. The specification includes year-month, day-of-week, and day-of-year fixed effects. Standard errors are clustered at the year-month level.

Figure 6 — Event-Study Estimates of the Variation in the Effect of the Lunar Cycle on Traffic Fatalities Based on Time of Year and Average Number of Cloudy Days in Each State- FARS



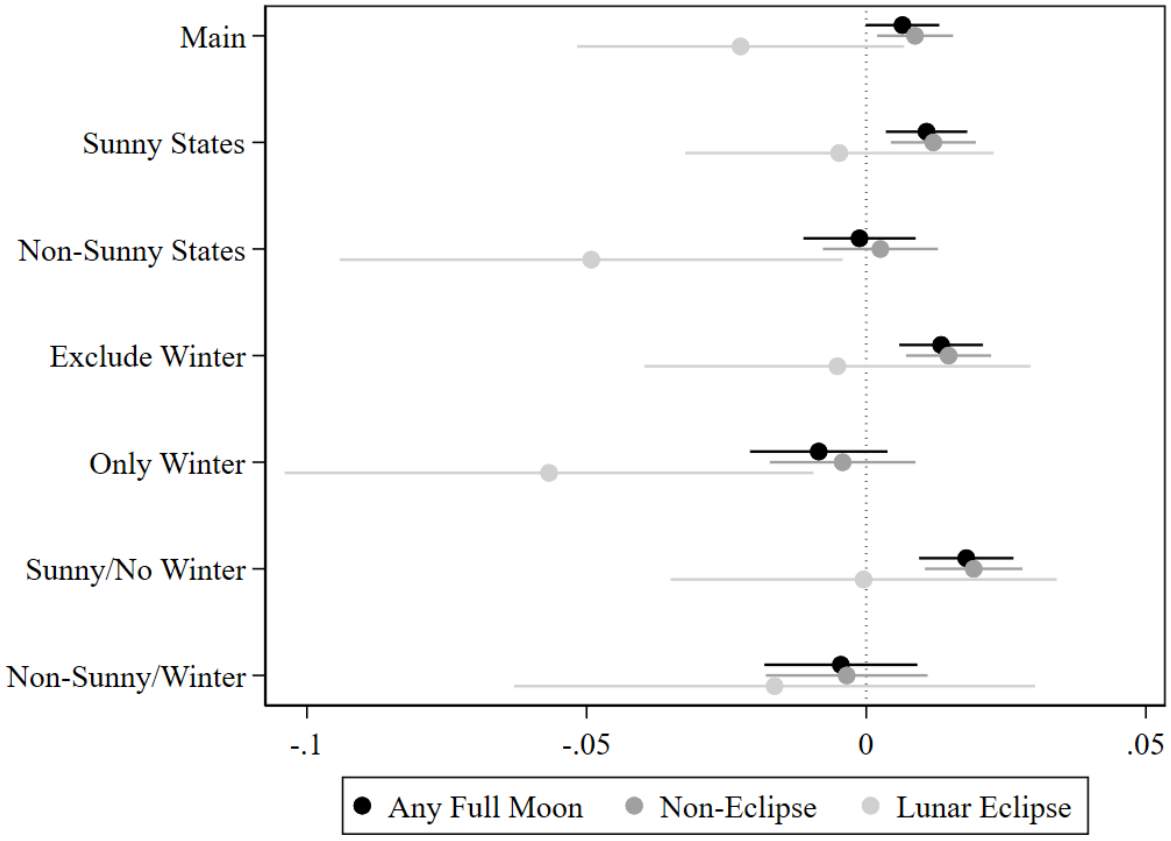
Note: This figure displays event-study estimates of the effect of the lunar cycle on fatalities from car crashes using data from the Fatality Analysis Reporting System (FARS) from 1975-2023. The top left graph displays the effect when excluding the months of November through February. The top right graph displays the effect when excluding all months except for November through February. The middle left graph displays the effect when the sample is restricted to the 25 states with the most 'clear sky' days per year. The middle right graph displays the effect when the sample is restricted to the 25 states with the fewest 'clear sky' days per year. The bottom left graph displays the effect when the sample is restricted to the non-winter months and the days with the most 'clear sky' days, while the bottom right graph displays the effect when the sample is restricted the winter months and the states with the fewest 'clear sky' days. The specification includes year-month, day-of-week, and day-of-year fixed effects. Standard errors are clustered at the year-month level.

Figure 7 — Coefficient Estimates of the Variation in the Effect of the Lunar Cycle on Sleep and Traffic Fatalities Based on Time of Year and Average Number of Cloudy Days in Each State



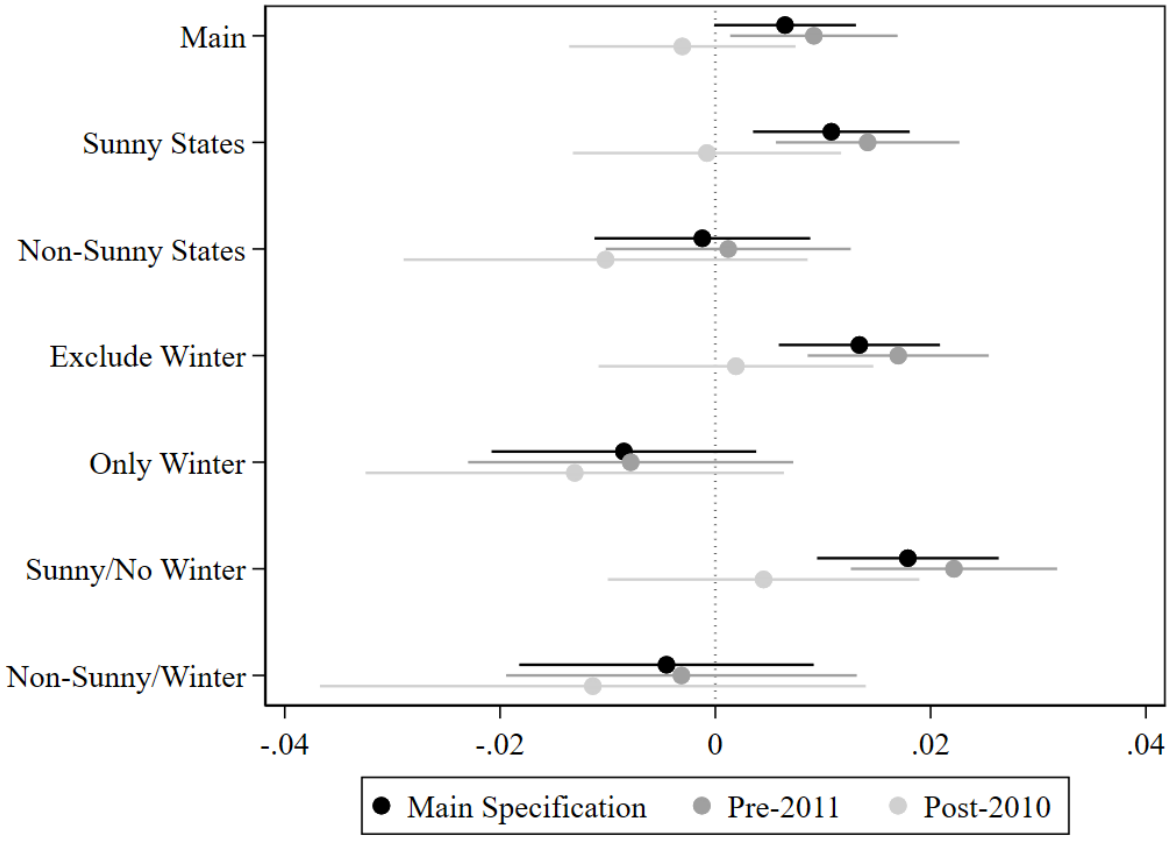
Note: This figure displays coefficient estimates of the effect of the lunar cycle on self-reported sleep from the Behavioral Risk Factor Surveillance System (BRFSS) adn the American Time Use Survey and fatalities from car accidents from the Fatality Analysis Reporting System (FARS). Each coefficient measures how much different the outcomes are for the four days following the full moon than for the rest of the month, controlling for day of week and year-month fixed effects for sleep, as well as day of year fixed effects for traffic fatalities. The first row displays the results without any sample restrictions. The second row displays the results the for 25 states with the most clear sky days, while the third row displays results for the 25 states with the fewest clear sky days. The fourth row displays results dropping the winter months of November through February, while the fifth row displays results on only November through February. The sixth row displays results for the 25 'clear sky' states while dropping the winter months, while the seventh row displays results for the 'non clear sky' states, including only the winter months.

Figure 8 — Coefficient Estimates of the Variation in the Effect of the Lunar Cycle on Sleep and Traffic Fatalities Based on Time of Year, Average Number of Cloudy Days in Each State, and Whether the Full Moon was a Total Lunar Eclipse.



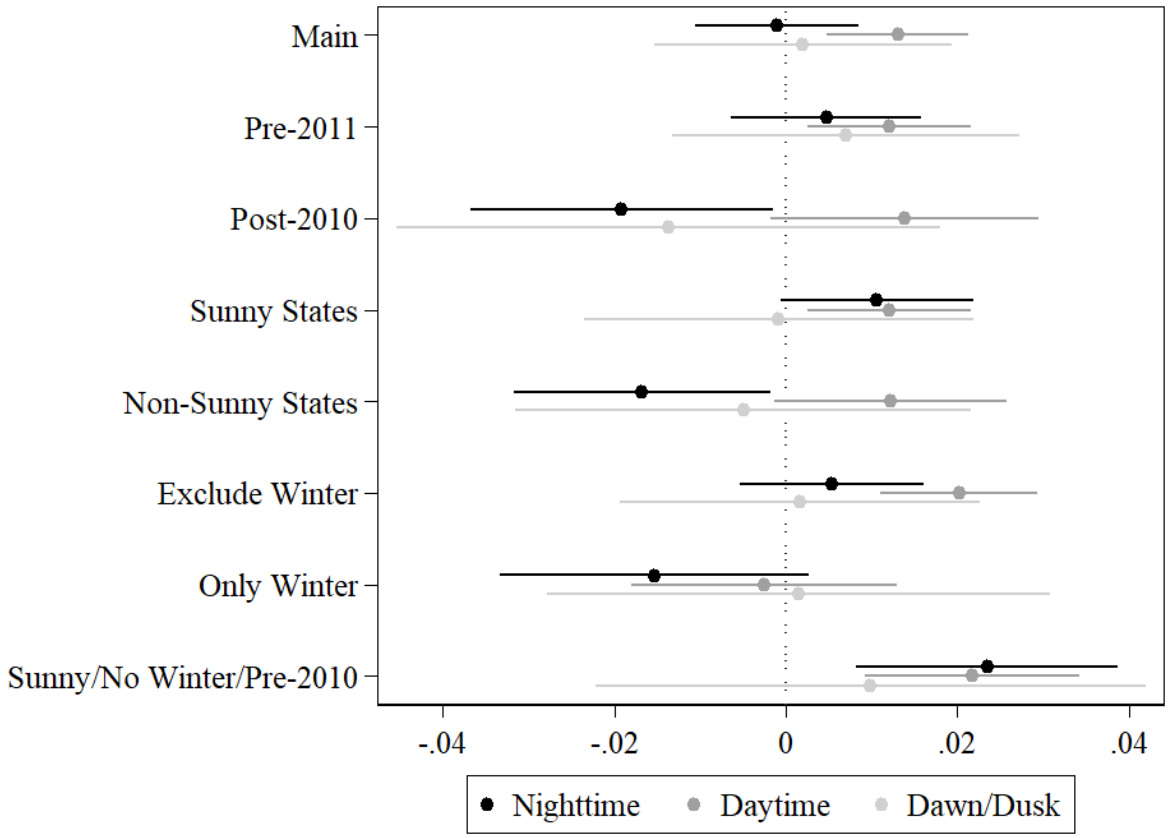
Note: This figure displays coefficient estimates of how the effect of the lunar cycle on traffic fatalities varies based on whether the full moon is a total lunar eclipse using data from the Fatality Analysis Reporting System (FARS). Each coefficient measures whether there are more fatalities on the four days following the full moon than for the rest of the month, controlling for day of week, year-month, and day-of-year fixed effects. The first row displays the results without any sample restrictions. The second row displays the results the for 25 states with the most clear sky days, while the third row displays results for the 25 states with the fewest clear sky days. The fourth row displays results dropping the winter months of November through February, while the fifth row displays results on only November through February. The sixth row displays results for the 25 'clear sky' states while dropping the winter months, while the seventh row displays results for the 'non clear sky' states, including only the winter months.

Figure 9 — Coefficient Estimates of the Variation in the Effect of the Lunar Cycle on Sleep and Traffic Fatalities Based on Time of Year, Average Number of Cloudy Days in Each State, and Whether the Crashes Took Place Before or After 2010.



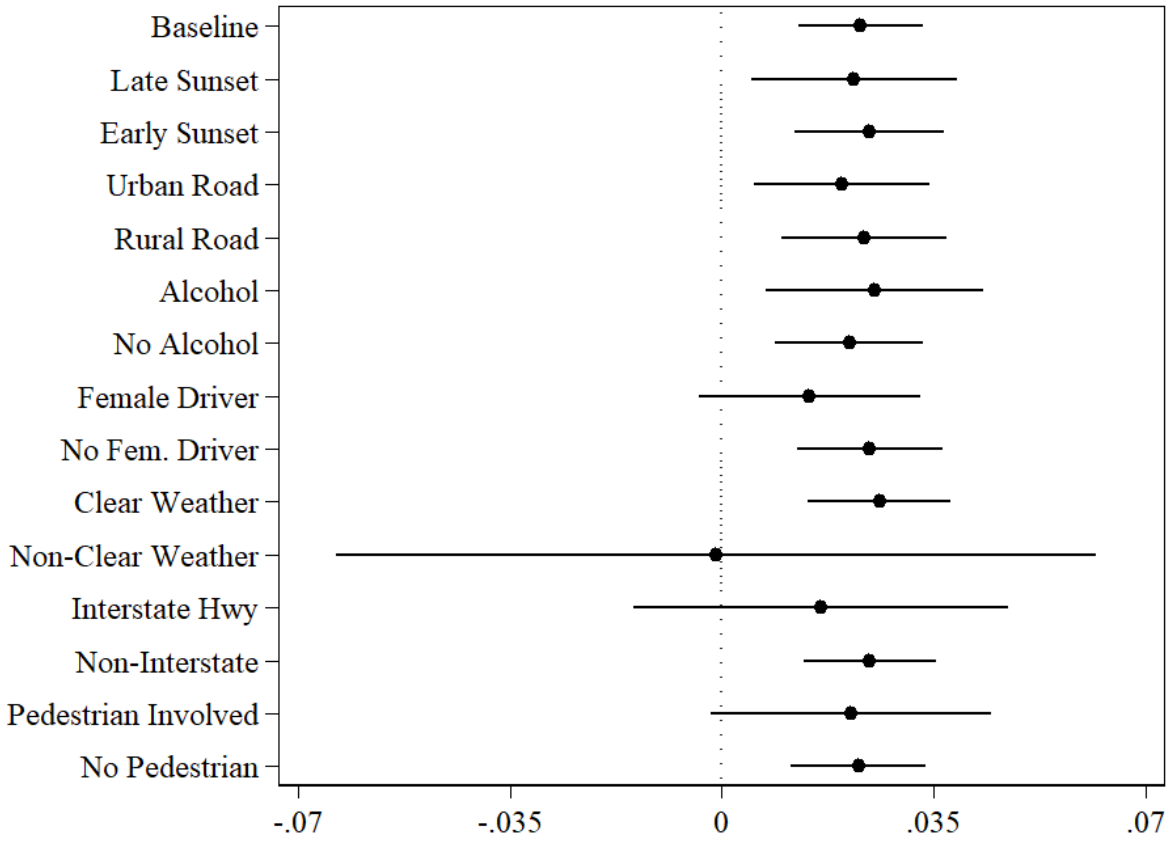
Note: This figure displays coefficient estimates of how the effect of the lunar cycle on traffic fatalities varies before and after the 'smartphone era' beginning in 2011 using data from the Fatality Analysis Reporting System (FARS). Each coefficient measures whether there are more fatalities on the four days following the full moon than for the rest of the month, controlling for day of week, year-month, and day-of-year fixed effects. The first row displays the results without any sample restrictions. The second row displays the results the for 25 states with the most clear sky days, while the third row displays results for the 25 states with the fewest clear sky days. The fourth row displays results dropping the winter months of November through February, while the fifth row displays results on only November through February. The sixth row displays results for the 25 'clear sky' states while dropping the winter months, while the seventh row displays results for the 'non clear sky' states, including only the winter months.

Figure 10 — Coefficient Estimates of the Variation in the Effect of the Lunar Cycle on Sleep and Traffic Fatalities Based on Time of Year, Average Number of Cloudy Days in Each State, and Time of Day the Crash Took Place



Note: This figure displays coefficient estimates of how the effect of the lunar cycle on traffic fatalities varies for crashes in the nighttime, dawn/dusk, or during the daytime using data from the Fatality Analysis Reporting System (FARS). Each coefficient measures whether there are more fatalities on the four days following the full moon than for the rest of the month, controlling for day of week, year-month, and day-of-year fixed effects. The first row displays the results without any sample restrictions. The second row restricts the same to only years prior to 2011. The third row restricts the sample to only years after 2010. The fourth row displays the results the for 25 states with the most clear sky days, while the fifth row displays results for the 25 states with the fewest clear sky days. The sixth row displays results dropping the winter months of November through February, while the seventh row displays results on only November through February. The eighth row displays results for the 25 'clear sky' states while dropping the winter months and restricting the sample to years before 2011. Standard errors are clustered at the year-month level.

Figure 11 — Heterogeneity of Main Treatment Effect of the Effect of the Lunar Cycle on Traffic Fatalities



Note: This figure displays coefficient estimates of how the effect of the lunar cycle on traffic fatalities varies by various types of crashes using data from the Fatality Analysis Reporting System (FARS). Each coefficient measures whether there are more fatalities on the four days following the full moon than for the rest of the month, controlling for day of week, year-month, and day-of-year fixed effects. The first row displays the main results, estimated on crashes taking place during the non-winter months of March through October, using data from the 25 states with the most clear-sky days, following eclipses which are not total lunar eclipses. The second and third row displays heterogeneity by whether the county where each crash takes place has an earlier or later than average sunset time between March and October. The fourth and fifth row compare results for urban versus rural roads. The sixth and seventh rows compare results for crashes which did and did not involve alcohol. The eight and ninth rows compare accidents which did and did not involve a female driver. The tenth and eleventh row compares effects for crashes during clear weather and non-clear weather. The twelth and thirteenth rows compare results for crashes on interstate versus non-interstate roads. Finally, the fourteenth and fifteenth rows compare results for crashes which did and did not involve a pedestrian.

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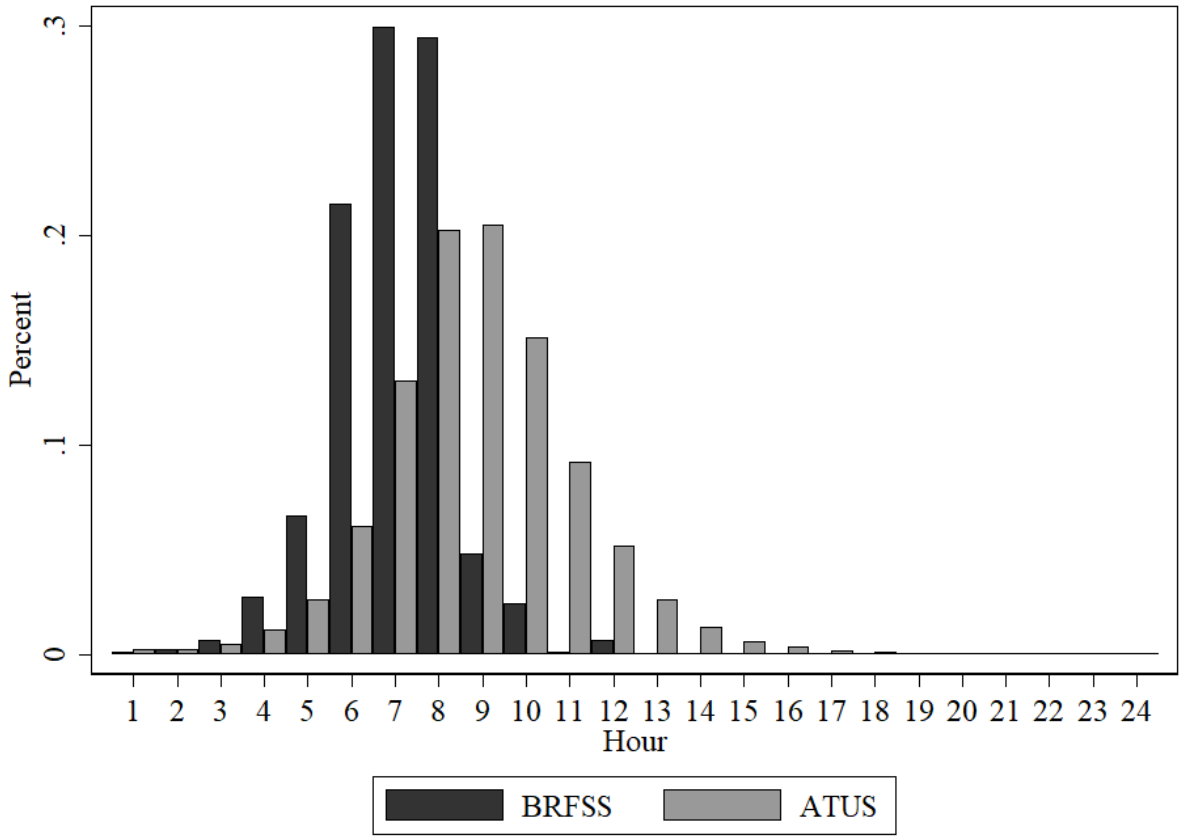
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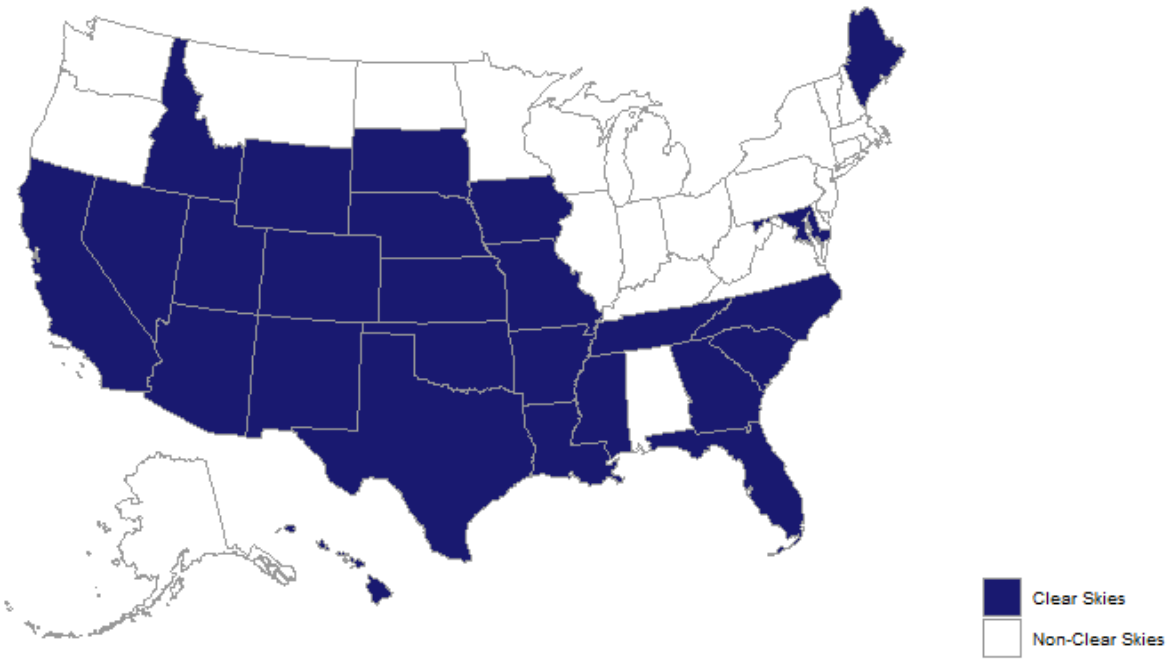
A. Online Appendix (Not for Publication)

Figure A.1 — Overlaid Histograms of Sleep Variable in BRFSS and ATUS



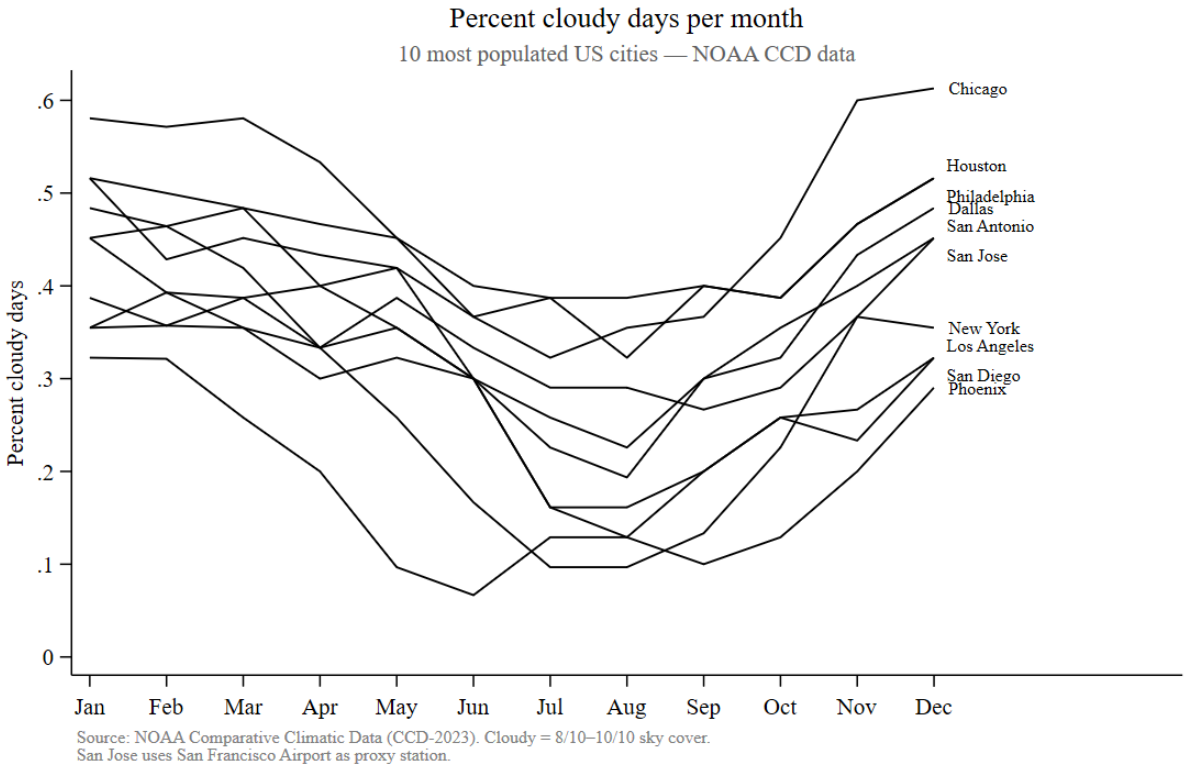
Note: This figure shows the distribution of the responses to the question "How Much Do You Sleep On Average?" using data from the Behavioral Risk Factor Surveillance System (BRFSS) from 2011,2013, 2014, 2016, 2018, 2020, and 2022 and the self-reported sleep from the American Time Use Survey from 2003-2023. in BRFSS, respondents are asked to report their average sleep in whole hour increments, meaning they are asked to round their responses to the nearest hour. Across the seven years where this question is asked, there are approximately 2.8 million observations. In ATUS, respondents keep time diaries over a 24-hour period, which we use to calculate the amount of time they spent asleep. Across the 21 years of data, there are 245,139 observations.

Figure A.2 — Classification of Sunny and Non-Sunny States



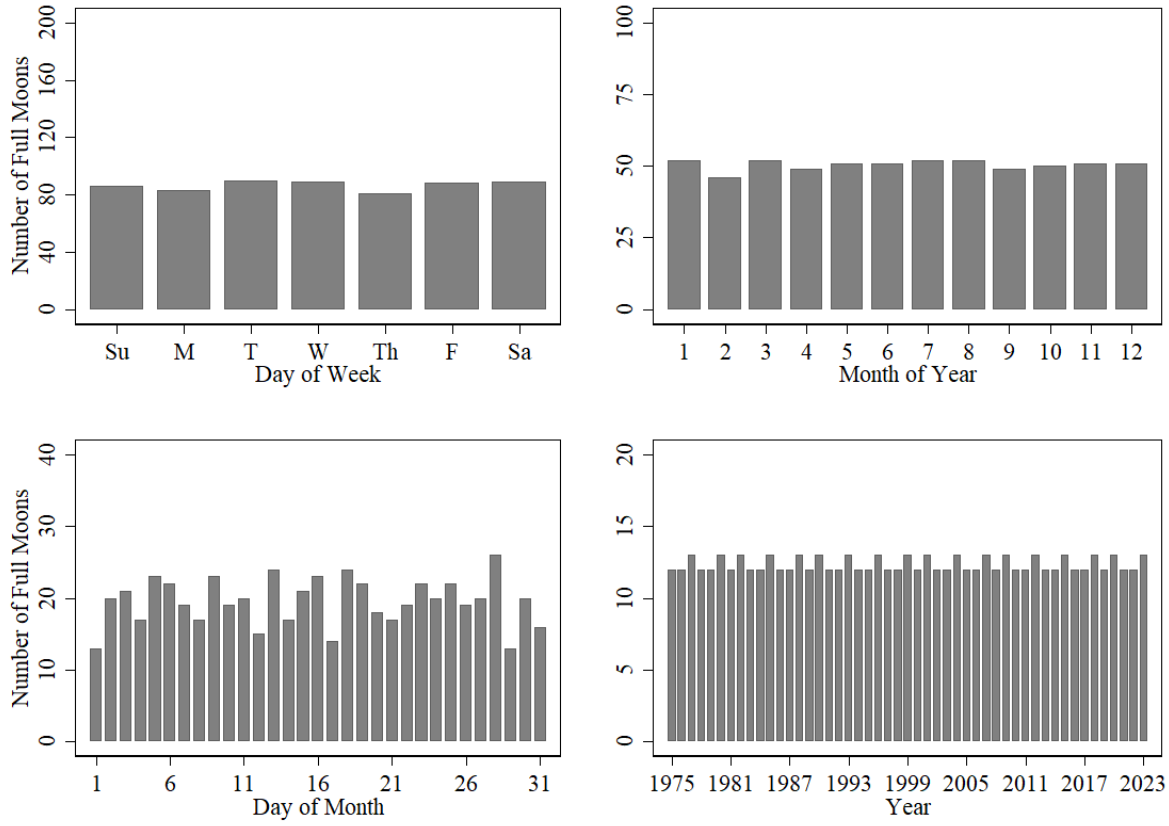
Note: This figure shows our classification of Sunny and Non-Sunny States, with Sunny States being shown in blue and Non-Sunny States being shown in White using data on the annual number of days with clear skies from the World Population Review.

Figure A.3 — Time-Series of the Percentage of Days Each Month Which are Considered 'Cloudy' - NOAA CCD 2023



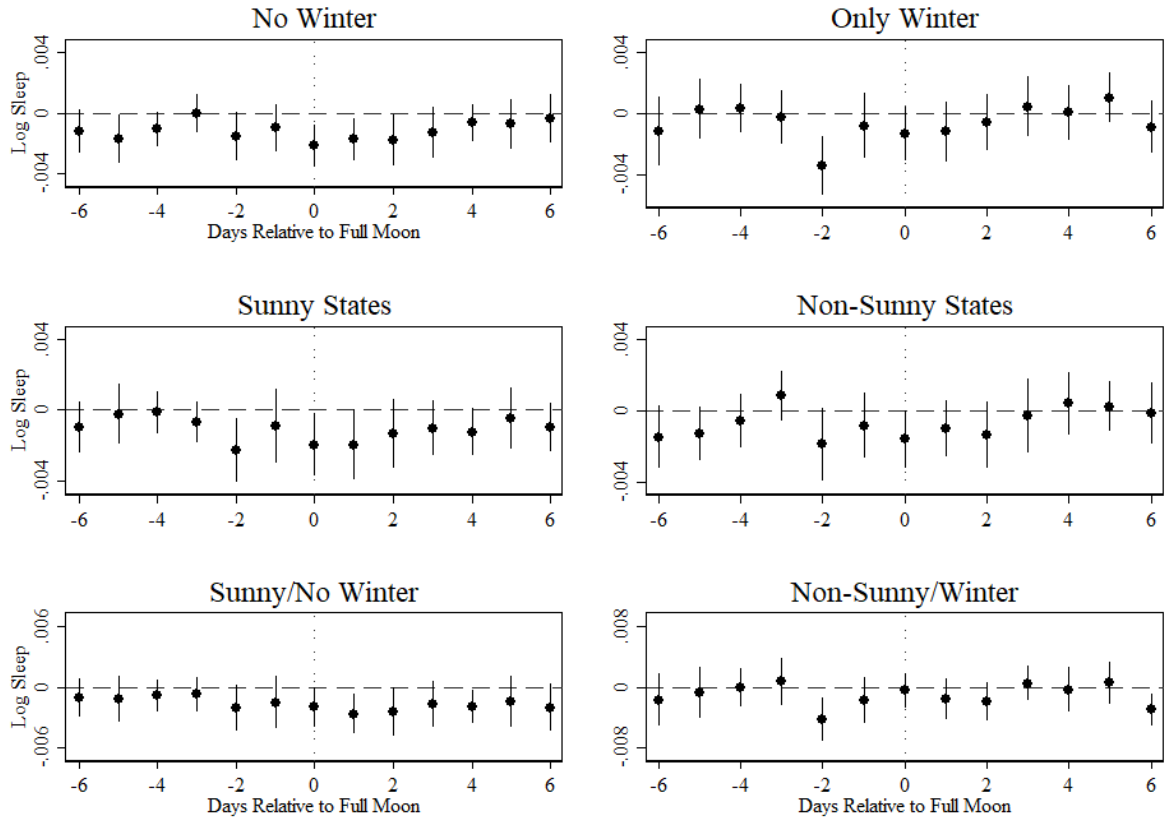
Note: This figure displays a time series of the percentage of days per month that are considered 'cloudy' in the 10 most populated US cities, using data from the National Oceanic and Atmospheric Administration's Comparative Climatic Data. In this data, days are rated on a scale from 0-10 on how much cloud cover there is. We consider days to be 'cloudy' if they score at least an eight out of ten on this scale.

Figure A.4 — Distribution of Full Moons by Day of Week, Month of Year, Day of Month, and Year - 1975-2023



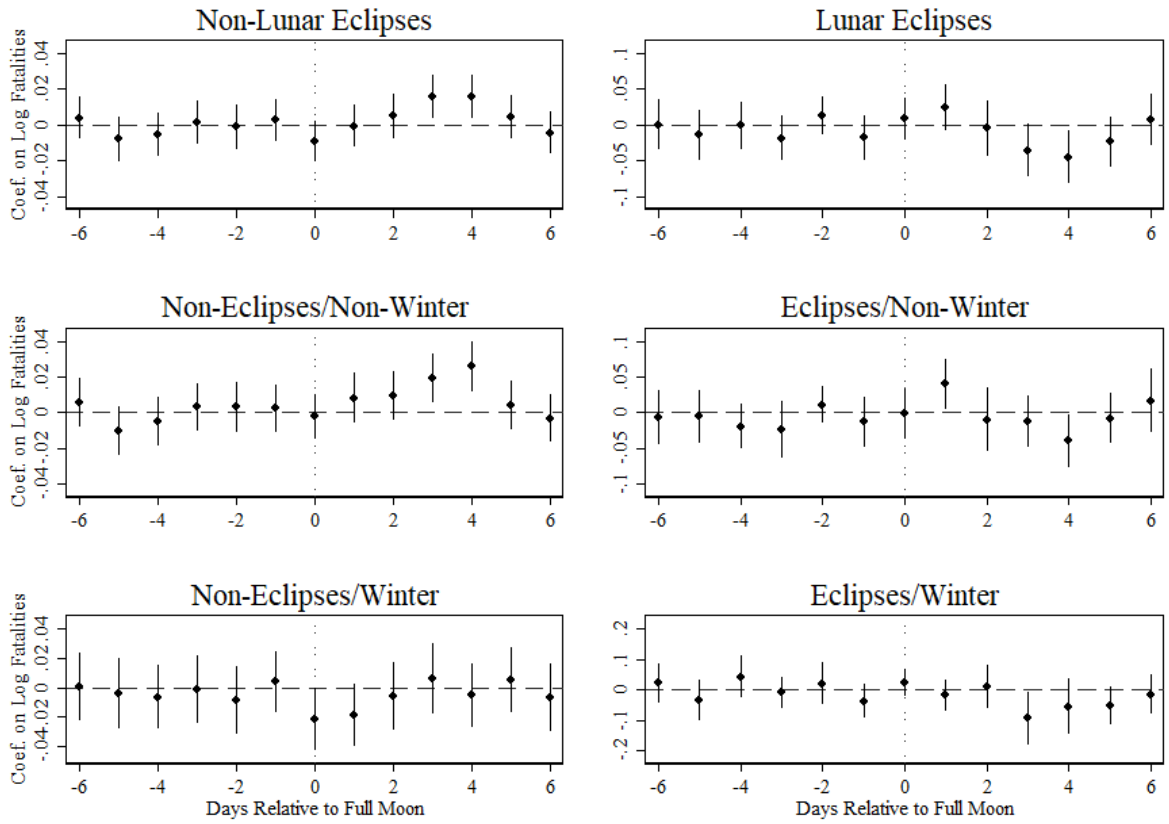
Note: This figure displays the distribution of full moon dates across the days of the week, the months of the year, the days of the month, and across years, using data for the precise date of each full moon from 1975-2023 from fullmoon.info

Figure A.5 — Event-Study Estimates of the Variation in the Effect of the Lunar Cycle on the Log of Self-Reported Sleep Based on Time of Year and Average Number of Cloudy Days in Each State- BRFSS



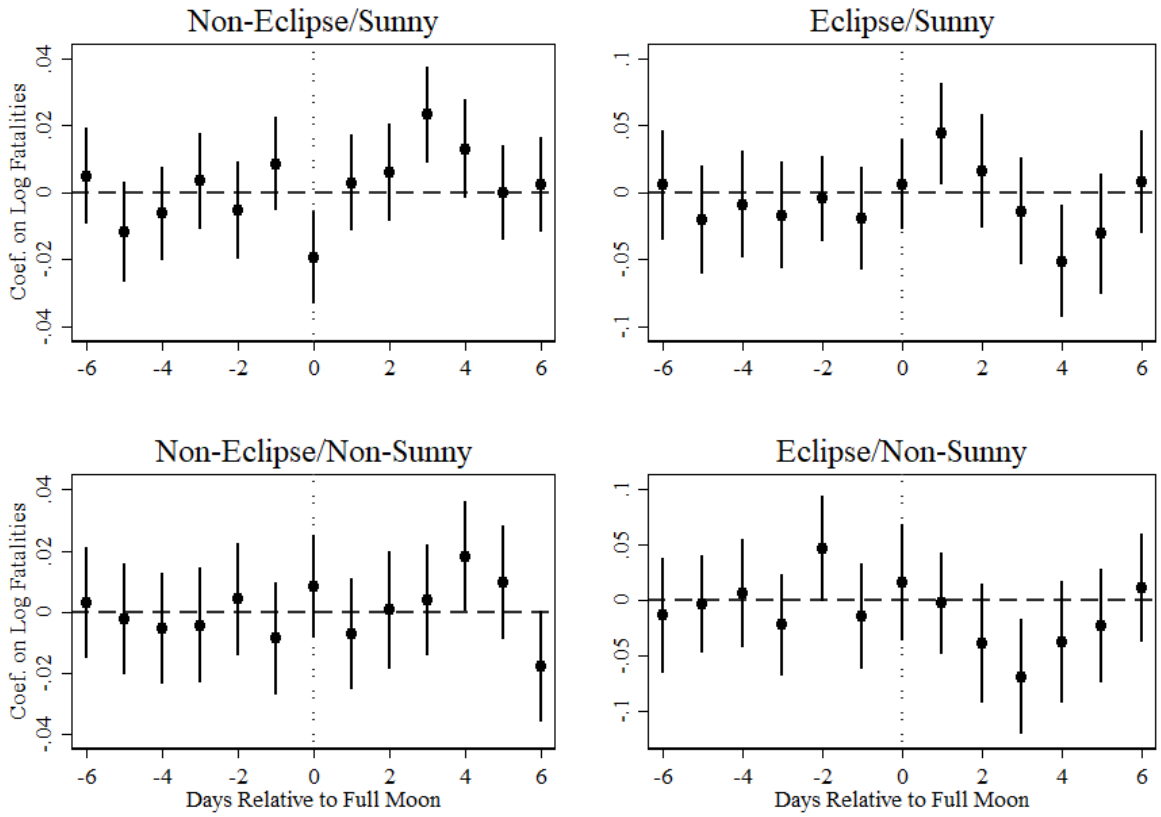
Note: This figure displays event-study estimates of the effect of the lunar cycle on the log of self-reported sleep using data from the Behavioral Risk Factor Surveillance System (BRFSS). Each graph shows the evolution of self-reported sleep for the six days leading up to the full moon, the date of the full moon, and the six days following the full moon, compared with the rest of the lunar cycle. The top left graph displays the effect when excluding the months of November through February. The top right graph displays the effect when excluding all months except for November through February. The middle left graph displays the effect when the sample is restricted to the 25 states with the most 'clear sky' days per year. The middle right graph displays the effect when the sample is restricted to the 25 states with the fewest 'clear sky' days per year. The bottom left graph displays the effect when the sample is restricted to the non-winter months and the days with the most 'clear sky' days, while the bottom right graph displays the effect when the sample is restricted the winter months and the states with the fewest 'clear sky' days. Each specification includes fixed effects for age, gender, and race, as well as year-month and day-of-week fixed effects. Standard errors are clustered at the state level.

Figure A.6 — Event-Study Estimates of the Variation in the Effect of the Lunar Cycle on Traffic Fatalities Based on Whether Full Moon is a Lunar Eclipse and Time of Year - FARS



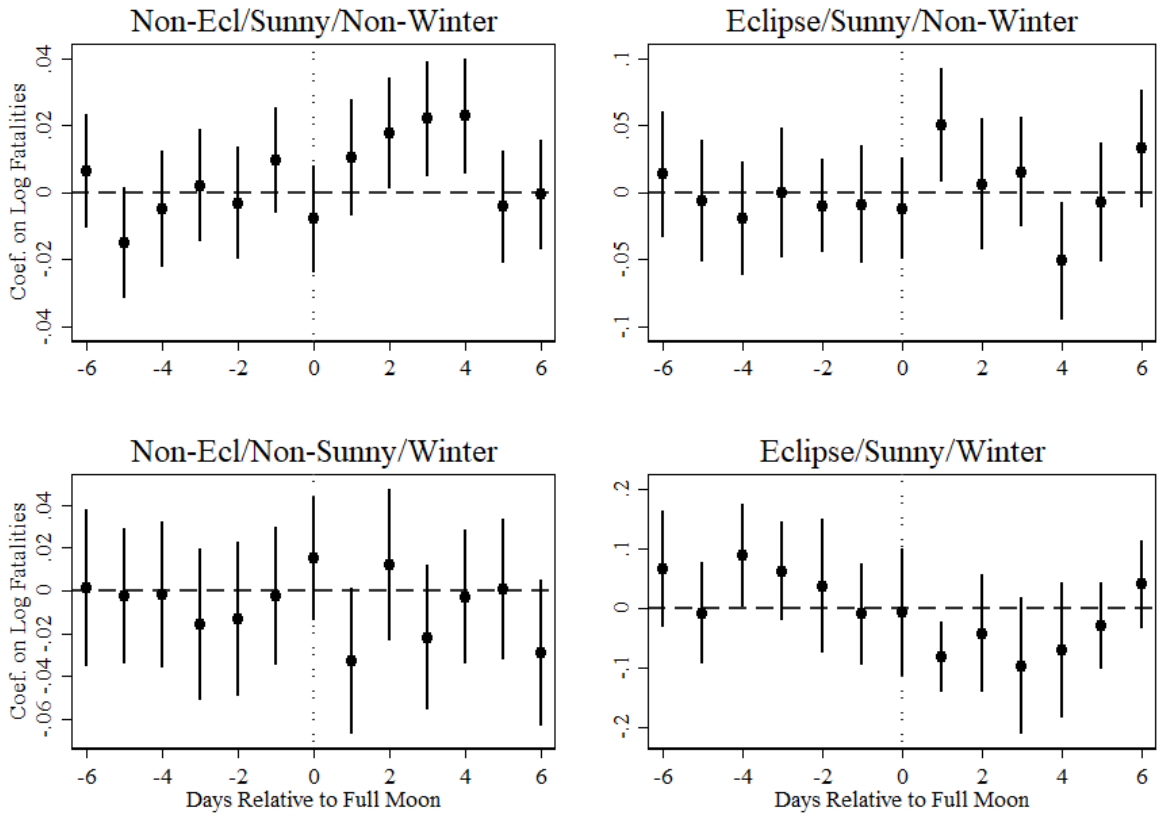
Note: This figure displays event-study estimates of the effect of the lunar cycle on fatalities from car crashes using data from the Fatality Analysis Reporting System (FARS) from 1975-2023. The top left graph displays the effect when excluding full moons which are also lunar eclipses. The top right graph displays the effect when including only total lunar eclipses. The middle left graph displays these effects on non-eclipses when the sample is restricted to the months of March through October, while the bottom row displays these effects when the sample is restricted to the months of November through February. The specification includes year-month, day-of-week, and day-of-year fixed effects. Standard errors are clustered at the year-month level.

Figure A.7 — Event-Study Estimates of the Variation in the Effect of the Lunar Cycle on Traffic Fatalities Based on Whether the Full Moon is a Total Lunar Eclipse and the Average Number of Cloudy Days in Each State- FARS



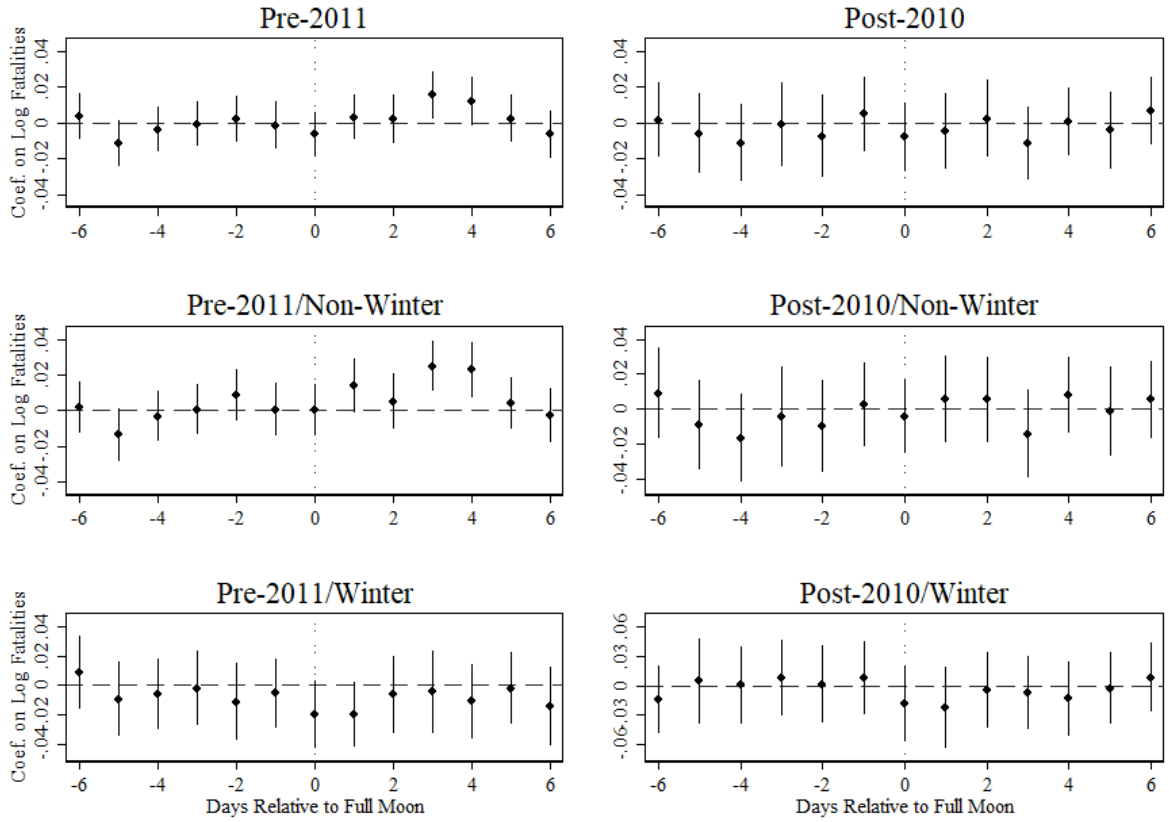
Note: This figure displays event-study estimates of the effect of the lunar cycle on fatalities from car crashes using data from the Fatality Analysis Reporting System (FARS) from 1975-2023. The top left graph displays the effect when the sample is restricted to the 25 states with the most 'clear sky' days per year and excluding full moons which are also lunar eclipses. The top right graph displays the effect when the sample is restricted to the 25 states with the most 'clear sky' days per year and including only total lunar eclipses. The bottom row displays these same effects when the sample is restricted to the states with the fewest 'clear sky' days. The specification includes year-month, day-of-week, and day-of-year fixed effects. Standard errors are clustered at the year-month level.

Figure A.8 — Event-Study Estimates of the Variation in the Effect of the Lunar Cycle on Traffic Fatalities Based on Whether the Full Moon is a Total Lunar Eclipse, Time of Year, and Average Number of Cloudy Days in Each State- FARS



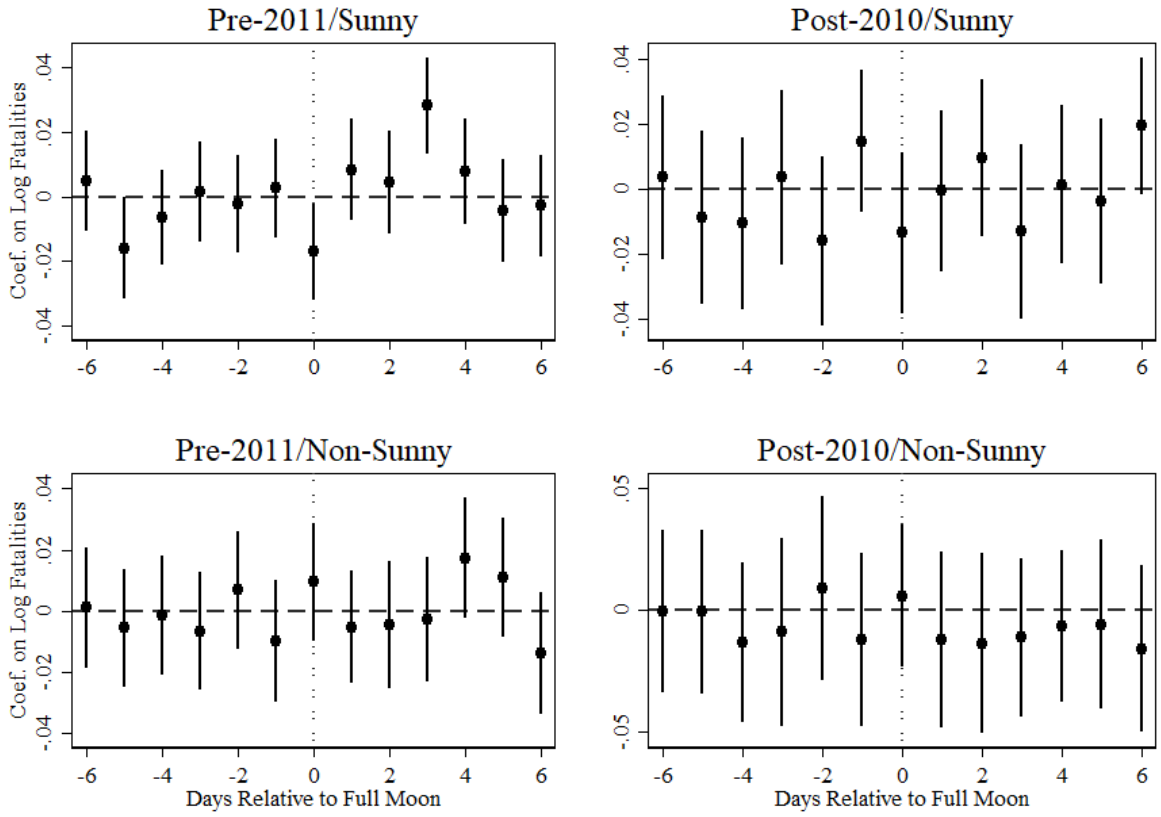
Note: This figure displays event-study estimates of the effect of the lunar cycle on fatalities from car crashes using data from the Fatality Analysis Reporting System (FARS) from 1975-2023. The top left graph displays the effect when the sample is restricted to the 25 states with the most 'clear sky' days per year during the months of March through October and excluding full moons which are also lunar eclipses. The top right graph displays the same effects including only total lunar eclipses. The bottom row similar displays effects for full moons which are eclipses (bottom left) and non-eclipses (bottom left) when the sample is restricted to the states with the fewest 'clear sky' days during the months of November through February. The specification includes year-month, day-of-week, and day-of-year fixed effects. Standard errors are clustered at the year-month level.

Figure A.9 — Event-Study Estimates of the Variation in the Effect of the Lunar Cycle on Traffic Fatalities Before and After the Smartphone Era and by Time of Year - FARS



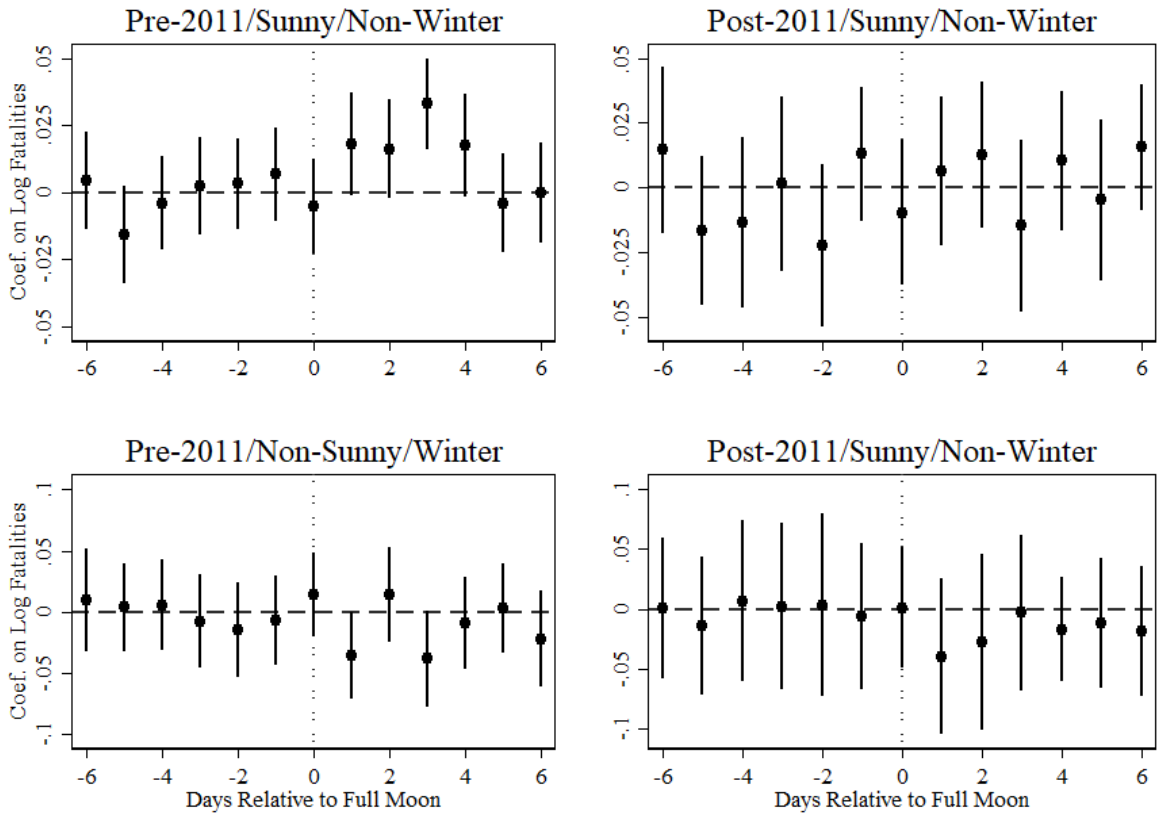
Note: This figure displays event-study estimates of the effect of the lunar cycle on fatalities from car crashes using data from the Fatality Analysis Reporting System (FARS) from 1975-2023. The top left graph displays the effect prior to 2011. The top right graph displays the effect after 2010. The middle row displays the pre-2011 and post-2010 effects when the sample is restricted to the months of March through October, while the bottom row displays these effects when the sample is restricted to the months of November through February. The specification includes year-month, day-of-week, and day-of-year fixed effects. Standard errors are clustered at the year-month level.

Figure A.10 — Event-Study Estimates of the Variation in the Effect of the Lunar Cycle on Traffic Fatalities Before and After the Smartphone Era and by the Average Number of Cloudy Days in Each State- FARS



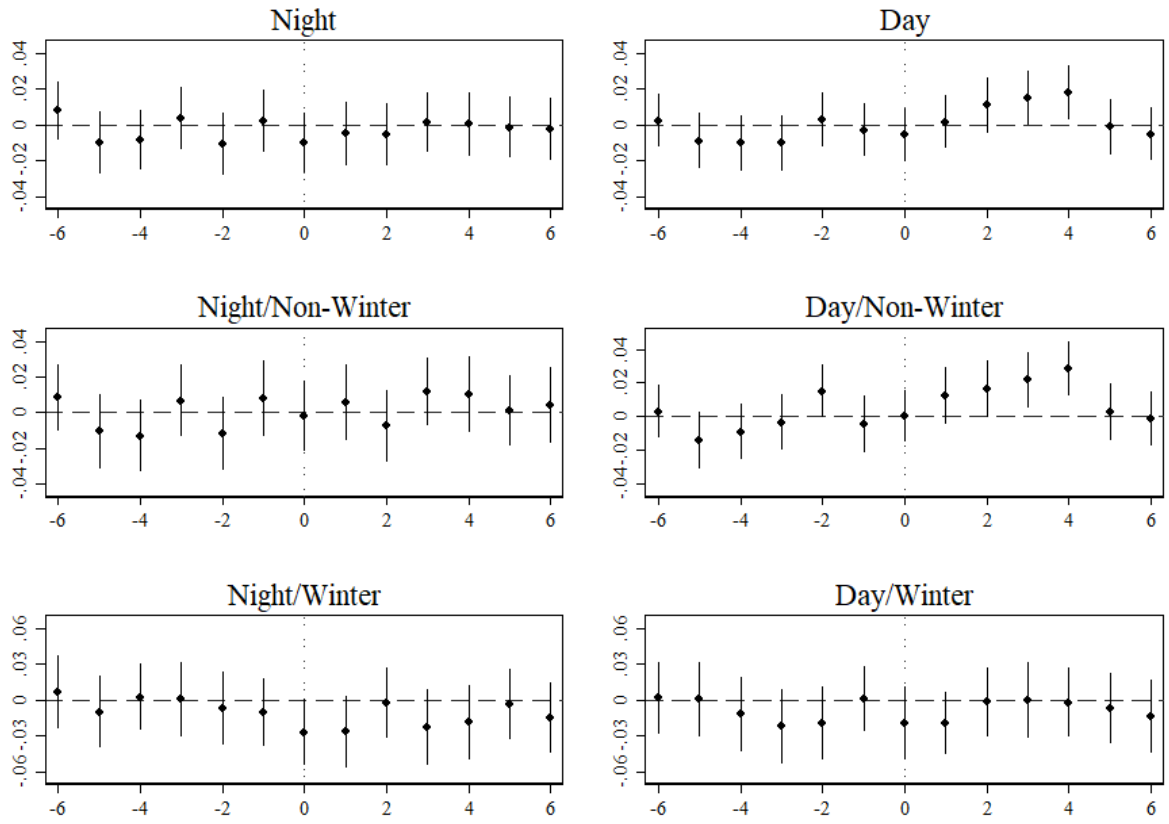
Note: This figure displays event-study estimates of the effect of the lunar cycle on fatalities from car crashes using data from the Fatality Analysis Reporting System (FARS) from 1975-2023. The top left graph displays the effect when the sample is restricted to the 25 states with the most 'clear sky' days per year and using data prior to 2011. The top right graph displays the effect when the sample is restricted to the 25 states with the most 'clear sky' days per year and using data after 2010. The bottom row displays these same effects when the sample is restricted to the states with the fewest 'clear sky' days. The specification includes year-month, day-of-week, and day-of-year fixed effects. Standard errors are clustered at the year-month level.

Figure A.11 — Event-Study Estimates of the Variation in the Effect of the Lunar Cycle on Traffic Fatalities Before and After the Smartphone Era, by Time of Year, and by Average Number of Cloudy Days in Each State- FARS



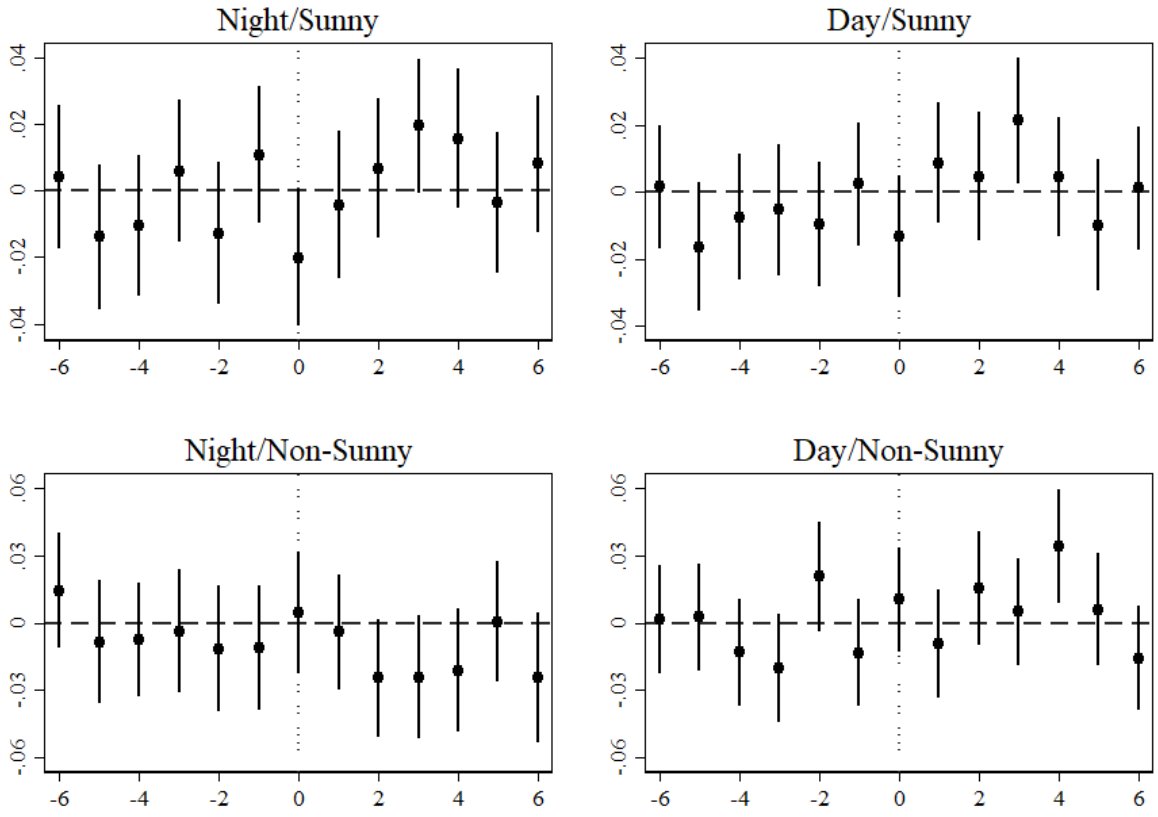
Note: This figure displays event-study estimates of the effect of the lunar cycle on fatalities from car crashes using data from the Fatality Analysis Reporting System (FARS) from 1975-2023. The top left graph displays the effect when the sample is restricted to the 25 states with the most 'clear sky' days per year during the months of March through October and using data prior to 2011. The top right graph displays the same effects using data after 2010. The bottom row similar displays effects for pre-2011 data (bottom left) and post-2010 (bottom left) when the sample is restricted to the states with the fewest 'clear sky' days during the months of November through February. The specification includes year-month, day-of-week, and day-of-year fixed effects. Standard errors are clustered at the year-month level.

Figure A.12 — Event-Study Estimates of the Variation in the Effect of the Lunar Cycle on Traffic Fatalities by Time of Day and by Time of Year - FARS



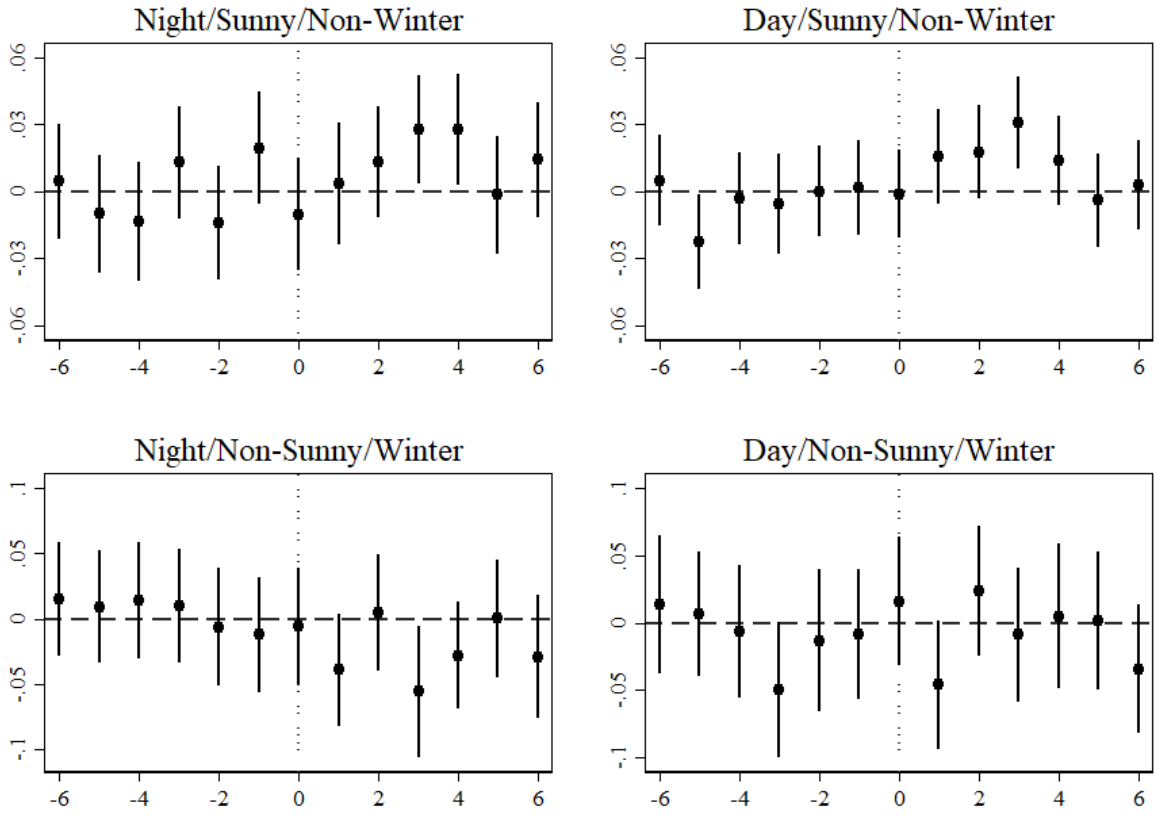
Note: This figure displays event-study estimates of the effect of the lunar cycle on fatalities from car crashes using data from the Fatality Analysis Reporting System (FARS) from 1975-2023. The top left graph displays the effect on nighttime crashes. The top right graph displays the effect for daytime crashes. The middle row displays the nighttime and daytime effects when the sample is restricted to the months of March through October, while the bottom row displays these effects when the sample is restricted to the months of November through February. The specification includes year-month, day-of-week, and day-of-year fixed effects. Standard errors are clustered at the year-month level.

Figure A.13 — Event-Study Estimates of the Variation in the Effect of the Lunar Cycle on Traffic Fatalities by Time of Day and by the Average Number of Cloudy Days in Each State- FARS



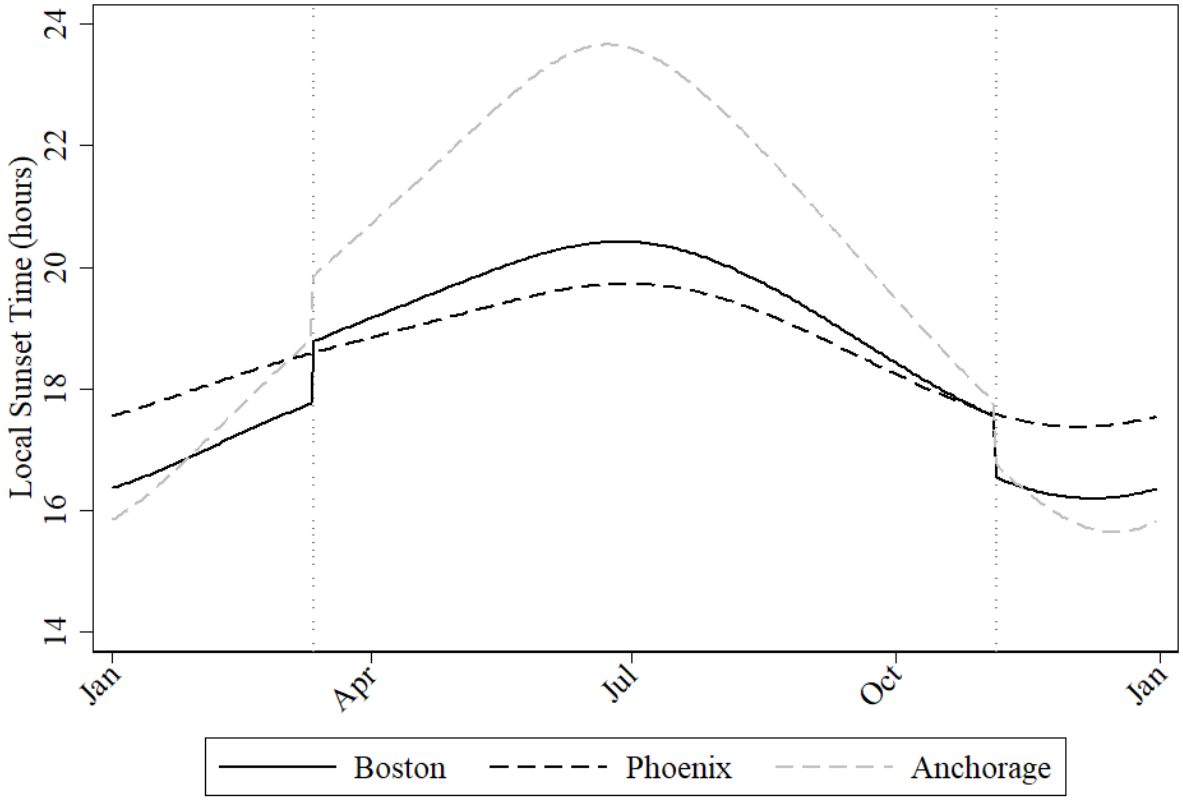
Note: This figure displays event-study estimates of the effect of the lunar cycle on fatalities from car crashes using data from the Fatality Analysis Reporting System (FARS) from 1975-2023. The top left graph displays the effect on nighttime crashes when the sample is restricted to the 25 states with the most 'clear sky' days per year. The top right graph displays the effect on daytime crashes when the sample is restricted to the 25 states with the most 'clear sky' days per year. The bottom row displays these same effects when the sample is restricted to the states with the fewest 'clear sky' days. The specification includes year-month, day-of-week, and day-of-year fixed effects. Standard errors are clustered at the year-month level.

Figure A.14 — Event-Study Estimates of the Variation in the Effect of the Lunar Cycle on Traffic Fatalities by Time of Day, Time of Year, and Average Number of Cloudy Days in Each State- FARS



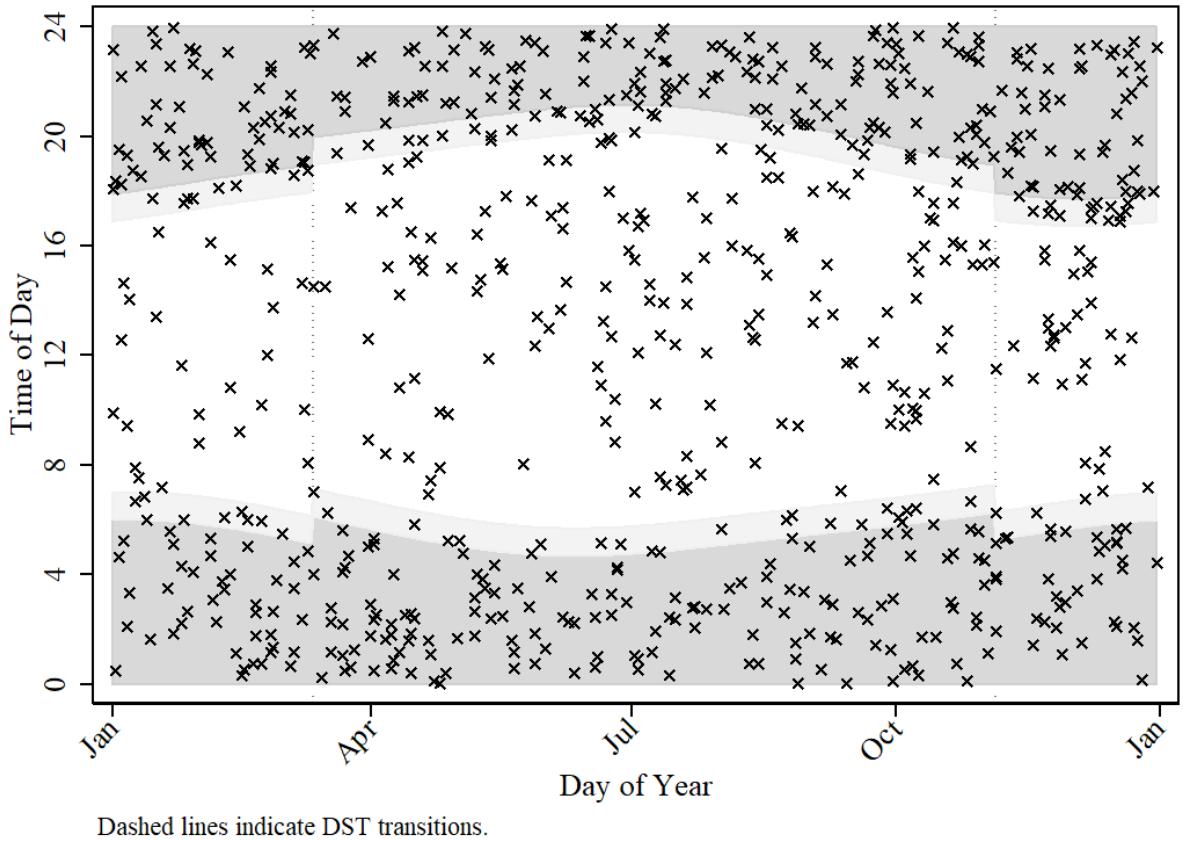
Note: This figure displays event-study estimates of the effect of the lunar cycle on fatalities from car crashes using data from the Fatality Analysis Reporting System (FARS) from 1975-2023. The top left graph displays the effect on nighttime crashes when the sample is restricted to the 25 states with the most 'clear sky' days per year during the months of March through October. The top right graph displays the effects on daytime crashes. The bottom row similar displays effects for nighttime (bottom left) and daytime (bottom left) when the sample is restricted to the states with the fewest 'clear sky' days during the months of November through February. The specification includes year-month, day-of-week, and day-of-year fixed effects. Standard errors are clustered at the year-month level.

Figure A.15 — Calculated Local Sunset Times Across US Time Zones



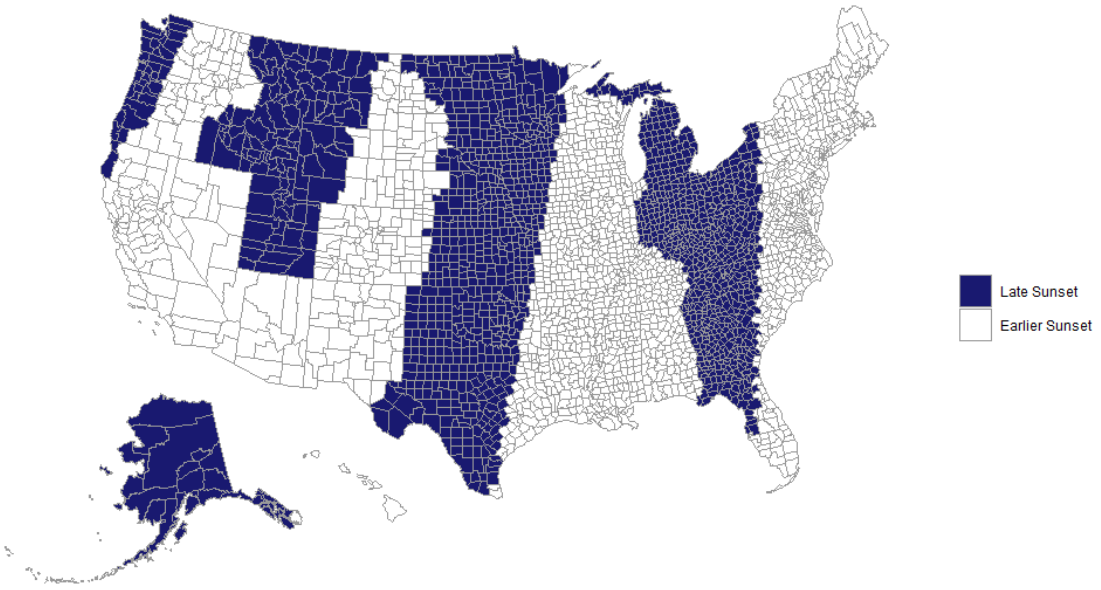
Note: This figure displays local sunset times for Boston, Massachusetts, Phoenix, Arizona, and Anchorage, Alaska, using the latitude and longitude of each county centroid. These are obtained from the U.S. Census Bureau's Gazetteer Files and then used as inputs to the solar position algorithm described by the National Oceanic and Atmospheric Administration (NOAA), which is based on equations from Meeus (1998) to calculate daily sunrise and sunset times throughout the year. The start and end of daylight savings time (DST), which impact Boston and Anchorage but not Phoenix, are marked with vertical lines. The evolution of sunset times over the three American cities demonstrates how policy and geographic positioning impact sunset times throughout the course of the year.

Figure A.16 — Fatal Car Accidents in Los Angeles in 2023 by Time of Day and Day of Year - FARS



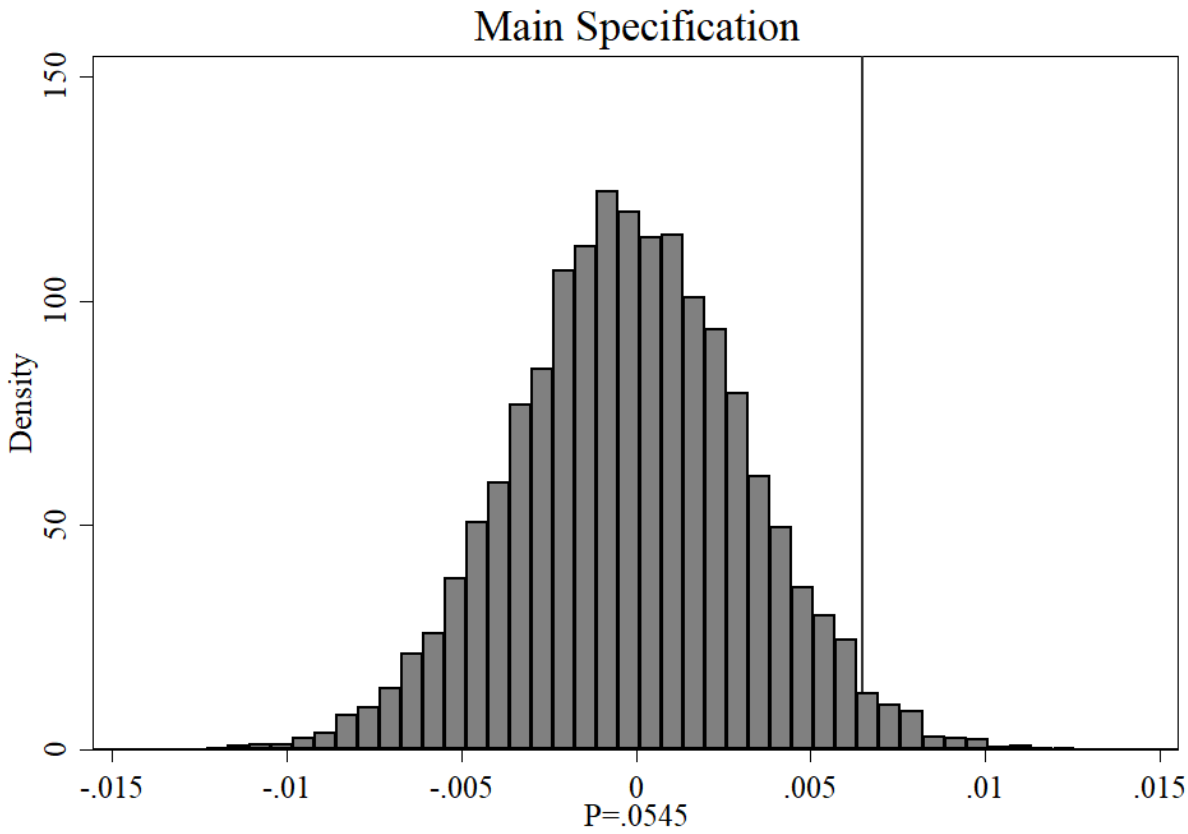
Note: This figure displays the evolution of sunrise and sunset times for Los Angeles County using the latitude and longitude of the county centroid, obtained from the U.S. Census Bureau's Gazetteer Files, as inputs to the solar position algorithm described by the National Oceanic and Atmospheric Administration (NOAA), which is based on equations from Meeus (1998). In addition, every fatal car accident which happened in Los Angeles County in 2023 is plotted to the exact date and time which it occurred with a black 'x' using data from the Fatality Analysis Reporting System (FARS). Nighttime hours are shaded in the darkest gray, while the hour just before sunrise and just after sunset are shaded in light gray, while daytime hours are not shaded. This graph demonstrates the accuracy of the solar position algorithm by showing that there is a sharp increase in accidents just after sunset.

Figure A.17 — Classification of Counties by Whether the Average Non-Winter Sunset Time is Earlier or Later than the Median



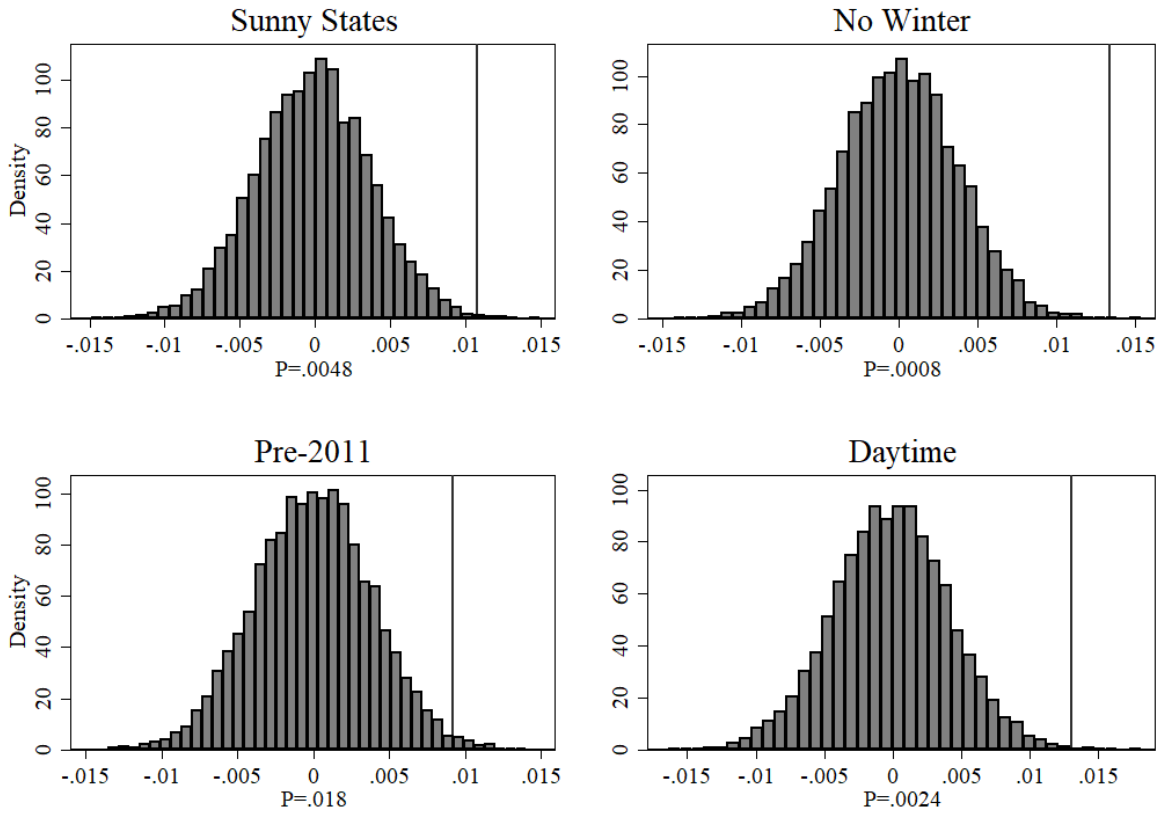
Note: This figure shows our classification of early and late sunset time counties, with late sunset counties being shown in blue and early sunset counties being shown in white using average sunset time from March through October. These are obtained from the U.S. Census Bureau's Gazetteer Files and then used as inputs to the solar position algorithm described by the National Oceanic and Atmospheric Administration (NOAA), which is based on equations from Meeus (1998) to calculate daily sunrise and sunset times throughout the year.

Figure A.18 — Placebo Simulations of the Effect of the Lunar Cycle on Traffic Fatalities



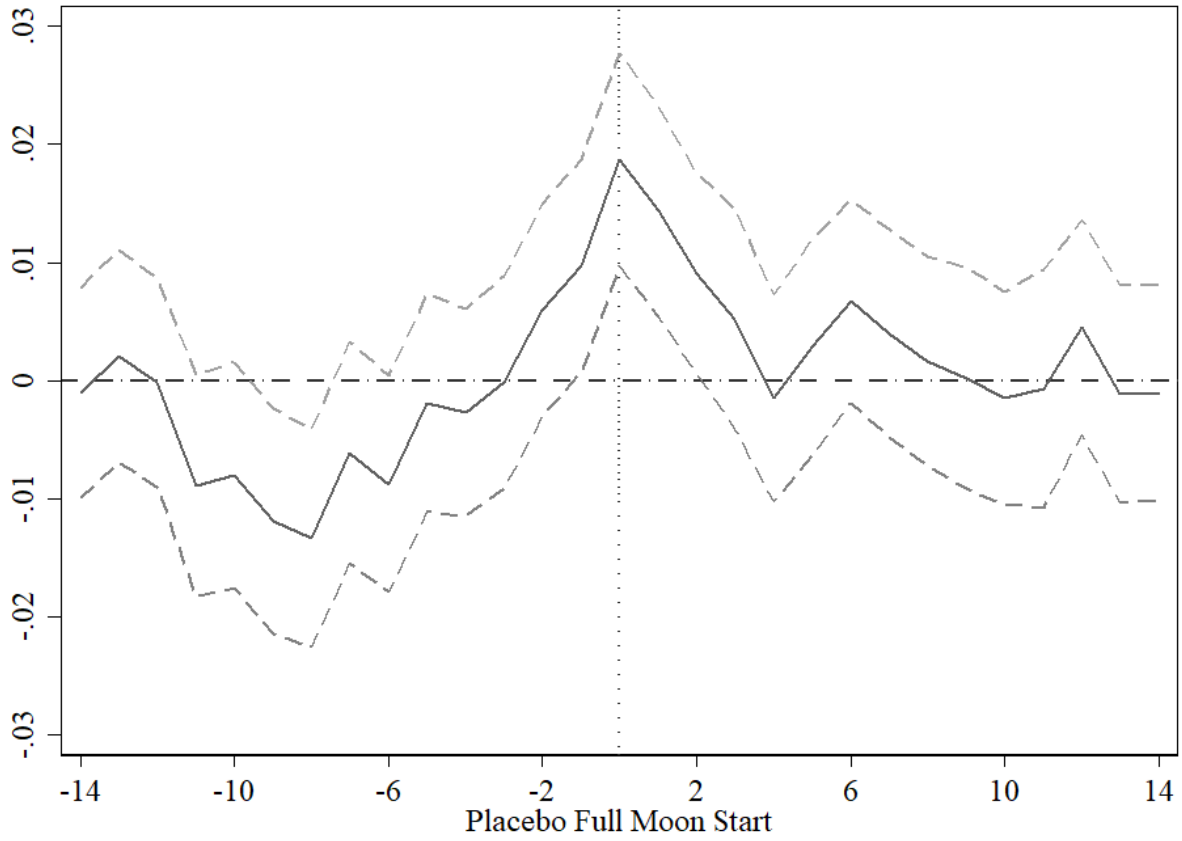
Note: This figure displays the distribution of 10,000 placebo estimates of the effect of the lunar cycle on traffic fatalities using data from the Fatality Analysis Reporting System (FARS) from 1975-2023. Each simulation randomly assigns one day in each 29-day period to be the full moon, and assigns treatment status to the four days following the full moon. We then estimate our main specification of the effect of this treatment on the log of traffic fatalities, with year-month, day-of-week, and day-of-year fixed effects. The vertical line represents our actual estimate of this specification, and the p-value is calculated by adding one to the number of estimates which are larger in magnitude than our estimate and dividing by 10,000

Figure A.19 — Placebo Simulations of the Effect of the Lunar Cycle on Traffic Fatalities



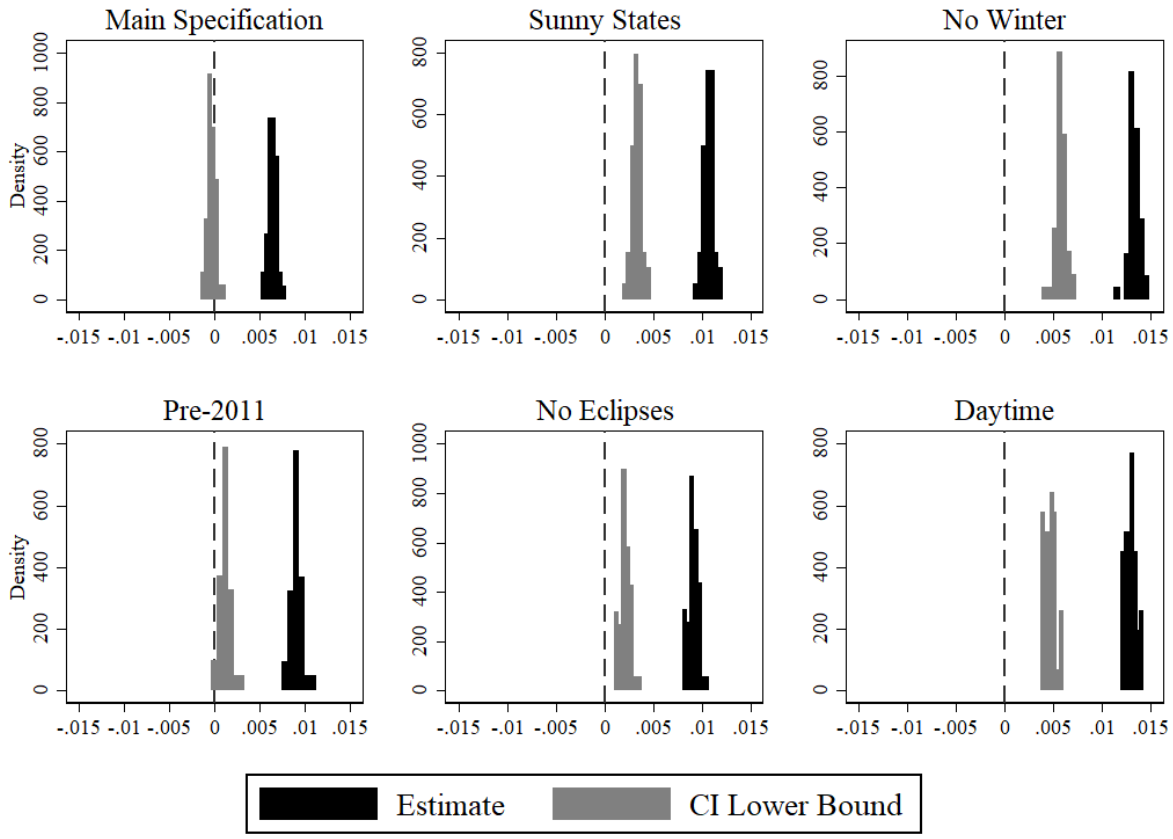
Note: This figure displays the distribution of 10,000 placebo estimates of the effect of the lunar cycle on traffic fatalities using data from the Fatality Analysis Reporting System (FARS) from 1975-2023. Each simulation randomly assigns one day in each 29-day period to be the full moon, and assigns treatment status to the four days following the full moon. We then estimate our main specification of the effect of this treatment on the log of traffic fatalities, with year-month, day-of-week, and day-of-year fixed effects. The vertical line represents our actual estimate of this specification, and the p-value is calculated by adding one to the number of estimates which are larger in magnitude than our estimate and dividing by 10,000. Each graph includes a sample restriction that we utilize in our main analysis. In the top left graph, we restrict the sample to the 25 states with the most 'clear sky' days. In the top right graph, we drop the months of November through February. In the bottom left graph, we drop all years after 2010. In the bottom right graph, we estimate the effects only on crashes that happen between sunrise and sunset.

Figure A.20 — Placebo Start Dates of the Effect of the Lunar Cycle on Traffic Fatalities



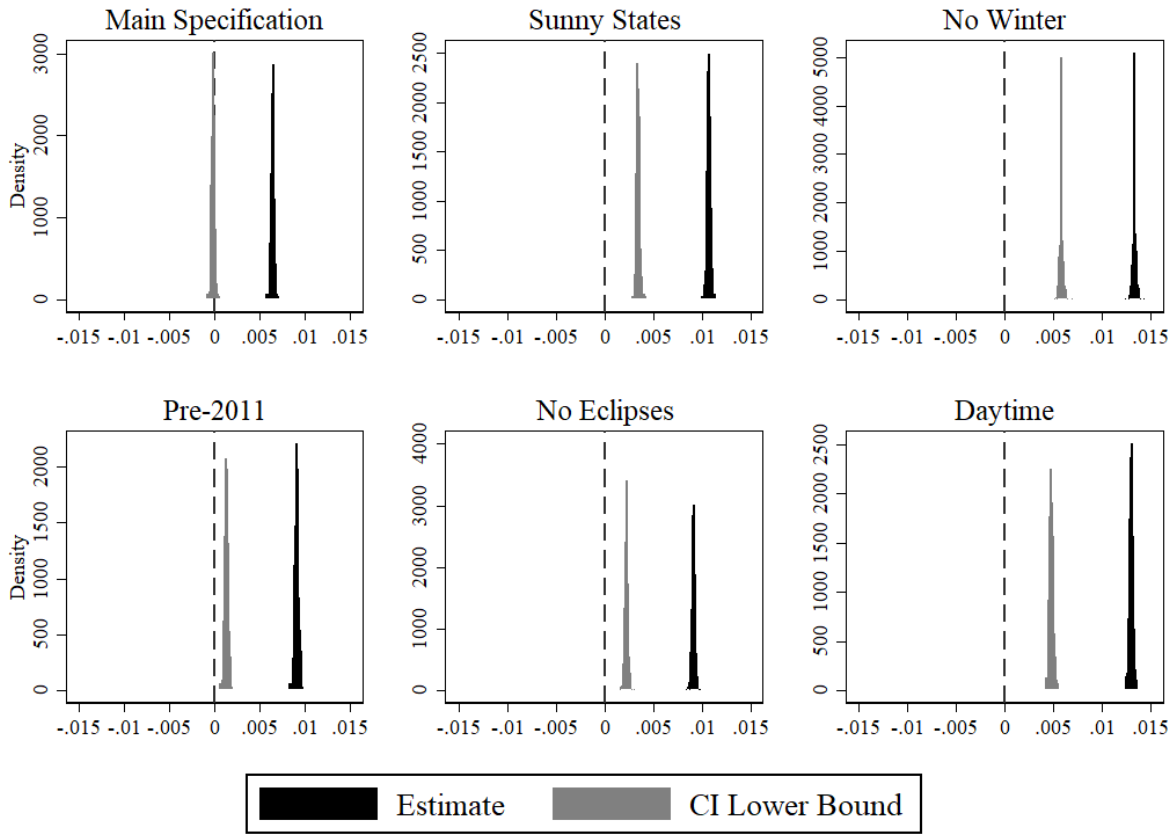
Note: This figure displays placebo estimates of the effect of the lunar cycle on traffic fatalities using data from the Fatality Analysis Reporting System (FARS) from 1975-2023. Each simulation assigns one day in the lunar to be the full moon, and assigns treatment status to the four days following the full moon. We then estimate our main specification of the effect of this treatment on the log of traffic fatalities, with year-month, day-of-week, and day-of-year fixed effects.

Figure A.21 — Distribution of Coefficients from a Leave-One-Out Analysis On the Effect of the Lunar Cycle on Traffic Fatalities - Iteratively Dropping Each Year from 1975-2023



Note: This figure displays the distribution of estimates from a 'leave-one-out' analysis on the effect of the lunar cycle on traffic fatalities using data from the Fatality Analysis Reporting System (FARS) from 1975-2023. In each round, we iteratively exclude one year from our sample and reestimate our main specifications on the log of traffic fatalities, with year-month, day-of-week, and day-of-year fixed effects. This is done in order to see if our results are sensitive to the exclusion of any single year. In each graph, the distribution of estimates is displayed in black, while the distribution of the lower bounds of the 95% confidence interval are displayed in gray. In the top left graph, we estimate our main specification with no sample restrictions. Each subsequent graph includes a sample restriction that we utilize in our main analysis. In the top middle graph, we restrict the sample to the 25 states with the most 'clear sky' days. In the top right graph, we drop the months of November through February. In the bottom left graph, we drop all years after 2010. In the bottom middle graph, we estimate the effects only on crashes that happen between sunrise and sunset. In the bottom right graph, we estimate the effects only on full moons which were not also a total lunar eclipse.

Figure A.22 — Distribution of Coefficients from a Leave-One-Out Analysis On the Effect of the Lunar Cycle on Traffic Fatalities - Iteratively Dropping Each of the 606 Full Moons from 1975-2023



Note: This figure displays the distribution of estimates from a 'leave-one-out' analysis on the effect of the lunar cycle on traffic fatalities using data from the Fatality Analysis Reporting System (FARS) from 1975-2023. In each round, we iteratively exclude one of the 606 full moons we observe from 1975-2023 from our sample and reestimate our main specifications on the log of traffic fatalities, with year-month, day-of-week, and day-of-year fixed effects. This is done in order to see if our results are sensitive to the exclusion of any single full moon. In each graph, the distribution of estimates is displayed in black, while the distribution of the lower bounds of the 95% confidence interval are displayed in gray. In the top left graph, we estimate our main specification with no sample restrictions. Each subsequent graph includes a sample restriction that we utilize in our main analysis. In the top middle graph, we restrict the sample to the 25 states with the most 'clear sky' days. In the top right graph, we drop the months of November through February. In the bottom left graph, we drop all years after 2010. In the bottom middle graph, we estimate the effects only on crashes that happen between sunrise and sunset. In the bottom right graph, we estimate the effects only on full moons which were not also a total lunar eclipse.