Sleep Tight, Act Right?
The Effect of Clock Time Policy on Student Behavior Outcomes

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Abstract

We study the effects of reduced sleep induced by late sunset time on student discipline. Using a regression discontinuity design and national school-level data, we leverage variation in sunset time generated by time zone boundaries. A one-hour-later sunset significantly increases disciplinary incidents —the likelihood of students receiving one out-of-school and multiple out-of-school suspensions increases by 32.1% and 43.8% off the baseline rate, respectively. These impacts are driven by male and middle grade students. Our findings highlight the role that sleep plays in student behavior, with implications for human capital development and ongoing debates over time policy and school start times.

1 Introduction

Students' outcomes are often influenced by factors beyond their control. At the highest level, transportation and labor policies (e.g., Lubienski, Gulosino and Weitzel, 2009; Dahl and Lochner, 2012), as well as housing and safety net policies (e.g., Bergman et al., 2024; Hoynes, Schanzenbach and Almond, 2016), have been shown to impact students' educational outcomes. These policies can affect students, for example, by leading to inequities in transportation options that influence their access to schools (e.g., Valant and Lincove, 2023) or by mitigating (or exacerbating) labor market shocks in their cities that could ultimately affect their behavioral outcomes (Acton, King and Smith, 2023). Although extensive research has investigated the impacts of social policies on education, less work has investigated the role of even broader policies that govern citizens' day-to-day social interactions and behaviors.

One such example is time zone policy. Though clock time is perceived as a stable or given structure, it is instead an active, manipulable policy decision that has important consequences on a variety of outcomes (Giuntella and Mazzonna, 2019; Johnson and Malow, 2023; Smith, 2016). Time zones determine clock time's alignment with solar time, in turn affecting biological processes such as circadian rhythms and sleep. Living on the western edge of a time zone creates greater misalignment between solar time and clock time than on the eastern edge —in other words, two people living only miles apart may experience markedly different exposures to sunlight relative to their schedules and, by extension, important differences in sleep duration. Ultimately, circadian rhythms and sleep play a key role in health and behavioral outcomes (Hafner et al., 2017), and the disruption of these rhythms can, for instance, negatively affect productivity and mental (Neumann and von Blanckenburg, 2025) and physical health (Giuntella and Mazzonna, 2019). For children and adolescents, many of whom lack sufficient sleep (Paruthi et al., 2016), reduced sleep duration is associated with increases in challenging (Astill et al., 2012) and risk-taking behaviors (Short and Weber, 2018; Shochat, Cohen-Zion and Tzischinsky, 2014) and leads to reduced emotional regulation (Baum et al., 2014) and learning (Beebe, Rose and Amin, 2010; Lo et al., 2016). These findings highlight how even seemingly neutral policies like the setting of time zones can have far-reaching effects on individual well-being and behavior.

Within the literature on education and human capital formation, documentation of the consequences of sleep loss on K-12 students is lacking —a group exceptionally vulnerable to changes in solar-clock time and, consequently, changes in sleep patterns (Carskadon, Acebo and Jenni, 2004; Astill et al., 2012; Dewald et al., 2010). That which does exist focuses on academic outcomes, is conducted in a localized context (e.g., Gaski and Sagarin, 2011), and frames these consequences as a result of school start times (e.g., Heissel and Norris, 2018), not broader national policy. Research has yet to examine how time zone policy affects non-academic outcomes, such as suspensions, despite evidence that these consequences can negatively influence students' long-term outcomes (Bacher-Hicks, Billings and Deming, 2024; Holt et al., 2022; Davison et al., 2021; Rumberger and Losen, 2016). This limited understanding is especially concerning given recent policy interest in establishing nationwide, permanent Daylight Savings Time (DST) (Diamond, 2025) —a policy that would systematically increase clock-solar time misalignment (Johnson and Malow, 2023). More evidence is needed to understand how time zone policy impacts children's behavioral outcomes, as measured by suspensions, at a national scale. We aim to fill this gap.

In this paper, we examine behavioral outcomes at a national level, and understand our impacts as a result of manipulable policy. We explore the impact of time policy on key student behavioral outcomes as measured by three types of school-level suspension rates: in-school, single out-of-school, and multiple out-of-school suspension. We find that a greater misalignment between clock-solar time (approximately 1 hour) results in increased rates of students receiving one out-of-school suspension by nearly 1 percentage point (pp) and those receiving multiple out-of-school suspensions by 0.78pp. Off the sample baseline, these equate to 32.1 percent and 43.8 percent increases, respectively. These increases are driven by middle and high school grades and by male students, though we still find impacts on female students' outcomes. We also find evidence of a slight substitution effect, with harsher, out-of-school punishments being more common relative to in-school consequences. These results add to the mounting body of evidence that documents the detriments of policies that increase clock-solar misalignment (e.g., Johnson and Malow, 2023; Giuntella and Mazzonna, 2019), such as the enactment of permanent DST. In addition to contributing to ongoing time zone policy debates, we discuss how school start times could mitigate impacts of these broader policies.

2 Guiding Literature

2.1 Time zone policy and its effects

Standardization of time has remained the subject of ongoing policy debates in the United States. Four time zones were originally introduced in 1883, with changes in time zone boundaries and standardization occurring throughout the 20th century and culminating with the Uniform Time Act of 1966. This act established the status quo: all states are mandated to be on Standard Time and shift to and from daylight saving time (DST) in the winter and spring, if they choose to observe it (Clark and Cunningham, 2020).[1]

When a state observes DST, it sets its clocks forward by one hour in the spring, and then back by one hour to Standard Time in the fall. When clock time deviates significantly from solar time—as it often does at the western edges of time zones or during DST—sleep and circadian processes are disrupted (Roenneberg, Winnebeck and Klerman, 2019), particularly for adolescents (Carskadon, Acebo and Jenni, 2004). Despite these negative effects and the recommendations of medical and health researchers (e.g., American Academy of Pediatrics, 2014; Rishi et al., 2020), federal policymakers have repeatedly tried (and, thus far, failed) to

[1] The following US states and territories do not observe DST: American Samoa, most of Arizona, Guam, Hawaii, the Northern Mariana Islands, Puerto Rico, and the Virgin Islands. Currently, states fall within one or two of the four time zones within continental US (excluding Alaska)—the Eastern, Central, Mountain, and Pacific time zones. Most states fit squarely within a given time zone while 13 are split between two zones. From Eastern to Western US: Florida, Indiana, Kentucky, Michigan, and Tennessee fall within both the Eastern and Central time zones. Kansas, Nebraska, North Dakota, South Dakota, and Texas span both the Central and Mountain time zones. Lastly, Idaho, Nevada, and Oregon are in both the Mountain and Pacific time zones.

pass legislation establishing permanent DST. Today, the Sunshine Protection Act, the most recent bill proposed, carries substantial support from the executive and legislative branches (Diamond, 2025). In parallel, over a third of US states have thus far enacted their own legislation in support of a permanent DST change contingent on federal law (e.g., Texas 89th Legislature, 2025; Oklahoma State Legislature, 2024).

Despite this policy momentum, evidence on the broader consequences of a permanent DST shift, especially as they relate to students' outcomes, remains limited in scope. Researchers have shown that such a shift is likely to negatively affect academic outcomes for students by increasing the deviation between solar and clock time, thereby affecting their sleep, but existing studies have only been conducted within highly isolated (e.g., within a state with multiple time zones) or international contexts (e.g., Gaski and Sagarin, 2011; Jagnani, 2024). Little is known of its potential effects on students' behavioral outcomes.

Current evidence certainly substantiates that time zone policy can be viewed as a form of sleep health policy due to its shared influence on sleep and related outcomes. Clock changes and DST have been shown to influence a variety of outcomes spanning worker productivity and cancer diagnoses to road safety and crime (Neumann and von Blanckenburg, 2025; Roenneberg, Winnebeck and Klerman, 2019; Smith, 2016). Sleep, or the lack thereof, is the primary mechanism identified as driving most of these effects. DST influences the circadian rhythm, which in turn affects several biological functions, namely sleep (Rishi et al., 2020; Johnson and Malow, 2023). By shifting the clock by one hour during DST, wake-up time occurs before the body is ready and sleep time occurs later, increasing the misalignment between clock time and solar time. *Social jet lag* is a measure used to understand to what extent these times are misaligned.

Based on the current understanding of social jet lag, a permanent DST shift would exacerbate —or at least increase the likelihood of experiencing —social jet lag. Social jet lag has deleterious effects on health outcomes, and evidence of varying rigor indicates that it could have mixed economic and social effects. At a broad population level, a shift to

DST is expected to negatively impact health outcomes (e.g., Giuntella and Mazzonna, 2019; Johnson and Malow, 2023; Smith, 2016; Hadlow et al., 2014), increase electricity usage (e.g., Bellia et al., 2020; Guven et al., 2021), and decrease criminal activity (e.g., Domínguez and Asahi, 2023). In tandem, rigorous evidence on the economic consequences of such a shift is limited. Descriptive evidence suggests that a permanent DST shift may lead to increased consumer spending (Farrell, Narasiman and Ward, 2016). However, the literature on worker productivity more broadly suggests that decreased sleep duration (such as that caused by a DST shift) would lead to reduced productivity and, thus, economic losses (e.g., Hafner et al., 2017) —an expectation corroborated by causal evidence at a national scale (Giuntella and Mazzonna, 2019).

Although social jet lag is more likely to affect people with specific chronotypes,[2] it peaks for those aged 10 to 17—young children and adolescents with early school start times (Borisenkov et al., 2017; Roenneberg, Winnebeck and Klerman, 2019; Edwards, 2012). Within the education field, sleep and its consequences are typically discussed within the (relatively small) school start-time literature (e.g., Heissel and Norris, 2018), within which few studies consider the structural barrier that solar-clock time presents in determining sleep quality and duration. As social jet lag is strongly correlated with sleep duration (Wittmann et al., 2006), DST is most likely to lead to sleep deficiencies in youth—especially those on the eastern side of time zone borders.

2.2 Sleep loss and student outcomes

Ample evidence underscores the critical role of sleep in supporting children's cognitive, behavioral, and emotional development. Insufficient sleep is consistently linked to increased behavioral problems, compromised emotional regulation, and poorer academic performance for children and youth (e.g., Astill et al., 2012; Dewald et al., 2010; Heissel and Norris, 2018; Sadeh, Gruber and Raviv, 2002). Behavioral problems and compromised emotional regu-

[2] Evening vs. morning (see Johnson and Malow (2023) for an overview).

lation create issues across a child's life course when they result in exclusionary disciplinary practices (e.g., suspension or expulsion). Exclusionary practices have been shown to cause increased likelihood of criminal activity (Bacher-Hicks, Billings and Deming, 2024), reduced academic achievement, increased absenteeism, increased risk of dropout (and reduced graduation) (Sorensen, Bushway and Gifford, 2022; Holt et al., 2022; Welsh and Little, 2018), and are associated with reduced employment and earnings (Davison et al., 2021). It is not difficult to conclude that exclusionary discipline results in reduced human capital formation among youth. Further, in the extant literature (Welsh and Little, 2018) and in our study (see Table 1), boys, especially Black boys, experience exclusionary disciplinary practices at a significantly higher rate than girls. In addition to their impacts on students themselves, these behaviors present difficulties for teachers who must address this behavior (Griffith and Tyner, 2019).

Most of the existing literature on sleep health has focused on youth, who face (what has been coined) a *perfect storm* of factors impacting their sleep —after the onset of puberty, youth's biological regulation of sleep changes, making their sleep more sensitive to shifts in light exposure and psychosocial forces (Crowley et al., 2018). Evening light exposure is an important determinant of sleep duration, as it can delay the release of sleep hormones and, consequently, bedtimes (Reynolds et al., 2023). During early puberty, youth experience an increased biological sensitivity to evening light relative to older adolescents, making them particularly susceptible to later bedtimes (Crowley et al., 2015). Psychosocial forces, such as screen time and academic pressure, also tend to impact adolescents' sleep (e.g., LeBourgeois et al., 2017). These forces are likely to affect older adolescents, who have more autonomy of their schedules and experience additional external pressures (e.g., academic, social, and economic). It is important to note that the circadian response to light is biological and thereby likely consistent across racial groups, but racial and ethnic minority youth often face additional social and environmental challenges that lead to shorter sleep durations (Guglielmo et al., 2018). Findings within this literature highlight that, by delaying bedtimes, evening light exposure has deleterious effects on adolescents' sleep duration —light exposure that would systematically increase during a permanent DST shift.

Beyond evening light, institutional factors such as school start times also play a critical role in shaping adolescent sleep. Extensive literature has investigated how school start times, and related sleep duration, affect youth's academic and health outcomes. This literature focuses on the time at which students awake by evaluating the impact of start time shifts on their outcomes (Ziporyn et al., 2022), which does not necessarily involve considering students' bedtimes. Reviews of the literature in fields such as pediatrics and epidemiology show that later school start times lead to longer sleep duration and quality, higher academic achievement, and improved attendance and well-being (Yip et al., 2022; Wheaton, Chapman and Croft, 2016). These results are consistent with findings within the social sciences, who focus on impacts on academic outcomes for children as they enter puberty (Edwards, 2012), through secondary school (Groen and Pabilonia, 2019) and into late adolescence (Carrell, Maghakian and West, 2011).

It is reasonable to expect that sleep (or a lack thereof) may differentially impact students' outcomes through various mechanisms. Though the above studies consistently link increased sleep duration to positive academic outcomes, some identify heterogeneity in the effects of later school start times. For instance, one study finds that boys' sleep duration may not lengthen in response to a later start time, mitigating its positive effects (Groen and Pabilonia, 2019). In addition, relative to boys, girls exhibit stronger sleep spindle activity —a brain rhythm tied to learning and memory —suggesting more active neural pathways regulating their sleep (Markovic, Kaess and Tarokh, 2020). As such, girls' quality of sleep may be systematically higher, such that losing sleep may not be as impactful for them as it would be for boys. A lack of sleep may also exacerbate the severity of students' existing medical conditions or increase their susceptibility to contract illnesses (e.g., Evans et al., 2017; Orzech et al., 2014). In addition, children who experience behavioral difficulties, such as impulsivity, tend to be more prone to sleep problems and vice versa (Bauducco, Salihovic and Boersma,

2019) —difficulties which often reinforce one another. Losing sleep in a systematic manner (likely to occur for those living in the eastern border of time zone, or under a permanent DST shift) may disparately impact students' outcomes by negatively impacting achievement for boys more so than girls, increasing the prevalence of health issues for students with existing conditions, or exacerbating difficult behavior.

Though the above literature has extensively documented the role that sleep —typically as a consequence of later school start times —plays on academic outcomes, little is known about the structural impact of clock-solar time misalignment on student outcomes (especially above and beyond achievement outcomes). One study, conducted within the state of Florida, estimates the impact of later school start times while considering the role that shifting sunrise time plays, leveraging within-student, cross-time-zone moves (Heissel and Norris, 2018). The authors find that a one-hour increase in start time relative to sunrise improves students' academic outcomes. Similarly, a few studies have documented the negative impact of less sleep on students' academic and achievement outcomes due to exogenous variation in sunset times (Jagnani, 2024) and changes due to DST (Gaski and Sagarin, 2011), either outside the US or in specific states with time zone variation. Nonetheless, the impact of clock-solar time misalignment on student outcomes, such as behavior and achievement, *regardless of school start times*, remains underexplored. Evidence remains especially limited for studies conducted at the national level and spanning multiple seasons (Johnson and Malow, 2023). This gap limits our understanding of the broader and potentially compounding effects of permanent time policies on youth outcomes.

3 Current Study

We use the placement of time zone boundaries to study the impact of time zone policy on students. Specifically, we ask the following research questions:

Research Question 1: How do later sunset times impact students' behavioral outcomes?

Research Question 2: Is there heterogeneity in these impacts by race, sex, or grade level?

3.1 Data and Sample

To derive our outcomes of interest, we rely on data from the Common Core of Data (CCD) and Civil Rights Data Collection (CRDC). From the CCD, we use a school's latitude and longitude. From the CRDC, we rely on measures of suspension, on average, as well as by race and sex. We use all available years (2011, 2013, 2015, and 2017).

Our primary measures of interest are school suspension rates, which we measure as the number of students per 100 enrolled who experience an in-school, single out-of-school, or multiple out-of-school suspensions in an academic year. The single out-of-school suspension rate is measured as the number of students per 100 enrolled who received only one out-of-school suspension that academic year. The multiple out-of-school suspension rate is measured as the number of students per 100 enrolled who received *more than one* out-of-school suspension in a given year. In-school suspension rates are measured as the number of students who received at least 1 in-school suspension per 100 enrolled. We windsorize our data to exclude the top 99th percentile of suspension rates.[3] We construct measures of racial and gender disparity in exposure to suspension as adjusted risk differences (ARDs), which are derived as the difference in suspension rates between two groups (*0,1*) of interest:

$$ARD_{st} = \frac{SuspensionRate_{1,st}}{Enrollment_{1,st}} - \frac{SuspensionRate_{0,st}}{Enrollment_{0,st}}$$

We match suspension data from the CRDC to data from the CCD on a school's physical location as measured by latitude and longitude. This allows us to derive the distance between a school's physical location and the closest time zone boundary.

Our empirical strategy (which we discuss in 3.2 and in the Appendix) relies on two key

[3] We reestimated our primary specifications using the full sample and found those results consistent with those presented here. Results available upon request.

measures: (1) a school's sunset time and (2) distance from the closest time zone border. We calculate a school's sunset time based on the National Oceanic Atmospheric Administration's (NOAA) sunset time calculator, which allows us to estimate sunset times based on latitude and longitude.[4] For each school in our sample, we calculate the average sunset time over the course of a year, which is our key source of identifying variation to estimate the impacts of later sunset (and less sleep) on our outcomes of interest (see Figure 1). Also using a school's latitude and longitude, we estimate the distance to the closest time zone boundary, which we derive from relevant ArcGIS shapefiles. Because Alaska and Hawaii do not share boundaries with other US states, we exclude these states from our sample. Ultimately, our primary sample includes over 100,000 unique schools across all years.[5]

3.2 Strategy

To conduct our estimation, we rely on random variation in sunset time in a specific area induced by a time zone boundary. Figure 1 displays all schools in our sample by decile of sunset time. Specifically, the variation in sunset time is the greatest at the border of a time zone—directly east of a time zone border, sunset time is one hour later than directly west of the border (see Figure 1b). Prior work has shown that living due east of a time zone border results in approximately 19 minutes of less sleep, on average (Giuntella and Mazzonna, 2019).

We use a boundary regression discontinuity design with state fixed effects to estimate the impact of this jump in sunset time at a time zone border. The intuition of this approach is straightforward—a school located just east of a time zone border is comparable to a school just west of a time zone border, especially when schools are located in the same state. Any differences that we do observe would be attributable to differences in clock-solar time misalignment induced by the time zone border. That is, if but for the time zone border, there would expect there to be no difference in our outcomes of interest. We provide a

[4] We derive the formula used to generate sunset time from the Excel sheets provided at this link: NOAA Solar Calculator

[5] Our effective sample is between 2481 (multiple out-of-school suspension) and 6821 (in-school suspension) unique schools, depending on the optimal bandwidth determined for each primary measures.

variety of tests in Section 4.1 to support this exogeneity assumption. Formally, we estimate the following equation:

$$Y_{st} = \beta_0 + \phi \mathrm{D}_s + \nu \mathrm{East}_s + \alpha_c + \gamma_t + \epsilon_{\mathrm{st}} \tag{1}$$

where Y_{st} represents one of our outcomes of interest for school s; D_s is a binary indicator for schools located in the east side of a time zone boundary (i.e., schools where the sun sets "later") and is determined by our running variable East_s, a measure of the distance in kilometers between the time zone boundary and school s; ϵ_{st} is an idiosyncratic error term with the usual properties; and ϕ is our parameter of interest and indicates the difference in outcomes between schools just east of the time zone border relative to those just west of the border. We include academic year (γ_t) and state (α_c) fixed effects in our preferred model. The inclusion of state fixed effects restricts our identifying variation to schools within states that contain multiple time zones, which allows for greater comparability and reduces any potential variation that may arise from time zone boundaries occurring at state boundaries. Sample sizes vary across estimates due to differences in demographic composition across schools (e.g., some schools do not have any Black students).[6]

4 Results

Figure 3 presents binned scatter plots without fixed effects, showing a stark difference in suspension rates at the time zone boundary. Students in areas with a later sunset time have greater rates of suspension, especially suspensions likely reserved for more severe or persistent misbehavior (multiple out-of-school). The single out-of-school suspension rate is also higher due east of the time zone border. There is evidence of a potential substitution effect, with in-school suspensions being less prevalent east of the border.

In our preferred specification with state fixed effects, having a later sunset time results

[6] All estimation is conducted using `rdrobust` (Calonico, Cattaneo and Titiunik, 2014), with coefficients, standard errors, and p-values from robust estimation presented.

in 0.939 more students per 100 enrolled receiving single out-of-school suspension and 0.780 more students per 100 enrolled receiving multiple out-of-school suspensions (see Figure 4 and Table 2). While small in absolute magnitude, relative to the sample average, single suspension rate of 2.9 percent and multiple out-of-school suspension rate of 1.8 percent, single and multiple out-of-school suspension rates are 32.1 percent and 43.8 percent greater in late sunset areas, respectively. We find that these effects are driven by males (Figure 4 and Table 4) and by middle and high school grades (Figure 5). Notably, our measure that is likely commensurate with habitual difficult behavior (multiple out-of-school suspensions) is solely driven by middle school students, especially males (Figures 5 and 8).

We also find evidence of a potential substitution effect—on average, schools with later sunset times have fewer in-school suspensions. However, this result is driven entirely by elementary schools (Figure 5), as middle and high school students experience higher rates of in-school suspension.[7] We find these results to be in line with the onset of puberty that usually occurs in the middle grades, making sufficient sleep even more important for better student behavior and emotional regulation. This result is also in line with literature suggesting that youth aged 10 to 17 are most impacted by social jet lag (Borisenkov et al., 2017; Roenneberg, Winnebeck and Klerman, 2019), with puberty marking a particularly sensitive period (Heissel and Norris, 2018; Edwards, 2012).

We find limited differences in effects by race. We do not find this surprising, as there is not an *ex ante* reason to believe that there are biological racial differences in sleep sensitivity. Indeed, we observe null results when examining the impacts of time zone borders on racial disproportionality in suspension rates (Table 3, Panel A).[8] We do observe slight differences, however, by sex. We observe that females are over-represented in in-school suspensions ($p < 0.05$), whereas males are over-represented in multiple suspensions ($p < 0.10$) suggesting slight

[7]Estimates exclude schools with combined grades (e.g., K-5, 6-12, K-8, or K-12 and are not directly comparable with full sample estimates.

[8]This exercise also functions as a falsification exercise—we observe no changes in an outcome that we would not expect to differ as a result of the policy as there is no reason to believe that there are racial differences in biological and behavioral responses to reduced sleep. We discuss this further in Section 4.1.

gendered differences in the role of clock-solar alignment and persistent behavior. Specifically, these results suggest that this misalignment could result in more persistent misbehavior for boys relative to girls, and perhaps more isolated misbehavior among girls relative to boys.

4.1 Robustness

We conduct a variety of exercises to assess the validity of our results. First, we conduct a placebo test, estimating the impact of a shifted time zone boundary. To do so, we move the time zone boundary by 435 kilometers, which is derived by half of the maximum distance between a school and a time zone. As such, we should expect that there should be no detectable impact of a randomly selected boundary where there is minimal difference in sunset time east to west of the boundary. We then re-estimate all models and find estimates to be insignificant and close to zero (Table 5).

Second, we test the sensitivity of our results to bandwidth selection. We use variations in the optimization routine provided by `rdbwselect` (Calonico, Cattaneo and Titiunik, 2014) and also scale our bandwidth. We reestimate our primary specifications using a bandwidth that is 1.25 or 0.75 times the optimal bandwidth and also different optimization routines for mean squared error minimization. We find our primary results regarding out-of-school suspensions generally robust to these changes in both magnitude and direction. However, our estimates of the impacts on in-school suspension lose precision.

When scaling our bandwidth by 0.75 times the optimal, we find that these results lose precision. We suggest that this may be due to active decision-making by families to live and attend school on one side of a time zone border, resulting in our results being endogenous to this decision. This means that limiting our sample and estimation to schools *very* close to the border may generate attenuated and imprecise estimates. As a robustness check, we implement a donut RD design, which removes schools that are very close to the border from our estimation. We eliminate schools that are within 10km (approximately 33 percent of our optimal bandwidth) of a time zone boundary (450 unique schools) and find that our results for out-of-school single and multiple suspensions nearly double in magnitude and retain significance at the 0.1 percent level (see Table 2, Column 3). We also conduct balance checks, estimating any differences in observable characteristics that occur at a time zone border. We show raw differences in Figure 7 and display coefficient estimates that rely on our preferred specification (year and state fixed effects) in Table 7. We find no statistically significant difference in school-level observable characteristics occurring at the time zone border.

We can also think of our estimates of racial disparity in suspension as a robustness check. Whereas there are reasons to believe there may be differences in response to changes in sleep patterns by sex, there is no reason to believe that there are racial differences in sleep response. Consequently, we observe in Table 3 that solar-clock time does not result in differences in racial disproportionality in suspension, but does result in disproportionality by sex – consistent with findings within the school start time (e.g., Groen and Pabilonia, 2019) and sleep literatures (e.g., Forest et al., 2022; Markovic, Kaess and Tarokh, 2020).

Lastly, we conduct a sensitivity analysis to ensure that our primary results regarding out-of-school suspension are not driven by a single state. To do so, we rerun our preferred model dropping a given state from the analysis. As shown in Figures **??** and 8b, we find that no single state is driving our results—all estimates are clustered around our effect and retain statistical significance. Further, this figure demonstrates that our variation is restricted to only states with multiple time zones—when excluding states with only one time zone (e.g., West Virginia), our estimates remain *completely* unchanged.

Taken together, these results suggest that our estimates of student suspension likelihood is likely due to the changes induced by the time zone boundary itself, not due to selection or other endogeneity concerns.

5 Limitations

This study is not without limitations. As with any research that investigates the use of suspension, the measure of suspension rates as a proxy for student behavior is imperfect. The ultimate record that we observe is the product of a complex process that originates with a student's behavior, but is subject to teacher biases, school policies, and the context of the behavior (Welsh, 2024).

Second, while ample evidence documents the effect that sunset time has on sleep, we do not have access to a national measure that allows us to instrument hours slept with sunset time. While this may be considered a limitation, we find that this may also be a strength of this study, as it allows us to focus on structural issues that contribute to the use of exclusionary practices within schools—not simply micro-level interventions.

Third, a strength of our study is that we use a nationwide sample to understand the generalizability of estimates from prior studies that focus on an individual state (e.g., Florida (Heissel and Norris, 2018)). To improve the precision of our estimates, however, we include state fixed effects which allows our variation to be concentrated on schools that are within the same state. As such, our effective variation is reduced to thirteen states. We do, however, provide estimates in Table 2 without state fixed effects and find results similar in magnitude and precision.

6 Discussion and Implications

Taken together, our results suggest that clock-solar alignment plays a significant role in influencing key outcomes for students —specifically, their behavioral outcomes. We find statistically and practically meaningful increases in suspension rates on average, especially for out-of-school suspensions. This persistence suggests an underlying difference in behavior that seems to result from habitual exposure to later sunset (and commensurately less sleep). As such, we document one of the many deleterious impacts of systematically lower sleep duration for children, many of which have been long noted by academic communities across several disciplines (e.g., American Academy of Pediatrics, 2014; Carskadon, 2011; Astill et al., 2012).

Our findings are nuanced. Increases in suspensions differ for students across school grade levels, concentrating in middle and high schools. These findings are consistent with existing literature documenting the effect of school start times, which shows that the onset of puberty is an important factor determining sleep duration (e.g., Heissel and Norris, 2018). Our results also support the hypothesis that early adolescents' increased biological sensitivity to evening light (Crowley et al., 2015) has a systematic impact on their sleep and, in turn, on their behavior —as has been documented for academic achievement (Heissel and Norris, 2018).

Impacts on some behavioral measures (i.e., in-school and single out-of-school suspensions) remain relatively stable into high school, likely due to the psychosocial forces that shape older adolescents' academic and social circumstances (e.g., homework, screen time, social activities), which in turn influence their sleep (LeBourgeois et al., 2017). These results are consistent with the *perfect storm* model, which underscores the importance of sleep duration for adolescents and the challenges for them to secure it (Carskadon, 2011; Crowley et al., 2018). It is worth noting that we also find gender disparities in behavioral outcomes across schooling grades. After middle school, female students on the east side of the time zone border have higher suspension rates than those on the west side. Male students also show elevated suspension rates —particularly in-school suspensions in middle and high school, multiple out-of-school suspensions in middle school, and single out-of-school suspensions in high school —though these differences are not significantly greater than those of female students.

Based on the existing literature, the above findings could be explained by multiple mechanisms. There is no biological basis as to why lower sleep *duration* would directly impact girls' engagement in difficult behaviors more or less than boys', but there are other factors that could indirectly affect it. For instance, since boys in our sample exhibit higher suspension rates, consistent with prior research (Welsh and Little, 2018), systematic sleep loss may be likely to contribute to more frequent or severe difficult behavior among male students with existing challenges given the bidirectional relationship between problem behaviors and sleep (e.g., Bauducco, Salihovic and Boersma, 2019; Reynolds et al., 2023). Existing literature also shows that adolescent girls often report more issues falling and staying asleep than boys do (Forest et al., 2022), but more robust evidence is needed to understand differences in these sex-specific patterns.

Our findings also show that male and female students' behavioral outcomes are influenced throughout middle and high school in distinct ways. The nature of boys' suspension rates indicates a decrease in severity or frequency of challenging out-of-school behavior from middle to high school. Based on the *perfect storm* model (Crowley et al., 2018), male students' sleep may merely be more impacted by evening light sensitivity and psychosocial forces during middle school, with their influence diminishing over time. In the case of girls, who biologically experience higher quality sleep (Markovic, Kaess and Tarokh, 2020), perhaps the loss of sleep time due to biological changes in middle schools and psychosocial forces throughout school leads to more consistent effects over time on all suspension measures. Indeed, recent American Time Use Survey data show that adolescent girls engage in more educational and other household-related activities relative to adolescent boys, though the latter group tends to engage in leisure activities involving screen time more frequently (Nguyen et al., 2022). Certainly, more research is needed to better understand the mechanisms underlying gender differences in sleep duration and patterns throughout children's life course.

We find our overall results troubling for at least three reasons. First, suspensions pose immense costs not only to students subjected to these practices. Suspension has been shown to negatively influence youth's human capital formation—the practice reduces academic achievement, graduation, increases rates of incarceration, and is associated with reduced employment and labor market earnings (Sorensen, Bushway and Gifford, 2022; Bacher-Hicks, Billings and Deming, 2024; Davison et al., 2021; Holt et al., 2022). Second, suspension has an estimated social cost of billions of dollars, primarily via suspension precipitating a student's dropping out (Rumberger and Losen, 2016). Third, the increased rates of suspension are attributable to a policy that is relatively random—a policy that is well outside a student's, parent's, or school's control, yet can result in immense, negative consequences for a child's life course.

Our study has several implications for policy. First, our findings suggest that a federal enactment of permanent DST is likely to have unintended consequences by negatively impacting student behavior. Although this policy may yield certain economic and safety-related benefits (e.g., Domínguez and Asahi, 2023), other social and economic costs may outweigh them (Rumberger and Losen, 2016; Neumann and von Blanckenburg, 2025). Second, our findings highlight the importance of aligning school start times with students' biological need for sleep. Policymakers can mitigate the harmful effects of early school start times on children by establishing start time benchmarks across schooling levels, as the state of California did in 2019 (Ziporyn et al., 2022). Other measures could include explicitly aligning start times (within reason) with solar time. Third, these results reinforce the need for disciplinary procedures (such as restorative justice (e.g., Adukia, Feigenberg and Momeni, 2025) or behavior manifestation determinations) to understand underlying and contextual variables that are often outside the control of students when addressing difficult behavior.

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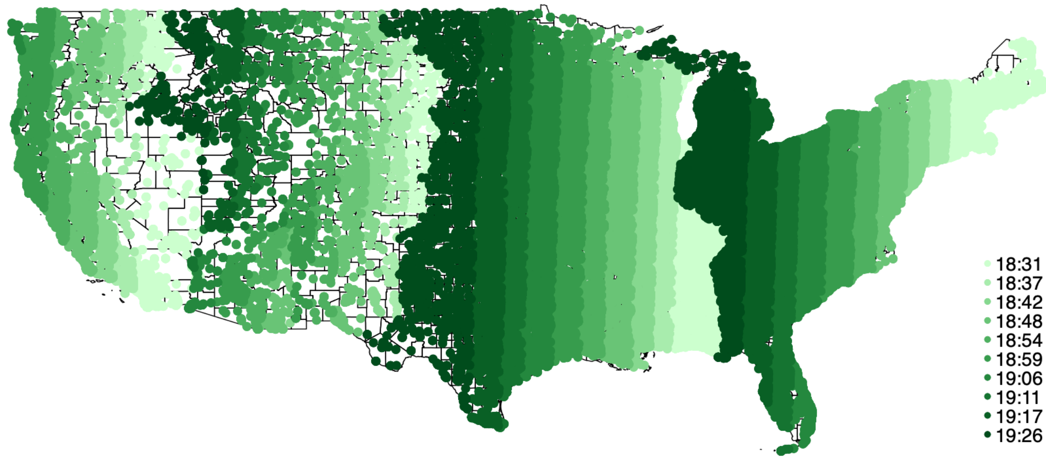
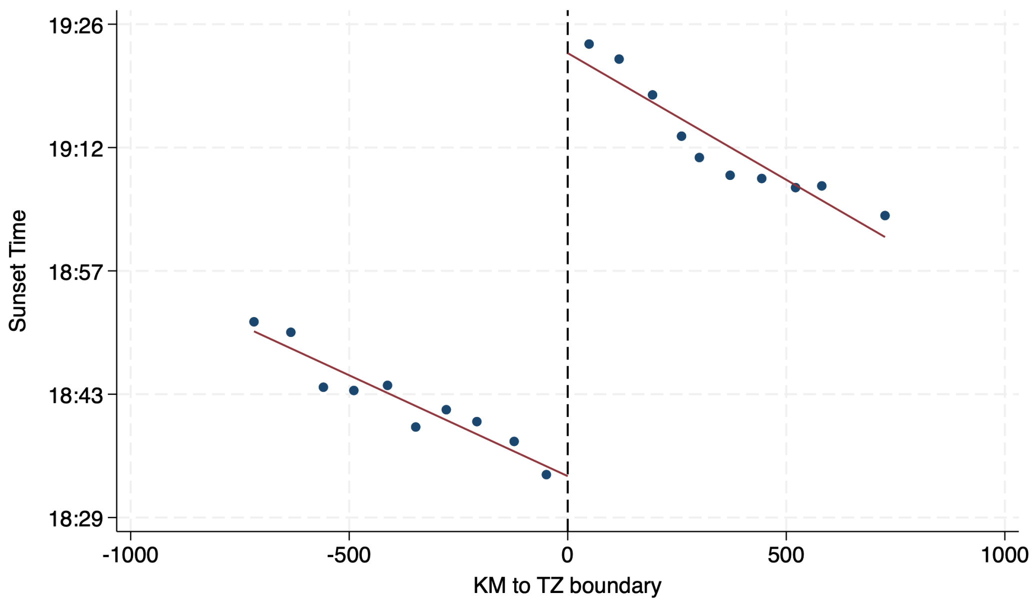
7 Figures and Tables

Figure 1: Yearly Average Sunset Time of Schools Across the Continental U.S.

(a) Deciles of average yearly sunset time



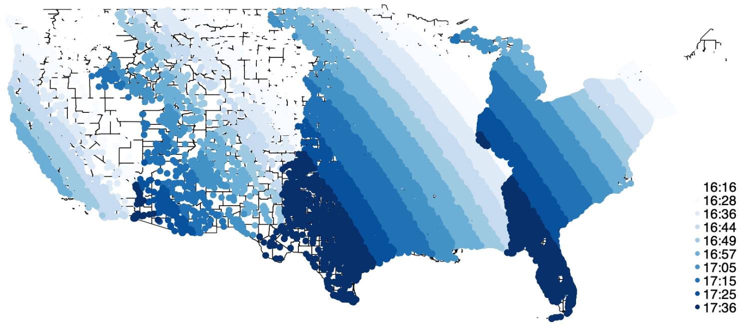
(b) Jump in Sunset Time at Time Zone Border



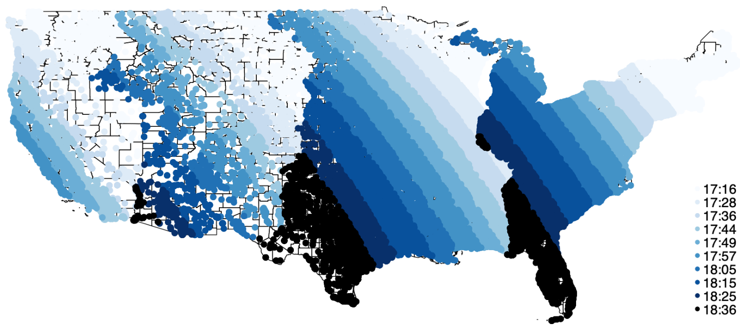
Notes. Panel A depicts all schools in our sample by decile of sunset time as determined by the NOAA sunset time calculator. Darker dots represent later sunset times. Panel B depicts binscatters of sunset times surrounding the discontinuity at the time zone border. Negative values indicate being west of the boundary, with positive values indicating being east of the boundary.

Figure 2: Deciles of Winter Sunset Time of Schools Across the Continental U.S.

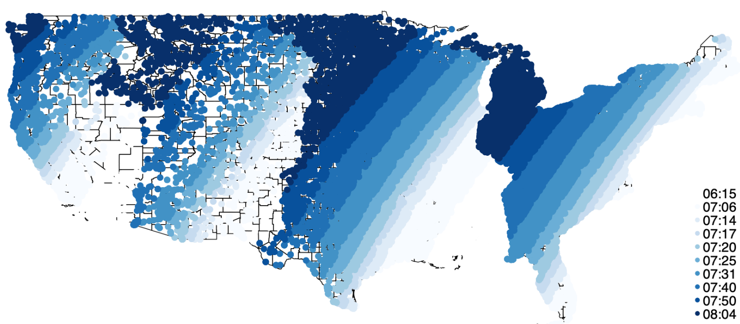
(a) Sunset times in the Status Quo



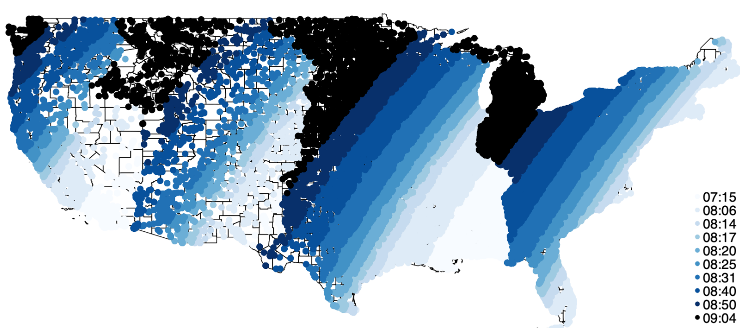
(b) Sunset time with Permanent DST



(c) Sunrise times in the Status Quo

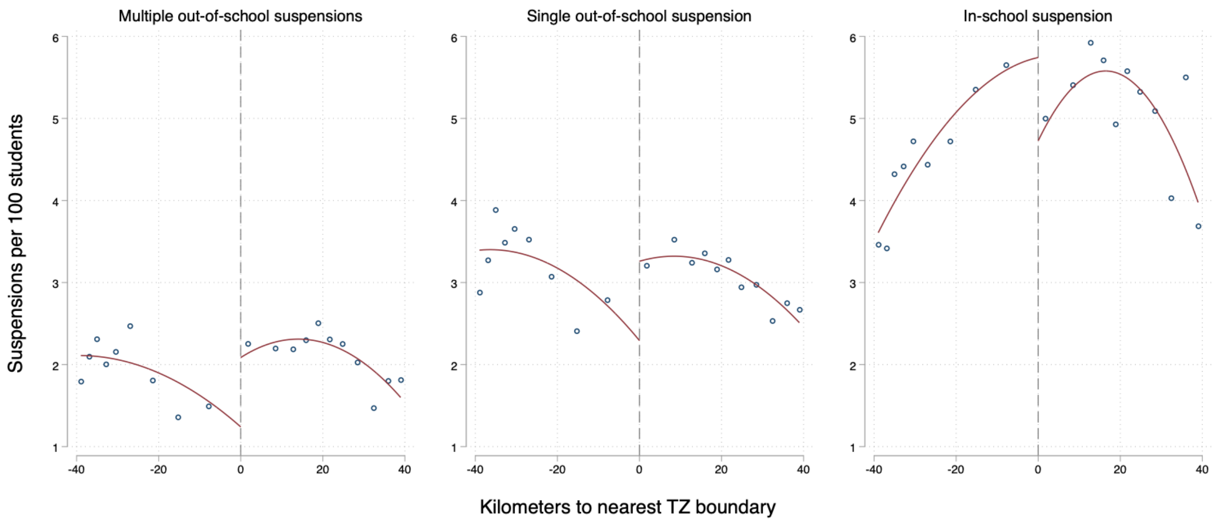


(d) Sunrise time with Permanent DST



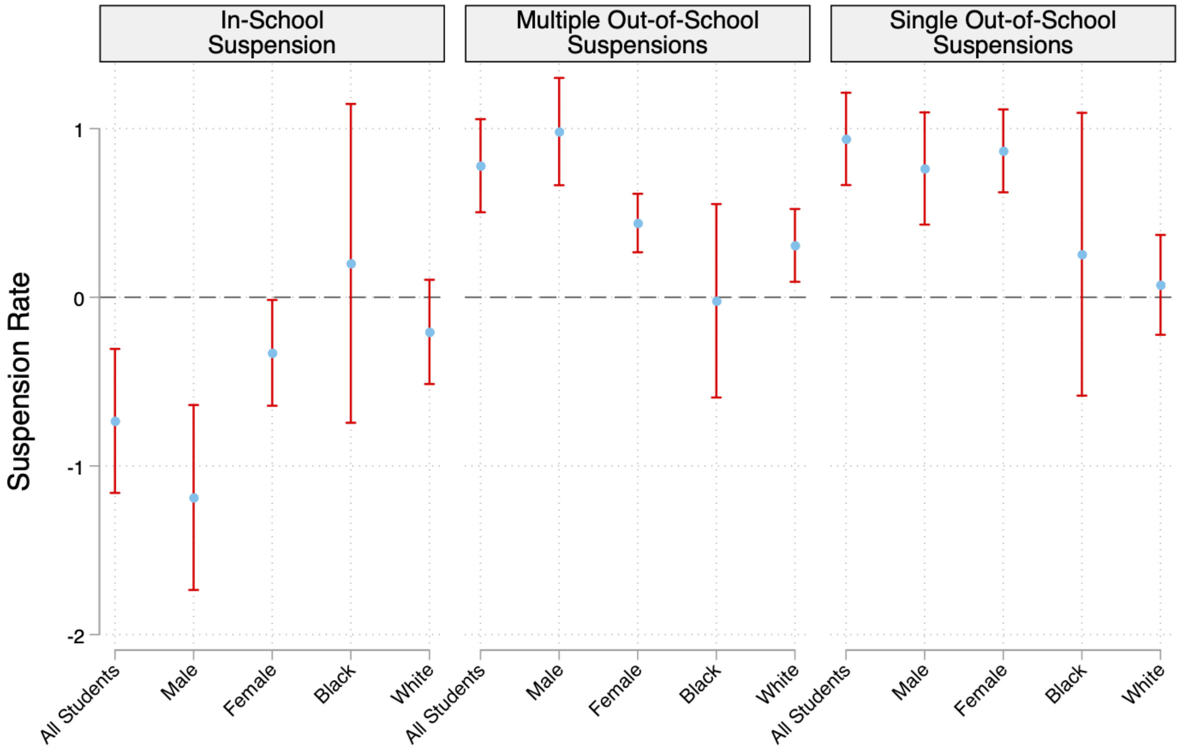
Notes. This figure depicts all schools in our sample by decile of sunset time as determined by the NOAA sunset time calculator on December 21, 2010 (winter solstice). Panel A depicts sunset times under the status quo. Panel B depicts sunset times should permanent DST be implemented. Darker dots represent later sunset times. Legend displays average sunrise and sunset time within a decile of sunrise or sunset time.

Figure 3: Effects on Suspension Outcomes



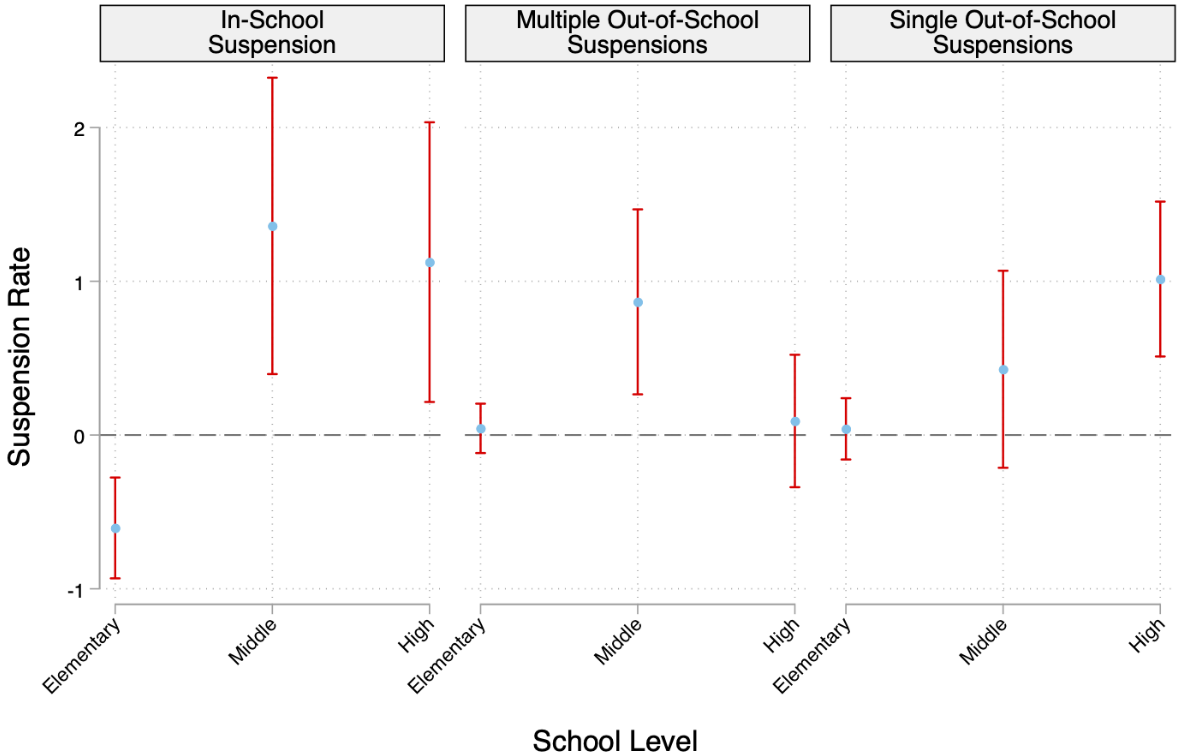
Notes. This figure presents binscatters of relevant rates of suspension between schools due east of a time zone boundary and those due west. 95% confidence intervals are displayed. Suspension rate is measured as the number of students subjected to a given suspension type per 100 students enrolled. Subgroup analyses use the number of students of a given group subjected to a given suspension type per 100 students of that subgroup enrolled.

Figure 4: Effects on suspension outcomes: by subgroup with preferred specification



Notes. Estimates indicate the difference in relevant rates of suspension between schools due east of a time zone boundary and those due west. 95% confidence intervals are displayed. Suspension rate is measured as the number of students subjected to a given suspension type per 100 students enrolled. Subgroup analyses use the number of students of a given group subjected to a given suspension type per 100 students of that subgroup enrolled.

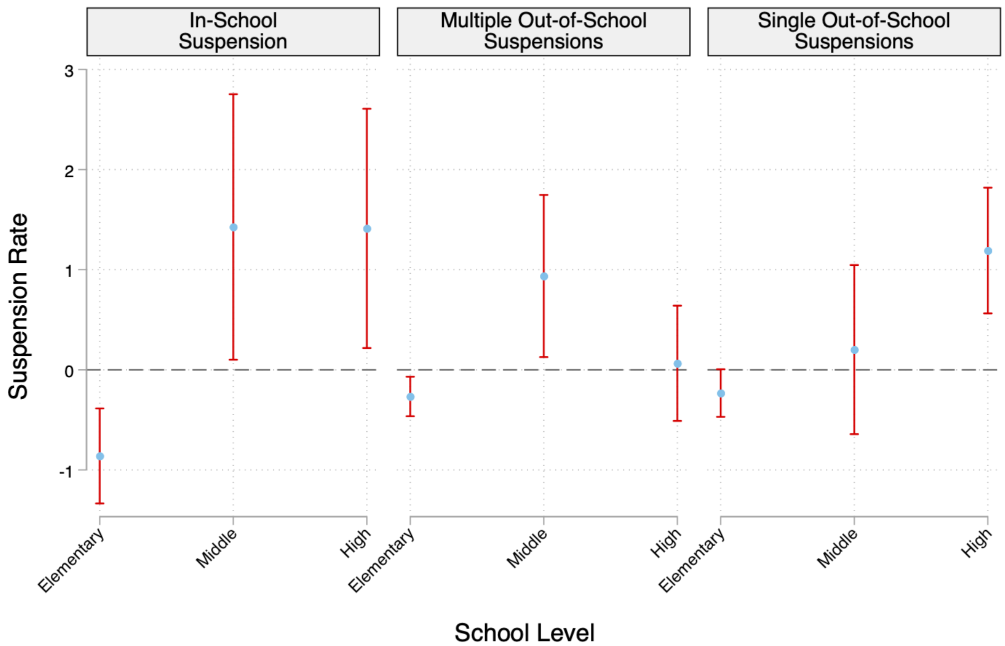
Figure 5: Effects on Suspension by School Grade Level



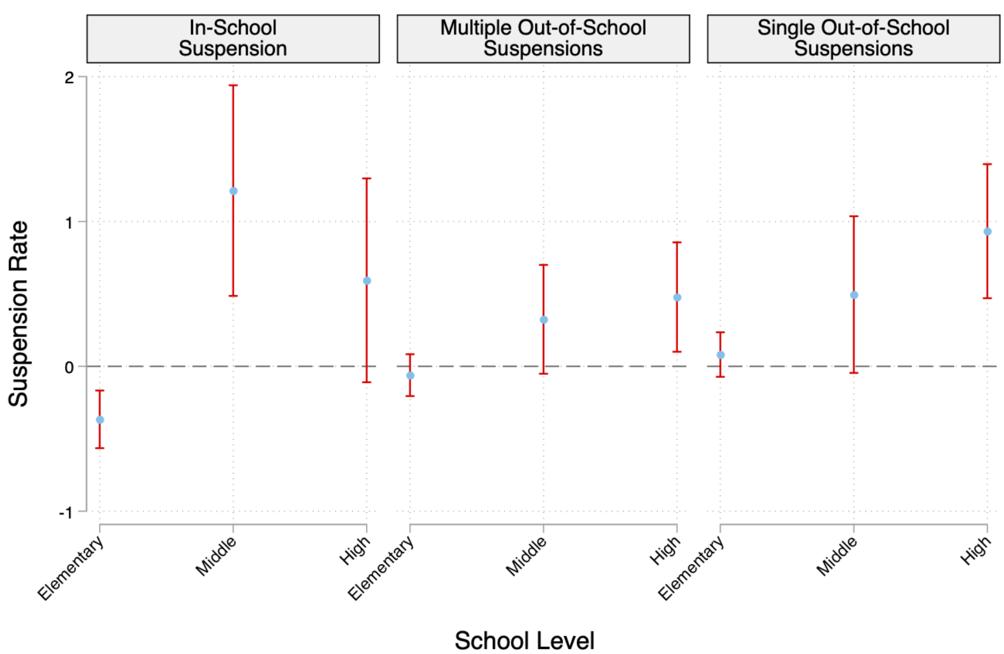
Notes. Estimates indicate the difference in relevant rates of suspension between schools due east of a time zone boundary and those due west. Schools with combined grades (e.g., K-8, 6-12, or K-12) are excluded. 95% confidence intervals are displayed. Suspension rate is measured as the number of students subjected to a given suspension type per 100 students enrolled.

Figure 6: Effects on Suspension by School Grade Level: By Sex

(a) Male Students



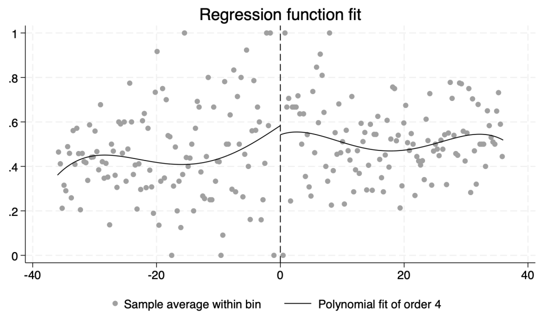
(b) Female Students



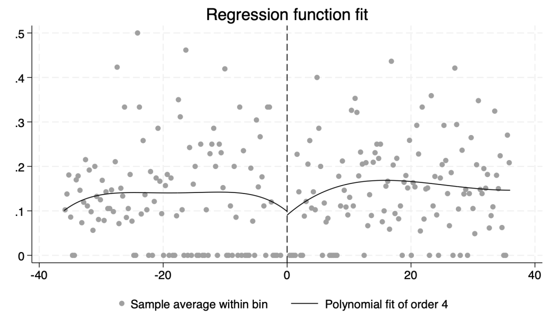
Notes. Estimates indicate the difference in relevant rates of suspension between schools due east of a time zone boundary and those due west. Estimates restrict to elementary schools (K-5), middle schools (6-8) and high schools (9-12) and thus exclude schools spanning multiple levels (e.g., K-12s or 6-12s). 95% confidence intervals are displayed. Suspension rate is measured as the number of students of a group subjected to a given suspension type per 100 students of that group enrolled.

Figure 7: Balance Tests

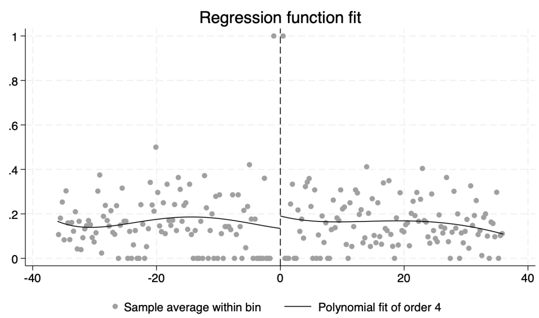
(a) Elementary Schools



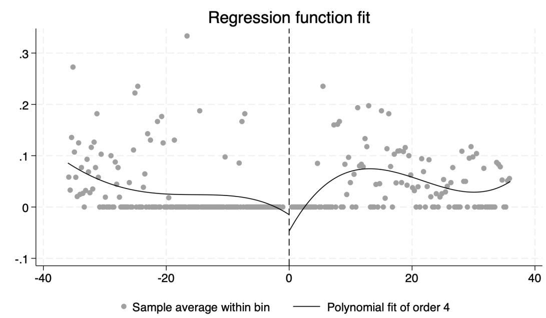
(b) Middle Schools



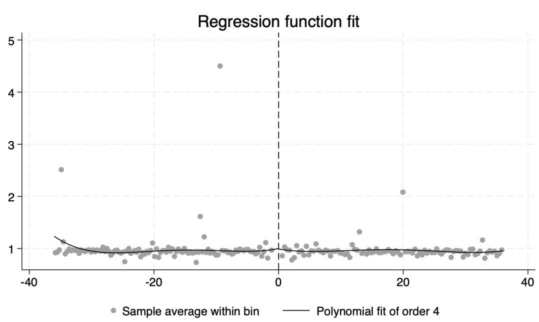
(c) High Schools



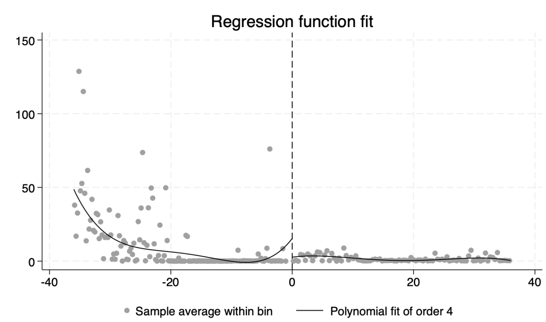
(d) Charter Schools



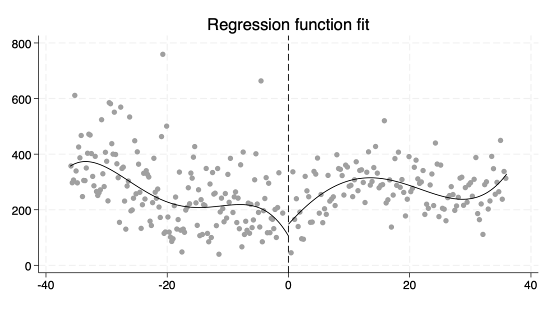
(e) Male-Female Enrollment Ratio



(f) Black-White Enrollment Ratio



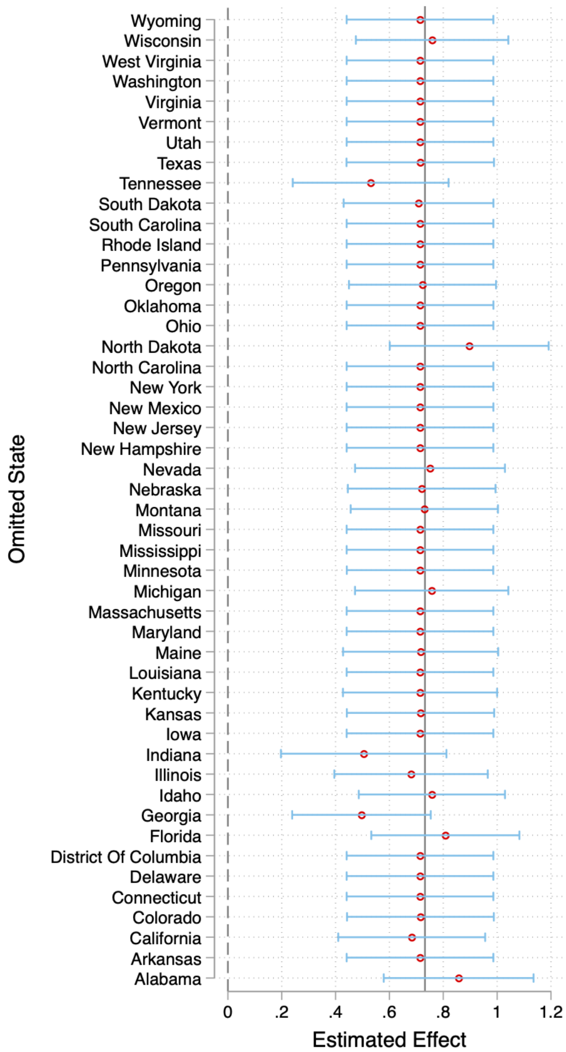
(g) FRPL Enrollment



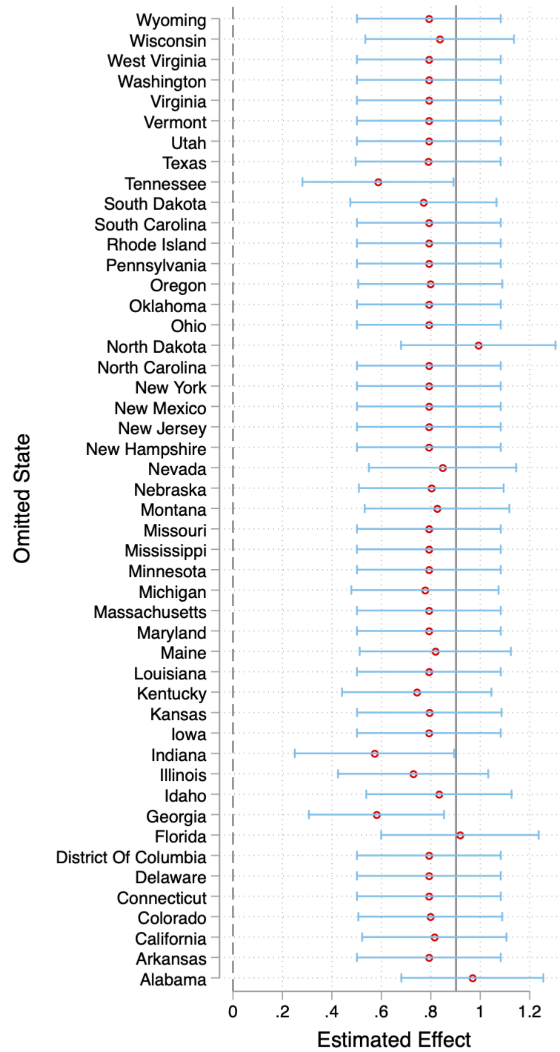
Notes. Estimates indicate the difference in relevant variables between schools due east of a time zone boundary and those due west using the bandwidth from our primary estimate of multiple out of school suspensions (36km).

Figure 8: Robustness to Omitting Each State

(a) Multiple out-of-school suspensions



(b) Single out-of-school suspensions



Notes. Estimates indicate the difference in relevant rates of suspension between schools due east of a time zone boundary and those due west. Each estimate relies on optimized bandwidth from the full sample such that estimates are directly comparable to preferred estimates with the full sample. Solid line indicates the primary estimated effect. 95% confidence intervals are displayed. Suspension rate is measured as the number of students subjected to a given suspension type per 100 students enrolled.

Table 1: Summary Statistics

Variable	**Mean**	**Std. Dev.**
Single out-of-school suspension rate (total)	2.92	(3.7)
White	2.8	(15.249)
Black	5.652	(11.472)
Male	3.939	(4.734)
Female	1.852	(3.262)
Multiple out-of-school suspension rate (total)	1.779	(3.104)
White	1.583	(9.499)
Black	3.777	(9.951)
Male	2.556	(4.241)
Female	0.954	(2.347)
In-school suspension rate (total)	4.267	(6.866)
White	3.815	(9.052)
Black	8.181	(16.612)
Male	5.842	(9.009)
Female	2.624	(5.125)
Black-White ARD		
In-school suspension	4.368	(15.499)
Single out-of-school suspension	2.772	(18.88)
Multiple out-of-school suspension	2.133	(13.239)
Male-Female ARD		
In-school suspension	3.238	(5.341)
Single out-of-school suspension	2.099	(3.37)
Multiple out-of-school suspension	1.609	(3.026)
Elementary school indicator	0.622	
Middle school indicator	0.315	
High school indicator	0.248	
Urban	0.573	
Charter school	0.06	
At least one student enrolled in...		
1st grade	0.564	
2nd grade	0.564	
3rd grade	0.563	
4th grade	0.559	
5th grade	0.541	
6th grade	0.362	
7th grade	0.298	
8th grade	0.298	
9th grade	0.239	
10th grade	0.240	
11th grade	0.241	
12th grade	0.241	
Total Enrollment	541.457	(444.106)
Observations	349,501	

Notes. Mean and standard deviation of school characteristics are presented for the full sample.

Table 2: All estimation strategies

	Year FEs	**+ State FEs**	**Donut RD (10 km)**
Panel A. In-school suspension			
Late Sunset	-0.803	-0.733	-0.378
	(0.320)	(0.218)	(0.203)
	[0.012]	[0.001]	[0.063]
Mean	4.267	4.267	4.262
Panel B. Single out-of-school suspensions			
Late Sunset	0.897	0.939	1.967
	(0.160)	(0.140)	(0.242)
	[<0.001]	[<0.001]	[<0.001]
Mean	2.920	2.920	2.919
Panel C. Multiple out-of-school suspensions			
Late Sunset	0.879	0.780	1.370
	(0.148)	(0.141)	(0.257)
	[<0.001]	[<0.001]	[<0.001]
Mean	1.779	1.779	1.777
Observations	349,501	349,501	347,912

Notes. Standard errors in parentheses, p-values in brackets. All estimation is conducted using rdrobust, with bandwidths optimized based on rdbwselect. Bandwidths vary across each outcome due to different optimal bandwidths selected by rdbwselect.

Table 3: Effects of Later Sunset on Race and Sex Suspension Disparities

	In-School	**Single Out-of-School**	**Multiple Out-of-School**
Panel A. Black-White			
Late Sunset	0.307	0.321	0.123
	(0.426)	(0.412)	(0.274)
	[0.470]	[0.436]	[0.653]
Observations	309,158	309,158	309,158
Panel B. Male-Female			
Late Sunset	-0.262	-0.066	0.108
	(0.127)	(0.118)	(0.095)
	[0.039]	[0.579]	[0.258]
Observations	347,171	347,171	347,171

Notes. Standard errors in parentheses, p-values in brackets. All estimation uses school, academic year, and grade level fixed effects. All estimation is conducted using rdrobust, with bandwidths optimized based on rdbwselect. Bandwidths vary across each outcome due to different optimal bandwidths selected by rdbwselect.

Table 4: Estimates by subgroup

	Female	**Male**	**White**	**Black**
Panel A. In-school suspension				
Late Sunset	-0.330	-1.187	-0.205	0.201
	(0.160)	(0.280)	(0.158)	(0.482)
	[0.039]	[<0.001]	[0.193]	[0.677]
Mean	2.624	5.842	3.815	8.181
Panel B. Single out-of-school suspension				
Late Sunset	0.868	0.763	0.073	0.255
	(0.125)	(0.170)	(0.151)	(0.428)
	[<0.001]	[<0.001]	[0.627]	[0.551]
Mean	1.852	3.939	2.800	5.652
Panel C. Multiple out-of-school suspension				
Late Sunset	0.440	0.982	0.307	-0.021
	(0.088)	(0.162)	(0.110)	(0.293)
	[<0.001]	[<0.001]	[0.005]	[0.943]
Mean	0.954	2.556	1.583	3.777
Observations	347,876	348,795	343,738	313,563

Notes. Standard errors in parentheses, p-values in brackets. All estimation uses state and academic year fixed effects. All estimation is conducted using rdrobust, with bandwidths optimized based on rdbwselect. Bandwidths vary across each outcome due to different optimal bandwidths selected by rdbwselect.

Table 5: Placebo Tests

	Preferred Specification
Panel A. In-School	
Placebo Late Sunset	-0.001
	(0.092)
	[0.992]
Panel B. Single Out-of-School	
Placebo Late Sunset	0.075
	(0.061)
	[0.214]
Panel C. Multiple Out-of-School	
Placebo Late Sunset	0.014
	(0.055)
	[0.806]
Observations	349,501

Notes. Standard errors in parentheses, p-values in brackets. All estimation uses state and academic year fixed effects. All estimation is conducted using rdrobust, with bandwidths optimized based on rdbwselect. Bandwidths vary across each outcome due to different optimal bandwidths selected by rdbwselect.

Table 6: Sensitivity to Changing Bandwidths

	Minimizing Mean Squared Error				**Scaled Preferred Bandwidth**	
	Preferred	Two	Sum	Median	×0.75	×1.25
Panel A. In-school suspension						
Late Sunset	-0.733	0.139	-0.525	-0.733	-1.150	-0.837
	(0.218)	(0.154)	(0.274)	(0.218)	(0.646)	(0.434)
rpv	[0.001]	[0.365]	[0.055]	[0.001]	[0.075]	[0.054]
Left BW	63.449	180.687	43.465	63.449	27.430	45.717
Right BW	63.449	63.825	43.465	63.449	27.430	45.717
Panel B. Single out-of-school suspension						
Late Sunset	0.939	0.530	0.291	0.661	-0.396	0.508
	(0.140)	(0.102)	(0.110)	(0.115)	(0.328)	(0.217)
	[<0.001]	[<0.001]	[0.008]	[<0.001]	[0.227]	[0.019]
Left BW	39.940	50.992	63.137	50.992	26.067	43.445
Right BW	39.940	94.629	63.137	63.137	26.067	43.445
Panel C. Multiple out-of-school suspension						
Late Sunset	0.780	0.411	0.014	0.411	-0.202	0.461
	(0.141)	(0.100)	(0.076)	(0.100)	(0.327)	(0.207)
	[<0.001]	[<0.001]	[0.851]	[<0.001]	[0.536]	[0.026]
Left BW	35.448	60.157	87.046	60.157	25.954	43.257
Right BW	35.448	57.626	87.046	57.626	25.954	43.257
Observations	349,501	349,501	349,501	349,501	349,501	349,501

Notes. Standard errors in parentheses, p-values in brackets. All estimation uses state and academic year fixed effects. All estimation is conducted using rdrobust, with bandwidths optimized based on rdbwselect options (column titles). Bandwidths are measured in kilometers.

Table 7: Balance Tests

	Number of FRPL Eligible	**Male:Female Enrollment Ratio**	**Black:White Enrollment Ratio**	**Elementary**	**Middle**	**High**	**Charter**
Late Sunset	9.081	-0.036	-0.850	0.025	-0.034	0.028	-0.004
	(6.737)	(0.033)	(0.813)	(0.020)	(0.016)	(0.016)	(0.004)
	[0.178]	[0.272]	[0.295]	[0.199]	[0.040]	[0.084]	[0.329]
Observations	334,260	348,796	343,769	349,501	349,501	349,501	349,496

Notes. Standard errors in parentheses, p-values in brackets. All estimation uses state and academic year fixed effects. All estimation is conducted using rdrobust, with bandwidth based on the average from our preferred specification and primary results regarding out-of-school suspensions ($\tilde{3}$7km).