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IZA DP No. 17930

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ABSTRACT

Breaking the Early Bell: Lessons from the First Statewide Mandate on School Start Times

This study evaluates the impact of California's SB 328, the first statewide mandate delaying school start times for middle and high schools, on adolescent sleep, mental health, and academic outcomes. Using YRBS, ATUS, SEDA, and SAT data, we apply difference-in-differences and matched DID methods. SB 328 led to significant improvements in sleep duration and academic performance. We find suggestive mental health benefits, though estimates are imprecise, and substantial heterogeneity in effects, with stronger gains among boys and Hispanic students across both sleep and academic outcomes.

JEL Classification: I10, I20

Keywords: school start times, sleep, mental health, academic achievement

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1 Introduction

Sleep's crucial role in health, productivity, and well-being has captured widespread attention, from popular bestsellers to academic research (Huffington, 2016; Walker, 2017; Attia, 2023; Haidt, 2024). Increasing evidence demonstrates that sleep profoundly influences cognitive function, productivity, and long-term health outcomes, making it essential not just for individuals but for society at large (Lim and Dinges, 2010; Cappuccio et al., 2010; Grandner, 2022; Gibson and Shrader, 2018; Giuntella et al., 2024). For teenagers, sleep is particularly critical as it supports physical growth, emotional regulation, and cognitive development during a formative stage of life (Twenge et al., 2017; Lo et al., 2016; Giddens et al., 2022; Creswell et al., 2023). Recognizing these benefits, the CDC recommends that adolescents aged 13–18 get 8–10 hours of sleep per night (Paruthi et al., 2016). Despite this guidance, most adolescents fall short of these guidelines due to biological, social, and environmental factors (Pallesen et al., 2011; Carskadon et al., 1998; Carskadon, 2002; Haidt, 2024).

One of the most significant barriers to adequate sleep for adolescents is their delayed circadian phase, which shifts natural sleep-wake cycles later into the night (Crowley et al., 2007). This biological reality clashes with societal demands, particularly early school start times, creating a widespread sleep deficit among teens (Hafner et al., 2017). The problem is exacerbated by the increasing prevalence of electronic device usage, which further delays sleep onset (Twenge et al., 2019; Billari et al., 2018).

The relationship between school start times, sleep, and academic outcomes has garnered significant attention in the economics and education literature. However, most existing studies are either observational or leverage local quasi-experiments or randomized individual-level variations in school start times (Heissel and Norris, 2018; Carrell et al., 2011; Groen and Pabilonia, 2019; Hafner et al., 2017). While these studies have provided crucial evidence on the role of school start times, they do not capture the broader systemic impacts that arise when such policies are implemented on a statewide scale. Scaling interventions from controlled settings to broader populations often yields varying results due to factors like heterogeneity among participants, differences in implementation contexts, and unforeseen complexities in real-world applications (Adusumilli et al., 2024; List, 2022, 2024). By evaluating the statewide implementation of SB328, we assess its impact on adolescent sleep patterns, mental health, and academic outcomes, aiming to fill this gap in the existing literature on school-start times.

This study examines California's Senate Bill 328 (SB328), the first statewide mandate in the U.S. requiring middle and high schools to start no earlier than 8:30 a.m. This landmark policy represents a rare opportunity to analyze the systemic effects of delaying school start times on adolescent sleep, mental health, and academic outcomes. Unlike smaller-scale studies that often focus on individual districts or schools, SB328 reshapes the entire ecosystem of daily activities, including transportation, extracurricular schedules, and parental work routines. These general equilibrium effects make SB328 a unique natural experiment, with implications that extend beyond individual schools to influence community and state-level dynamics.

Our analysis draws on several data sources. First, using the Youth Risk Behavior Survey (YRBS) from 2007 to 2023, we compare the self-reported sleep duration of high school students before and after the implementation of SB328 in California, relative to other states. We find that SB328 led to a significant increase in the likelihood of students reporting at least 8 hours of sleep per night—the minimum recommended duration for this age group. Specifically, students were 14% more likely to meet this threshold ($p < 0.05$), with effects that were larger and more precisely estimated among boys. In addition to improved sleep duration, we observe some evidence of mental health benefits. There is a marginally significant decline in the likelihood of reporting difficulties in concentrating (-14%, $p = 0.10$). We instead find no significant effects on suicidal intentions, though the coefficients suggest a decline which is more precisely estimated among boys.

While the YRBS provides critical insights into adolescent self-reported sleep and mental health outcomes, the American Time Use Survey (ATUS) complements these findings by offering additional dimensions of sleep behavior, including wake-up and bedtimes, across a broader age range. This allows us to explore changes in wake-up times, bedtimes, and sleep duration among adolescents (15-18) and younger children (under the age of 13). The policy significantly altered sleep patterns for teenagers aged 15–18, with a 95% decline in those awake by 6 a.m. and a 9.5% increase in the share sleeping at least 8 hours. For children under 13, we also find that later wake times contributed to significant increases in sleep duration, with the share reporting to be awake at 6am declining by 63% and that reporting sleeping more than 8 hours increasing by 13%.

We then analyze the effects of the policy on academic performance. Using data from the Stanford Education Data Archive (SEDA), we match California districts to comparable districts in other states and conduct a matched DID analysis. We find that the introduction of SB 328 led to an increase of approximately 0.1 standard deviations in both math and English scores ($p < 0.01$).

To extend our analysis of academic outcomes beyond grades 3–8 captured in the SEDA data, we examine SAT scores as a measure of high school performance and college readiness. The policy led to significant improvements in SAT performance, with total scores increasing by 2%, driven by gains in both the math (+2%) and evidence-based reading and writing (+2%) sections.

Lastly, we examine the heterogeneity in these impacts to better understand how the policy's effects varied across demographic groups. Our analysis reveals notable heterogeneity in the effects of SB 328 across both gender and ethnicity for sleep, mental health, and academic outcomes. Using YRBS data, we find some evidence that boys experienced larger improvements in sleep duration compared to girls. Mental health outcomes showed complementary patterns with similar effects across gender on the likelihood of reporting any difficulty concentrating, but significant negative effects among boys on the likelihood of reporting sadness/hopelessness and suicidal intentions. Hispanic students showed large gains on both sleep and mental health outcomes. Consistent with these findings, ATUS data for adolescents aged 15–18 reveal similarly pronounced gains among Hispanic youth. However, gender differences in sleep behavior are less clear in the time-use data, though we observe notable shifts in wake-up times among boys. Academic outcomes exhibit similar patterns of heterogeneity. Hispanic students experienced the largest improvements in standardized test scores across both math and English, while gains among White students were smaller and less precisely estimated. If anything, boys appear to have benefited slightly more in terms of academic performance, though point estimates across gender are generally similar, and not statistically different.

Event-study style figures reveal no evidence of systematic differences in pre-trends, lending further credibility to the parallel trends assumption underlying our identification strategy. As a further robustness check, we conducted a permutation test, randomly assigning the policy adoption year to non-adopting states to generate a distribution of placebo treatment effects. This analysis confirms that the observed effects in California are unlikely to result from random chance or spurious correlation, supporting the conclusion that the policy intervention was the primary driver of the observed changes.

We contribute to three strands of the literature. First, we add to the body of research on the relationship between school start times and academic performance. Findings in this area are mixed, reflecting variations across contexts and student demographics. Early studies in the Minneapolis–St. Paul area found limited evidence of academic improvement with later start times, with slight grade increases in Minneapolis schools but no significant effects on ACT scores or standardized tests across multiple districts (Wahlstrom et al., 2001; Hinrichs, 2011). Nationally, however, later start times have been linked to improved state standardized test performance (Wong, 2012). Younger students consistently show greater benefits, such as improved math and reading scores in middle schoolers from Wake County, North Carolina, and Florida students exposed to more morning sunlight (Edwards, 2012; Heissel and Norris, 2018). College freshmen also demonstrate better academic outcomes with later start times (Carrell et al., 2011). Additionally, research highlights how time of day affects performance, with studies noting lower grades and higher absenteeism during early periods (Cortes et al., 2012), varied cognitive testing outcomes by time of day (Hansen et al., 2005; Pope, 2016), and gender differences in performance schedules (Lusher and Yasenov, 2018). For college students, later classes often correlate with higher grades, although males perform worse in early morning classes (Dills and Hernandez-Julian, 2008; Cotti et al., 2018; Diette and Raghav, 2017). These findings suggest that the effects of later start times are mediated by factors such as sunlight exposure, time of day, and demographics, underscoring their complex impact on academic achievement.

Second, we contribute to the growing literature on the relationship between sleep, human capital, and productivity. Seminal studies using time use surveys highlight a negative relationship between sleep and work hours, though causality remains unestablished (Biddle and Hamermesh, 1990; Basner et al., 2007). More recent analyses of naturally occurring data suggest that later sunset times are associated with reduced cognitive performance, lower earnings, and diminished productivity, likely driven by insufficient sleep (Giuntella et al., 2017; Gibson and Shrader, 2018; Costa-Font et al., 2024; Costa-Font and Fleche, 2020; Jagnani, 2021). Among U.S. university students, a strong positive relationship between academic performance and sleep has been observed, particularly during the first half of the academic term (Creswell et al., 2023). Recent field experiments provide additional insights into how interventions can influence sleep and productivity. Bessone et al. (2021) conducted a randomized experiment in India, where incentives and sleep aids increased nighttime sleep by 27 minutes over a 20-day period but showed no meaningful impact on cognition or productivity. This lack of effect may be due to the participants' severely sleep-deprived baseline and poor sleep quality. Consistent with this hypothesis, they did find evidence that high-quality sleep provided via office naps in quiet rooms improved productivity. In contrast, in a U.S. context, where baseline sleep quality is higher, Giuntella et al. (2024) found that incentives coupled with bedtime reminders and morning feedback significantly increased both sleep and academic performance among university students.

Third, this study builds on research emphasizing the critical role of sleep and circadian rhythms in health and mental well-being (Cappuccio et al., 2010; Tarokh et al., 2016; Giuntella et al., 2017; Giuntella and Mazzonna, 2019; Jin and Ziebarth, 2020). Our study contributes to this literature by examining the impact of the early start times mandate on students' mental health outcomes, providing causal evidence on how structural changes in school schedules can improve well-being.

Our study on SB328 represents the first comprehensive evaluation of a statewide mandate for later school start times, addressing a significant gap in the literature. By analyzing the statewide effects of SB328 on adolescent sleep patterns, mental health, and academic outcomes, we offer robust evidence on the broader implications of such structural interventions. The findings from this analysis can guide similar policy initiatives, such as Florida's House Bill 733, which mandates later school start times beginning in the 2026–2027 school year. As more states consider adopting similar policies, insights from California's experience will serve as a critical guide for scaling interventions aimed at improving adolescent well-being and educational performance.[1]

2 Background

2.1 SB 328

Senate Bill 328 (SB 328), signed into law by Governor Gavin Newsom on October 13, 2019, represents a groundbreaking statewide policy aimed at addressing adolescent sleep deprivation and its consequences. The legislation mandates that California middle schools start no earlier than 8:00 a.m., while high schools begin no earlier than 8:30 a.m. This change, effective July 1, 2022, or upon the expiration of existing collective bargaining agreements as of January 1, 2020, is designed to align school start times with the biological sleep patterns

[1] Florida is one such state that has already followed suit by enacting a similar mandate. In May 2023, Governor Ron DeSantis signed House Bill 733 into law, requiring middle schools to start no earlier than 8:00 a.m. and high schools no earlier than 8:30 a.m., starting with the 2026-2027 school year.

of adolescents, whose delayed circadian rhythms make it difficult to fall asleep early and wake up for early school schedules. By mandating later start times, the law seeks to improve student health, well-being, and academic performance. This legislation makes California the first state in the U.S. to enact a statewide mandate on school start times, positioning it as a key policy experiment with implications for student outcomes and community dynamics.

2.2 Previous evidence on school start times

Research on the relationship between high school start times and academic achievement has produced mixed findings. Early studies in the Minneapolis–St. Paul area explored changes in school schedules, where some districts delayed start times while others did not. Wahlstrom et al. (2001) reported slight grade improvements in Minneapolis schools after the shift, but Hinrichs (2011) found no impact on ACT scores or statewide standardized tests using data from both districts that adjusted schedules and those that did not. In contrast, Wong (2012) observed positive effects of later start times on state standardized test performance using a national dataset, additionally noting that increased sunlight before school hours also correlated with better test outcomes.

Evidence from other contexts shows positive effects of later start times, particularly for younger students and college freshmen. Edwards (2012) found improvements in math and reading test scores among middle school students in Wake County, North Carolina, following later start times. Heissel and Norris (2018), analyzing Florida students crossing time-zone boundaries, found that greater morning sunlight boosted math and reading scores, with stronger effects for older children. At the college level, Carrell et al. (2011) showed that U.S. Air Force Academy freshmen performed better in all classes when their day started later.

Related studies address how the time of day affects academic performance. Cortes et al. (2012) observed that Chicago high school students received lower grades and had higher absenteeism for first-period classes compared to later periods. Afternoon cognitive testing yielded better results than morning testing for high schoolers (Hansen et al., 2005), though

Pope (2016) found higher grades in morning math and English classes in Los Angeles, controlling for start times. Gender differences also emerge: Lusher and Yasenov (2018) found males performed relatively better than females when schools began in the afternoon. Among college students, later class times were generally associated with higher grades, as shown by Dills and Hernandez-Julian (2008), Cotti et al. (2018), and Diette and Raghav (2017). The latter found morning classes, especially at 8 a.m. or 9 a.m., had the most negative impact on male students' performance. Interestingly, the heterogeneity of our results on sleep and mental wellbeing by gender is consistent with the findings of Lusher and Yasenov (2018) and Diette and Raghav (2017).

3 Data and empirical specification

3.1 Data

Our analysis utilizes data from four primary sources: the Youth Risk Behavior Surveillance System (YRBS), the American Time Use Survey (ATUS), the Stanford Education Data Archive (SEDA), and state-level high school SAT score reports published in the College Board's annual report. Together, these datasets enable a robust examination of the effects of SB328 on sleep patterns, mental health, and academic outcomes.

3.1.1 Youth Risk Behavior Surveillance System (YRBS)

The Youth Risk Behavior Surveillance System (YRBS), conducted biennially by the Centers for Disease Control and Prevention (CDC), collects data on a nationally representative sample of high school students (grades 9–12). This survey provides insights into health behaviors, including sleep duration, mental health, physical activity, and substance use. In the context of SB328, YRBS data enable an analysis of changes in sleep quality, mental health outcomes, and related behaviors before and after the policy's implementation. By focusing on adolescents aged 14–18, the YRBS offers a vital lens into the broader health impacts of the legislation. The data contain information from 45 states with no data on Colorado, South Dakota, Vermont, Washington D.C., Vermont, and Wyoming. We focus on the years 2007-2023. Summary statistics are reported in Table A.1. The YRBS is biennial, with the survey being conducted every two years.

3.1.2 American Time Use Survey

The American Time Use Survey (ATUS), conducted annually by the U.S. Bureau of Labor Statistics, provides detailed self-reported data on the daily activities and time allocation of U.S. residents. For this study, we focus on adolescents aged 15–18 who were in school during the adoption of SB328, as well as wake-up times for children aged 0–13. This dataset allows us to analyze shifts in sleep patterns, including duration and timing, as a result of later school start times. We use data for the years 2003-2023. Summary statistics for both the sample of 15-18 respondents as well as for the bedtime and wake-up time outcomes of children under the age of 13 are reported in Table A.2. Our main analysis is restricted to weekdays.

3.1.3 Stanford Education Data Archive (SEDA)

The dataset we used in the study is the Stanford Education Data Archive (SEDA) 2024. The 2024 release of the SEDA provides a comprehensive, longitudinal database of standardized test score estimates and school district characteristics for U.S. public school students in grades 3 through 8, spanning the years 2009 to 2024. Although SB 328 mandates later start times for middle and high schools, we analyze academic outcomes for students in grades 3–8 using SEDA for two reasons. First, SEDA offers the only consistent, district-level test score data across years and states. Second, many California middle schools include grades 6–8—directly affected by the policy—and are captured within the SEDA sample. Additionally, the policy may generate spillover effects on younger students through shared household routines (Edwards, 2012; Groen and Pabilonia, 2019; Foster and Kalil, 2007), sibling interactions, or district-wide schedule adjustments, especially in K–8 or 6–12 school configurations. The test scores consist of the Mathematics scores and English Language Arts (ELA) scores. Developed and maintained by the Educational Opportunity Project (EOP) at Stanford University, SEDA enables rigorous analysis of academic performance, achievement gaps, and educational equity across time, geography, and student subgroups.

The test score estimates in SEDA 2024 are based on publicly available state accountability data derived from two main sources. For the years 2009–2019, the primary source is the U.S. Department of Education's EDFacts database, which aggregates data from states' standardized testing programs. EDFacts data include the number of students at each performance level—typically ranging from 2 to 5 levels—for each school, grade, subject, subgroup, and year. These performance levels reflect proficiency benchmarks determined by each state. While EDFacts includes extensive subgroup detail (e.g., gender, race/ethnicity, and economic disadvantage), it contains no individual-level student data.

For the post-pandemic period (2022–2024), the EDFacts data were not available in sufficient detail. Instead, the SEDA team used publicly released state accountability data compiled from state websites and the Zelma database. States included in the post-2021 dataset must meet minimum data quality thresholds, including reporting proficiency counts by demographic subgroup (school district, grade, subject) and using at least three proficiency categories. However, not all states met these standards, so the 2022–2024 data cover a subset of U.S. states. Notably, data from 2020 and 2021 are excluded due to widespread school closures and disruptions during the COVID-19 pandemic.

In addition to the state assessment data, SEDA uses the National Assessment of Educational Progress (NAEP) from 2009 to 2024 to anchor state-level test score distributions to a nationally comparable scale. To construct test score estimates, the SEDA team applies heteroskedastic ordered probit (HETOP) models to infer the underlying test score distributions from observed proficiency counts. The resulting average test scores—estimated for each school district, subject, grade, year, and subgroup—are then linked to the NAEP scale by aligning them with state-year-subject-grade NAEP means and standard deviations.

SEDA 2024 reports test scores in "grade-level equivalents," scaled such that one unit represents the average gain in NAEP points between grades (approximately 11 points between 4th and 8th grade in 2019). These grade-level units facilitate interpretation across years and student groups. For example, a change of -1.0 in math achievement between 2019 and 2022 indicates that students scored, on average, one full grade level below their 2019 counterparts. [2]

3.1.4 High-school SAT scores

To complement the SEDA data—which covers students in grades 3–8—we use SAT scores to capture academic outcomes for high school seniors, who are more directly affected by SB 328. This allows us to evaluate potential policy effects across a broader span of educational stages. We analyze SAT scores of high school seniors at the state level, as reported by the College Board.[3] The SAT was redesigned in 2016, and our analysis focuses on scores from 2018–2023 graduates who took the new SAT during high school. For students with multiple test attempts, the data records the most recent section scores and questionnaire responses. We only have SAT data aggregated at the state level, thus we cannot conduct any heterogeneity analysis on SAT scores.

3.2 Empirical specification

To identify the causal effects of school start times on sleep and academic achievement, we employ a difference-in-differences (DiD) analysis. Specifically, we compare changes in sleep, mental health, and academic outcomes for students in California—who have been

[2] Unlike earlier versions of SEDA (e.g., SEDA 5.0), which relied on geographic school district definitions that reassigned charter schools based on physical location, SEDA 2024 uses administrative school districts as defined by the National Center for Education Statistics (NCES). This distinction ensures that test score estimates correspond to the governance structure that sets policy for the schools, making the results more actionable for local education agencies. For more detailed methodological documentation see Fahle et al. (2024b,a).

[3] https://reports.collegeboard.org/sat-suite-program-results

affected by SB328 since its implementation in 2022—to those in other states. The timing of treatment varies slightly across datasets, reflecting differences in data collection schedules. For the YRBS, the treatment period corresponds to the 2023 wave, the first survey conducted after the policy's implementation. In the case of ATUS, which collects data continuously throughout the calendar year and includes month-level identifiers, we define the treatment period as beginning with the start of the 2022–2023 academic year, when the change in school start times would have taken effect. For both the SEDA and SAT score data, the treatment period begins with data collected in Spring 2023, since the policy was not in effect during Spring 2022, when the prior round of testing occurred. This staggered timing ensures that our DiD estimates are aligned with the actual implementation of SB 328 across each data source.

Formally, we estimate the following DID model:

$$y_{ist} = \alpha +_{st} SB328 + \gamma X_{ist} + \tau_t + \eta_s + \epsilon_{ist} \tag{1}$$

where y_{ist} is a metric of sleep, mental health, or academic performance;$_{st}$ captures the effect of the SB328 adoption in California, X_{it} is a battery of individual controls (i.e. sex, age), τ_t and η_s are respectively year and state fixed effects. Our baseline model relies on the assumption that the adoption of SB328 was not influenced by other time-varying factors that could affect our outcomes of interest and that, in the absence of the policy change, the outcomes in California and other states would have followed parallel trends. To indirectly test for this assumption, in the robustness checks, we perform a permutation test where we randomly assign the policy adoption year to other states and estimate the treatment effects under these placebo scenarios. By comparing the distribution of these placebo effects to the observed effect in California, we assess whether the observed effect is likely driven by the policy itself or could plausibly arise due to random chance or unobserved confounders. Since both YRBS and ATUS are nationally representative but not state representative, we employ weights from the National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER) Program. More specifically, we assign population weights to each respondent according to their state of residence, survey year, age, sex, and race.[4]

To examine dynamic treatment effects and assess the plausibility of the parallel trends assumption more directly, we also estimate an event-study specification of the form:

$$y_{ist} = \alpha + \sum_{k \neq -1} \delta_k \cdot \mathbf{1}(t - T_s = k) + \gamma X_{ist} + \tau_t + \eta_s + \epsilon_{ist} \tag{2}$$

where $\mathbf{1}(t - T_s = k)$ is an indicator for time relative to the adoption year T_s of SB328 in state s, omitting $k = -1$ as the reference period. The vector X_{ist} includes state-level covariates such as racial and ethnic composition, socioeconomic status, and income level.[5] Due to limited sample sizes in individual years for our population of interest in the ATUS, and the sparsity and inconsistent coverage of YRBS across states and years, we aggregate observations into multi-year bins for the event-study analysis of these data. This pooling improves statistical power while still allowing us to trace pre-trends and post-treatment dynamics over time.

In our analysis of SEDA data, we use district-level information and employ a matched difference-in-differences (DiD) approach. Districts in California are matched one-to-one with districts in other states using nearest neighbor matching, based on baseline socio-demographic characteristics and academic performance at the district level. Specifically, we implemented a propensity score matching approach to identify comparable treatment and control districts for our analysis of California's SB 328 policy. Using a logistic regression model, we estimated propensity scores based on several covariates capturing demographic and educational characteristics. Specifically, we matched on the share of Black, Hispanic,

[4]For the ATUS sample of children under the age of 13, since we do not observe individual's demographic characteristics, we weight observations by the population aged 0-12 in the given state-year pair.

[5]The vector X_{ist} in YRBS represents state-level characteristics including population, population density, % households with children, marital status and education-related variables, unemployment rate, median household income, and child poverty rate. In ATUS for respondents aged 15–18, X_{ist} represents state-level percentage of households with children, marital status, dropoff rate, unemployment rate, and child poverty rate. For children under the age of 13, X_{ist} includes the same variables as for 15–18, with the addition of state total population, % population below the age of 25, and median income.

and Asian students; an indicator of overall socioeconomic status; an indicator for urban status; and the average and standard deviation of math and English scores at the district level over the period 2009–2022. We matched each treatment district to its nearest control using one-to-one nearest neighbor matching with a caliper of 1 to ensure similarity in covariates between matched pairs. Unmatched districts were excluded from the analysis. This approach ensures that any observed differences in outcomes between treated and control districts can be more reliably attributed to the policy intervention rather than pre-existing disparities. Figure A.1 illustrates the differences in covariates and academic outcomes at baseline (2009) after matching. The figure confirms that the matching procedure successfully achieved balance on key demographic and academic characteristics.

To examine dynamic treatment effects of SB 328 on academic performance, we estimate the following event-study specification at the district level:

$$y_{dst} = \alpha + \sum_{k \neq -1} \delta_k \cdot \mathbf{1}(t - T_d = k) + \gamma X_{ds} + \tau_t + \eta_p + \epsilon_{dst} \tag{3}$$

where y_{dst} denotes the average math or English score in district d, state s, and year t; $\mathbf{1}(t - T_d = k)$ is an indicator for event time k relative to the adoption year T_d of SB 328, omitting $k = -1$ as the reference period. The vector X_{ds} includes district-level covariates such as racial and ethnic composition, socioeconomic status, and urbanicity. The specification includes year fixed effects τ_t and matched pair fixed effects η_p, reflecting our one-to-one matched difference-in-differences design. This approach enables comparisons between districts with similar baseline characteristics and allows us to trace the evolution of academic outcomes around the time of policy implementation.

The event-study plot reports yearly effects for the period 2016–2024—years in which most states report comparable district-level data. However, the underlying estimation uses the full 2009–2024 sample to improve precision. This allows us to define event-time indicators relative to 2023 (the implementation year), while maintaining a stable reference period and minimizing extrapolation.

4 Results

4.1 Effects of SB 328 on sleep

The implementation of SB 328, which mandated later school start times for high school students in California, was intended to address chronic sleep deprivation among teenagers. This subsection presents evidence from two data sources—the Youth Risk Behavior Survey (YRBS) and the American Time Use Survey (ATUS)—on how the policy affected sleep behavior among high school students and teenagers aged 15–18. These analyses explore changes in both the duration and timing of sleep, providing a comprehensive picture of the policy's impact.

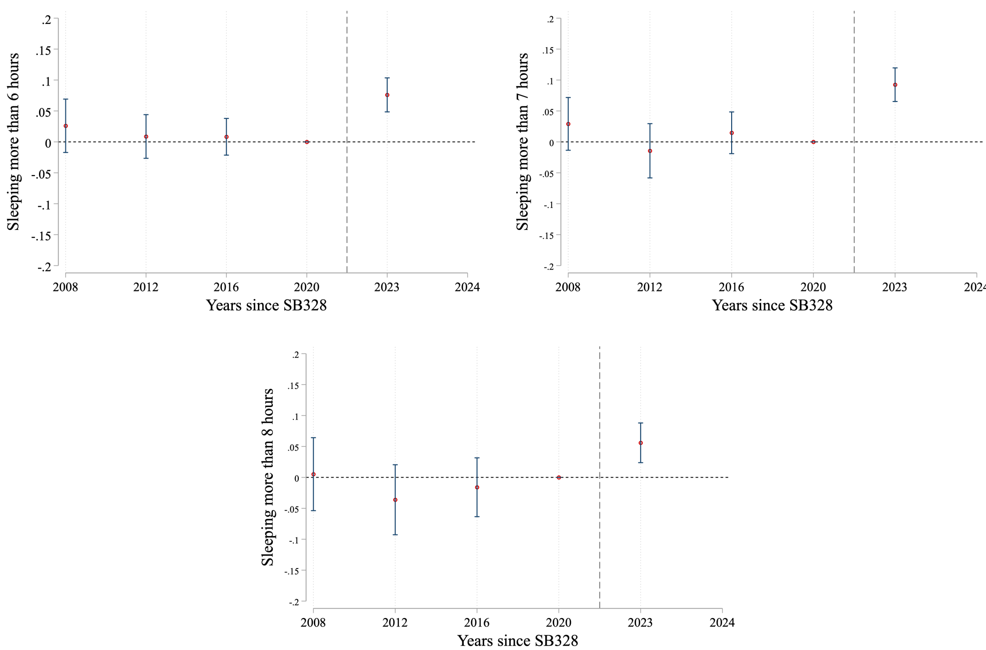
Table 1: Policy and Sleep Outcomes, YRBS (2007–2023)

	(1) Sleep $\geq$ 6 hours	(2) Sleep $\geq$ 7 hours	(3) Sleep $\geq$ 8 hours
CA SB 328	0.067***	0.070***	0.037**
	(0.017)	(0.017)	(0.017)
Observations	118,035	118,035	118,035
R-squared	0.024	0.037	0.037
Mean of dep. var.	0.792	0.558	0.271
Std. dev. of dep. var.	0.406	0.497	0.445

Notes: Data comes from the 2007-2023 national samples of the Youth Risk Behavior Survey (YRBS). Observations are weighted by population weights obtained from National Cancer Institute's SEER Program and assigned according to individual's state of residence, survey year, age, sex, and race. All specifications control for individual-level covariates (grade, race/ethnicity, sex) and state-level characteristics (population, population density, % households with children, marital status & education-related variables, unemployment rate, median household income, and child poverty rate). All regressions further include state and year fixed effects. Standard errors in parentheses, clustered at the state level. *** Significant at the 1% level ** Significant at the 5% level * Significant at the 10% level.

Table 1 reports the effects of the adoption of SB 328 on sleep behavior. The policy increased by 6.7 percentage points (8% with respect to the mean, $p < 0.01$) the share sleeping more than 6 hours, by 7 percentage points (13%, $p < 0.01$) the share sleeping more than 7 hours, and by 3.7 percentage points (14%, $p < 0.05$) the share of students sleeping more than 8 hours. Figure 1 reports the event-study, illustrating the difference in sleep among students in California and other states before and after the approval of SB 328. Reassuringly, there is no evidence of differential pre-trends, lending support to the parallel trends assumption. Overall, the event-study results corroborate the main difference-in-differences findings on sleep outcome, Table 1.

Figure 1: California SB 328 and Sleep and Mental Health, YRBS



Notes: The figure illustrates the differences in sleep behavior among students in California and other states before and after the adoption of SB 328. Data comes from the 2007-2023 national samples of the Youth Risk Behavior Survey (YRBS). Observations are weighted by population weights obtained from National Cancer Institute's SEER Program and assigned according to individual's state of residence, survey year, age, sex, and race. Survey years were pooled as follows: (1) 2008 combines 2007 & 2009; (2) 2012 combines 2011 and 2013; (3) 2016 combines 2015 and 2017; (4) 2020 combines 2019 and 2021; (5) 2023 stands on its own. Standard errors are clustered at the state level. Coefficient estimates are provided together with the 95% confidence intervals.

Table 2 Panel A restricts the analysis to high-school age ATUS respondents, focusing on individuals aged 15-18. We restrict the analysis to weekdays. In this group, there was a significant decline in the share of children awake at 6am (-95%, $p < 0.01$, column 1), 7am (-61%, $p < 0.01$, column 2), and 8am (-22%,$p < 0.01$, column 3). We also find significant later bedtime, especially after 10 pm(+36%, $p < 0.01$, columns 5). The overall increase in sleep hours is approximately 38 minutes ($p < 0.01$, column 7). The share of 15-18 years old sleeping at least 7 hours increased by 10.3 percentage points (+12%, $p < 0.01$, column 9), while the share sleeping at least 8 hours increased by 9.5 percentage points (+13%, $p < 0.05$ column 10).

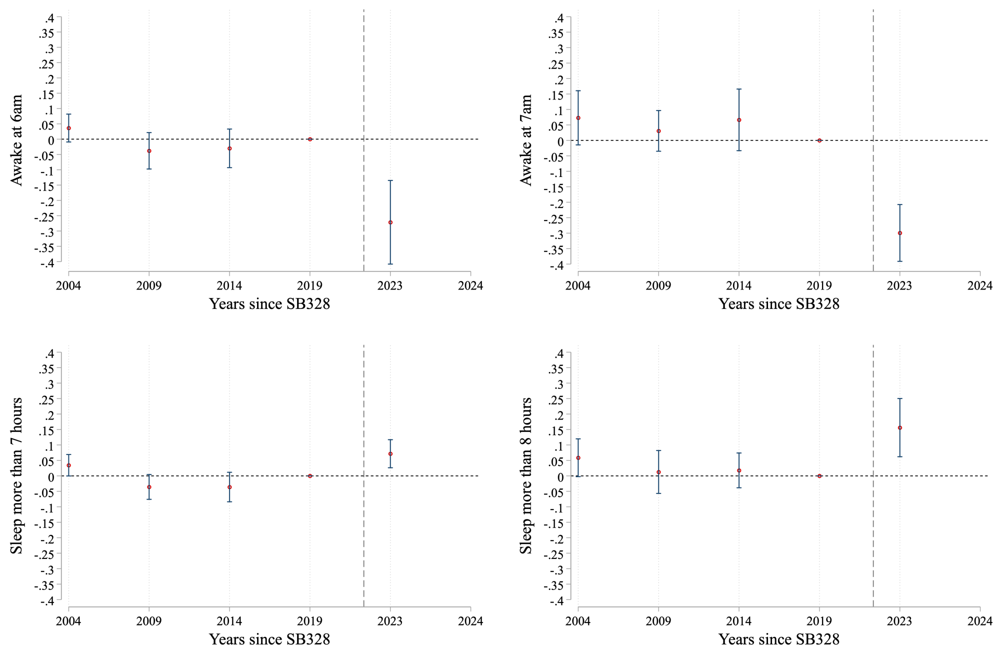
Table 2: SB 328, Wake-up Times and Sleep, Evidence from ATUS (2003–2023)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Wake-up time			Bedtime			Sleep			
	6am	7am	8am	after 9pm	after 10pm	after 11pm	sleep hours	sleep≥6	sleep≥7	sleep≥8
Panel A: Children aged 15–18										
CA SB 328	-0.267***	-0.358***	-0.154***	0.075*	0.130***	0.078*	0.625***	0.029	0.103***	0.095**
	(0.051)	(0.033)	(0.031)	(0.042)	(0.035)	(0.044)	(0.215)	(0.031)	(0.027)	(0.047)
Observations	5,822	5,822	5,822	5,822	5,822	5,822	5,822	5,822	5,822	5,822
R-squared	0.072	0.157	0.151	0.053	0.055	0.049	0.060	0.018	0.026	0.043
Mean of dep. var.	0.280	0.586	0.710	0.695	0.357	0.230	9.126	0.942	0.863	0.705
Std. dev. of dep. var.	0.449	0.493	0.454	0.460	0.479	0.421	2.343	0.234	0.344	0.456
Panel B: Children under 13 (Single-Child Households)										
CA SB 328	-0.081***	-0.095***	-0.023	0.073**	0.010	0.003	0.476***	0.059***	0.069***	0.113***
	(0.018)	(0.028)	(0.032)	(0.032)	(0.012)	(0.010)	(0.094)	(0.009)	(0.012)	(0.020)
Observations	11,939	11,939	11,939	11,939	11,939	11,939	11,939	11,939	11,939	11,939
R-squared	0.015	0.024	0.035	0.042	0.035	0.024	0.025	0.015	0.018	0.023
Mean of dep. var.	0.129	0.432	0.757	0.324	0.136	0.0668	9.648	0.964	0.937	0.875
Std. dev. of dep. var.	0.335	0.495	0.429	0.468	0.343	0.250	1.999	0.186	0.243	0.331

Notes: Data comes from the 2003–2023 American Time Use Survey (ATUS). Observations are weighted by population weights obtained from the National Cancer Institute's SEER Program and assigned according to individual's state of residence, survey year, age, sex, and race. Panel A restricts the analysis sample to children aged 15–18. Panel B restricts the sample to children under the age of 13 (and only considers households with a single child). All specifications control for state, year, and month fixed effects. Panel A regressions further control for individual-level covariates (age, sex, race/ethnicity) and state-level characteristics (% households with children, marital status & education-related variables, unemployment rate, and child poverty rate). Panel B regressions further control for individual-level covariates (race/ethnicity of the parent) and state-level characteristics (population, % households with children, marital status & education-related variables, unemployment rate, median household income, and child poverty rate). The analysis is restricted to weekdays. Standard errors in parentheses, clustered at the state level. *** Significant at the 1% level ** Significant at the 5% level * Significant at the 10% level.

Figure 2 reports the event-study, illustrating the difference in sleep among 15-18 individuals in California and other states before and after the approval of SB 328. Reassuringly, we do not see any evidence of a clear pre-trend, and overall confirm the results discussed in Table 2. Similarly, while some of the coefficients are significant when examining the outcomes of children under 13, the trend before 2022 is fairly flat, while we see some evidence of a decline in the share of children waking up early, and an increase in sleep duration (Figure 3).

Figure 2: California SB 328 and Sleep, ATUS (Children Aged 15-18)

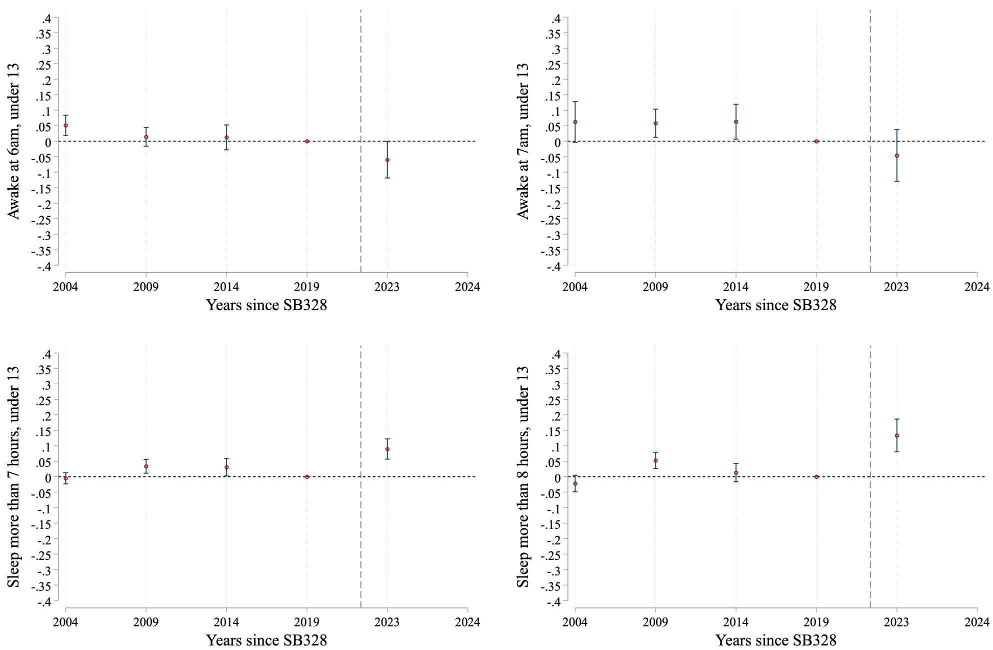


Notes: The figure illustrates the differences in sleep behavior among students in California and other states before and after the adoption of SB 328. Data comes from the 2003-2023 American Time Use Survey (ATUS). Observations are weighted by population weights obtained from National Cancer Institute's SEER Program and assigned according to individual's state of residence, survey year, age, sex, and race. Survey years were pooled as follows: (1) 2004 combines 2003-2006; (2) 2009 combines 2007-2011; (3) 2014 combines 2012-2016; (4) 2019 combines 2017-2021; (5) 2023 combines 2022 & 2023. Standard errors are clustered at the state level. Coefficient estimates are provided together with the 95% confidence intervals.

Using data from the American Time Use Survey on the time that the first household child under the age of 13 woke up for the day, we examine the impact of the policy on children wake-up times restricted to household with only one child (Panel B of Table 2).[6] As for

[6]Table A.3 reports results obtained including any household with at least one child under the age of 13. Results are substantially similar. Furthermore, in Table A.4, we report results obtained when excluding observation with an imputed sleep shorter than 2 or larger than 15 hours. Again results are largely consistent.

Figure 3: California SB 328 and Sleep, ATUS (Children Under 13)



Notes: The figure illustrates the differences in sleep behavior among students in California and other states before and after the adoption of SB 328. Data comes from the 2003-2023 American Time Use Survey (ATUS). Observations are weighted by population weights obtained from National Cancer Institute's SEER Program and assigned according to individual's state of residence, survey year, age, sex, and race. Survey years were pooled as follows: (1) 2004 combines 2003-2006; (2) 2009 combines 2007-2011; (3) 2014 combines 2012-2016; (4) 2019 combines 2017-2021; (5) 2023 combines 2022 & 2023. Standard errors are clustered at the state level. Coefficient estimates are provided together with the 95% confidence intervals.

Panel A, the analysis is restricted to weekdays. Children were significantly less likely to be awake before 6am. Specifically, since the adoption of the policy children under the age of 13 were 8.1 percentage points less likely to be awake before 6 am (-63%, $p < 0.01$, column 1, Panel B) and 9.5 percentage point before 7 am (-22%, $p < 0.01$, column 2, Panel B). As expected, given that the legislation mandates that California middle schools start no earlier than 8:00 a.m., while high schools begin no earlier than 8:30 a.m, we find no evidence of a significant effect on the likelihood to be awake before 8am. We find significant positive effect for later bed time after 9(+23%, $p < 0.05$, column 4, Panel B)

We then construct measures of sleep duration using assuming wake-up time and bedtime refer to the same individual restricted to household with only one child. We find some evidence of a change in sleep duration, increasing by approximately 29 minutes on average ($p < 0.01$, column 7, Panel B). There is also a 7 percentage point increase in the share of children sleeping more than 7 hours (a 7% increase with respect to the mean, $p < 0.01$ column 9) and a 11.3 percentage point increase in sleeping more than 8 hours (+13%, $p < 0.01$ column 10).

4.2 Effects on mental well-being

Adolescents face unique challenges related to sleep deprivation (Haidt, 2024), which is often exacerbated by early school start times that misalign with their biological rhythms (Wheaton et al., 2016; Chan et al., 2024). Insufficient sleep has been consistently linked to poor mental health outcomes, including increased levels of sadness, hopelessness, and even suicidal ideation (Scott et al., 2021). Aligning school schedules with adolescents' natural sleep patterns has been shown to improve sleep quality and duration, which in turn supports better mental health and overall well-being.

The Youth Risk Behavior Survey (YRBS) provides valuable insights into the impact of California's Senate Bill 328 (SB 328) on students' mental health and well-being (Table 3). We find some evidence of a decline in the likelihood of reporting any difficulty concentrating or in

Table 3: SB328 and Mental Health, YRBS (2007-2023)

	(1) Difficulty concentrating	(2) Felt sad/hopeless	(3) Suicidal intentions
CA SB 328	-0.054*	-0.024	-0.013
	(0.027)	(0.015)	(0.011)
Observations	48,199	134,396	119,283
R-squared	0.053	0.067	0.030
Mean of dep. var.	0.389	0.319	0.181
Std. dev. of dep. var.	0.487	0.466	0.385

Notes: Data comes from the 2007-2023 national samples of the Youth Risk Behavior Survey (YRBS). Observations are weighted by population weights obtained from National Cancer Institute's SEER Program and assigned according to individual's state of residence, survey year, age, sex, and race. All specifications control for individual-level covariates (grade, race/ethnicity, sex) and state-level characteristics (population, population density, % households with children, marital status & education-related variables, unemployment rate, median household income, and child poverty rate). All regressions further include state and year fixed effects. Standard errors in parentheses, clustered at the state level. *** Significant at the 1% level ** Significant at the 5% level * Significant at the 10% level.

making decisions because of physical or mental health conditions (-14%, $p < 0.10$, column 1). However, the event-study analysis reveals little evidence of statistically significant effects on these outcomes. There is no evidence of significant effects on sadness and suicidal intentions, although the estimated effects on sadness and suicide attempts are directionally negative.

These findings suggest that later school start times, as mandated by SB 328, may offer modest mental health benefits, including potential improvements in concentration and decision-making. Although we do not find significant effects on sadness and suicidal ideation, the direction of the estimates is broadly consistent with a possible decline in depressive symptoms, warranting further investigation. Furtheremore, as discussed below, we do find evidence of significant impacts on the mental health of boys and Hispanics.

4.3 Effects on academic outcomes

We then turn to analyzing the effects of delayed school start times on academic outcomes. The SEDA data allow us to examine English and math scores for students in grades 3–8.

Columns 1 and 2 report estimates from a two-way fixed effects model assessing the impact of SB 328 implementation in California. Math scores in 2023 and 2024 increased by approximately 0.11 standard deviations (column 1, $p < 0.01$), while English (ELA) scores increased by 0.13 standard deviations (column 2, $p < 0.01$). Columns 3 and 4 present results from our matched difference-in-differences (DID) approach, in which California school districts are matched to demographically and economically similar districts in other states that did not adopt similar policies. Using this approach, we find slightly larger effects on math scores, which increased by 0.17 standard deviations column 3, $p < 0.01$), and also same effects on English scores, which rose by 0.15 standard deviations (column 4, $p < 0.05$). These academic gains are more pronounced among Hispanic students and economically disadvantaged students. We explore these patterns in greater detail in the following sections.

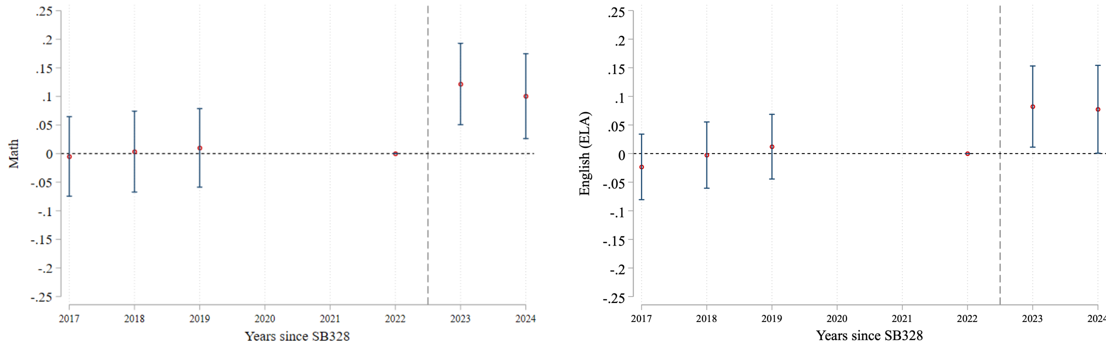
Table 4: CA SB 328 and School Performance

	(1) TWFE Sample *Math*	(2) TWFE Sample *English*	(3) Matched DID Sample *Math*	(4) Matched DID Sample *English*
CA SB 328	0.110*** (0.012)	0.131*** (0.011)	0.169*** (0.027)	0.149*** (0.027)
District Pair FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Observations	172,530	173,747	8,405	8,470

Notes: Data comes from the Stanford Education Data Archive (SEDA-2024), with observations from 2009 to 2024. All estimates include controls for the share of Hispanics, share of Whites, and the urban status of the district. All observations are weighted by the total population of students enrolled in the district. Standard errors in parentheses, clustered at the state level. *** Significant at the 1% level ** Significant at the 5% level * Significant at the 10% level.

Figure 4 documents how the average differences in both math and English scores between California school districts are non-significant or marginal before 2022. The data from 2020 and 2021 were not included because of the COVID-19 pandemic.

Figure 4: Effects of SB 328 on Academic Outcomes



Notes: Data are drawn from SEDA-2024 (2009–2024). All estimates include controls for year and district-pair fixed-effects, share of Hispanics, and share of Whites, and urban status of the district. All estimates are weighted by the total population of students enrolled in the district. Standard errors are clustered at the state level. Coefficient estimates are provided together with the 95% confidence intervals.

To further assess the academic impacts of SB328, we examined its effects on SAT scores for high school seniors, disaggregating total scores, math scores, and evidence-based reading and writing (ERW) scores. The results, presented in Table 5, indicate significant improvements across all measures of SAT performance. The implementation of SB 328 is associated with a statistically significant increase of 25 points in total SAT scores (0.26 standard deviations), representing a 2% gain relative to the mean ($p < 0.01$).. This substantial improvement highlights the potential for delayed school start times to positively influence college-readiness assessments. Disaggregating SAT scores into subject-specific components reveals that SB328 contributed to an increase of 11 points in math scores and $\approx$ 13 points in evidence-based reading and writing scores, both statistically significant at the $p < 0.01$ level. These effects demonstrate that the policy supports student performance across key academic domains. The magnitude of these improvements suggests that SB328 has a meaningful impact on high school students' standardized testing outcomes, which are critical for college admissions.

4.4 Robustness checks

To evaluate the robustness of our findings, we conduct a permutation test by randomly assigning the policy adoption year to other states that did not implement the policy (Figure 5).

Table 5: CA SB 328 and High School Seniors SAT Scores

	(1) SAT	(2) Math	(3) Evidence-based reading and writing score
CA SB 328	24.987***	10.673***	13.313***
	(4.793)	(2.288)	(2.535)
Observations	204	204	204
Mean of Dep. Var.	1112	549.7	562.3
Std. dev.	95.05	49.49	45.87

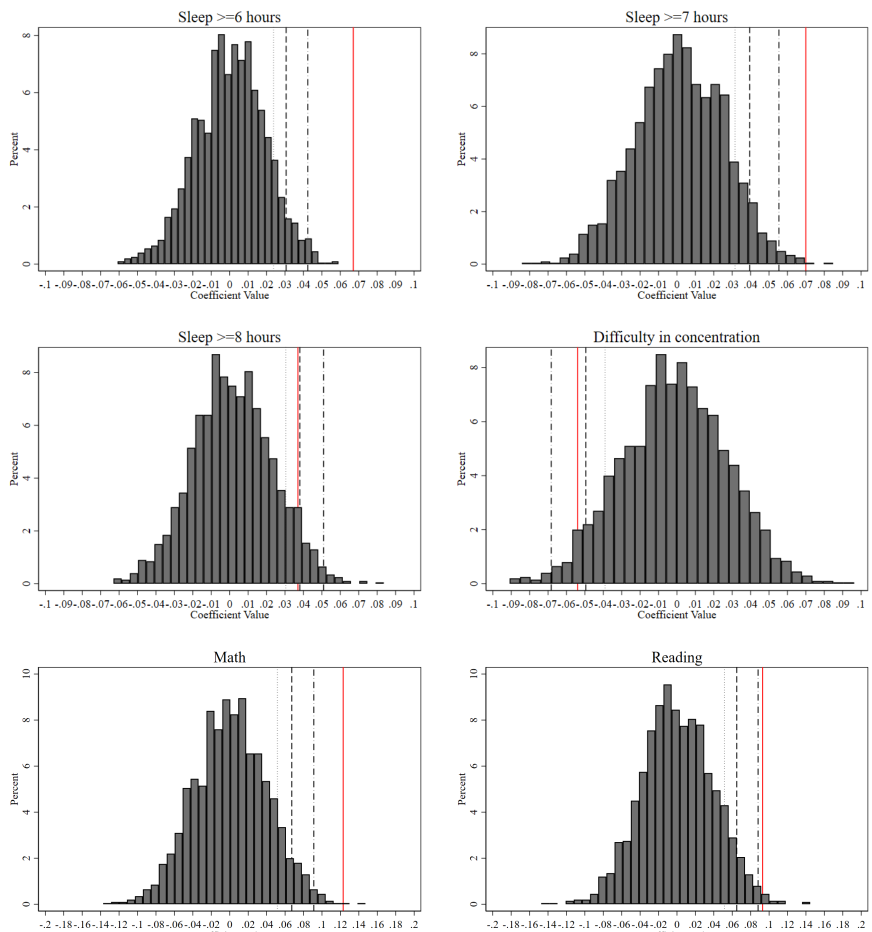
Notes: Data on SAT scores were published by the College Board. Data include 50 US states and Washington, D.C., for the years 2018, 2021, 2022, and 2023. All estimates include state and year fixed effects. Standard errors in parentheses,clustered at the state level. *** Significant at the 1% level ** Significant at the 5% level * Significant at the 10% level.

For each random assignment, we re-estimate the treatment effect, generating a distribution of placebo treatment effects under these simulated scenarios. This approach allows us to test whether the observed effect in California is likely driven by the policy itself or could plausibly arise due to random chance or unobserved confounding factors.

We limit the analysis to outcomes that showed statistically significant effects in our baseline results. Permutation tests for sleep duration confirm that the policy had a robust impact across several sleep thresholds. For individuals sleeping at least 6 or 7 hours, the estimated treatment effects lie in the lower tail of the placebo distribution, exceeding the 1% significance threshold—indicating a strong and consistent effect on reducing short sleep deficits. For those sleeping at least 8 hours, the effect falls just below the 5% threshold, suggesting a somewhat weaker but still meaningful impact. For reported difficulties concentrating due to mental health issues, the estimated treatment effect also exceeds the 5% significance threshold, reinforcing the policy's potential mental health benefits.

The policy significantly improved academic performance. For both math and English, the observed treatment effect exceeds the 1% significance threshold, indicating a robust and meaningful impact on student performance. In the Appendix, we report the permutation tests for the other outcomes studied (Figures A.3 and A.2), which largely confirm the results

Figure 5: Permutation Tests



Notes: The figure illustrates the results of permutation tests for various outcomes, where the policy adoption year was randomly reassigned to other states to create placebo scenarios. The red vertical line represents the observed treatment effect, while the dashed lines indicate the 1%, 5%, and 10% significance thresholds derived from the placebo distribution. By comparing the observed effect to the distribution of placebo effects, the test evaluates whether the observed policy effect is statistically significant or could plausibly arise by random chance. Outcomes with observed effects beyond the dashed lines suggest a significant and likely causal policy impact. For academic outcomes we use the SEDA 2024 district-level data. Standard errors are clustered at the state level.

presented in Table 2.

Overall, the permutation exercise strengthens confidence in the causal interpretation of the observed effects, as the policy's impacts on sleep, mental health, and academic outcomes are statistically significant and unlikely to arise by chance.

5 Heterogeneity

5.1 Effects by gender

Table A.5 reports the heterogeneity of the effects on sleep and mental wellbeing by gender using YRBS data. Panel A reports the effects among girls. Panel B reports the effects among boys. While both among girls and boys we find evidence that sleep increased, the effects are larger among boys. Specifically, the adoption of SB-328 led to a 6.9 percentage point increase in the likelihood of sleeping at least 6 hours among girls in grades 9-12 (+9%, $p < 0.01$, column 1); a 5.2 percentage increase in the likelihood of sleeping at least 7 hours (+10%, $p < 0.05$, column 2); and a non-statistically significant 3.2 percentage increase in the likelihood of sleeping at least 8 hours (column 3). We also find evidence of a 5.5 percentage point decline in the likelihood they reported difficulties in making decisions or concentrating because of physical or mental health problems (-12%, $p < 0.10$, column 4) and non-statistically significant 3.4 percentage point decline (column 5) in the likelihood of reporting feelings of sadness and hopelessness. There is no evidence of a decline in suicidal intentions.

Effects on sleep appear significantly larger among boys (Panel B). Specifically, the adoption of SB-328 led to a 6.8 percentage point increase in the likelihood of sleeping at least 6 hours among boys in grades 9-12 (+8.4%,$p < 0.01$, column 1); a 8.6 percentage increase in the likelihood of sleeping at least 7 hours (+15%, $p < 0.01$, column 2); and a 4.1 percentage increase in the likelihood of sleeping at least 8 hours (+14%, $p < 0.01$, column 3). Turning to mental wellbeing, we find evidence of a significant 5.6 percentage decline in the likelihood of reporting difficulties concentrating among boys (-19%, Panel B, column 4). We estimate a 2.3 percentage point decline in the likelihood of reporting feelings of sadness and hopelessness (-10%, $p < 0.05$, column 5). There is also a significant decline of 3.8 percentage points in suicidal intentions (-31%, $p < 0.01$, column 6).

Gender differences are less pronounced when examining time-use data. Table A.6 analyzes gender differences in the effects of SB 328 on wake times, bedtimes, and sleep outcomes for children aged 15–18, using ATUS data from 2003–2023. Panel A presents results for girls, and Panel B for boys Among female respondents aged 15–18, there was a significant decline in the likelihood of being awake at 6am by 33 percentage points ($p < 0.01$, column 1). There is also evidence of negative effects on the likelihood of being awake at 7am or 8am (-25 and -13 percentage point, respectively). For bedtimes, there is evidence of later bedtime with a significant decrease of 14 percentage points after 9pm (-20%, $p < 0.01$, column 4), and a significant 11 percentage point decrease of bedtime after 11pm (-47%, $p < 0.01$, column 6). This result suggests that girls are more likely to compensate for the later wake-up time with the later bedtime, as a result of the policy.

Overall, the changes in wake and sleep times still resulted in a highly significant increase in sleep duration. On average, female respondents experienced an increase of one hour (+11%, $p < 0.01$, column 7) in total sleep hours, with a statistically significant 5 percentage point increase in the likelihood of sleeping at least 6 hours (+5%, $p < 0.1$, column 8). Furthermore, the likelihood of sleeping at least 8 hours rose by 40 percentage points (+57%, $p < 0.01$, column 10).

Male respondents in the same age group also experienced significant declines in early wake times (Panel B). The likelihood of being awake at 6am fell by 25 percentage points (-91% ,$p < 0.01$, column 1), while the likelihood of being awake at 7am declined by 46 percentage points (-77%, $p < 0.01$, column 2). There is also evidence of significant negative changes in the likelihood of being awake at 8am. We also find evidence that boys were 32% more likely to go to bed after 9pm ($p < 0.01$, column 4), and also significant increasing effects on bedtimes after 10pm and 11pm (+25 and 21 percentage points respectively, columns 5-6). The changes in wake and bedtime patterns resulted in an insignificant marginal increase in overall sleep duration among boys. However, the likelihood of sleeping at least 7 hours increased by 15 percentage points (+17%, $p < 0.01$, column 9). There is instead no significant effect on the likelihood of reporting at least 8 hours of sleep.

In Table A.9, we find overall similar results for boys and girls, although if anything the coefficient on boys are sligthly larger for both math and English scores (columns 2 and 3).

5.2 Heterogeneity by ethnicity

Given that Hispanic students represent the largest ethnic group in California's public school system and represent 56% of the population, examining the effects of SB 328 on this population is especially relevant to understand the broader implications and impacts of equity.

Among Hispanic students (Panel A) using samples from the YRBS in Table A.7, the likelihood of sleeping at least 6 hours increased by 5.7 percentage points (7%, $p < 0.1$, column 1). Similarly, the likelihood of sleeping at least 7 hours increased by 4 percentage points (+7%, $p < 0.01$, column 2). The likelihood of reporting difficulties concentrating decreased by 9.9 percentage points (-25%, $p < 0.01$, column 4). There was instead no evidence of a significant impact feelings of sadness/hopelessness or on suicidal intentions. Although the effects among Whites are marginally larger on sleep, we find smaller effects among Whites on the likelihood of reporting difficulties in concentration due to mental health challenges. Instead there is a marginally significant effect on the declining likelihood of reporting feelings of sadness or hopelessness at 3.1 percentage point (-10%, $p < 0.1$, column 5).

The effects were slightly larger among White children who were 8 percentage points more likely to sleep at least 6 hours (+10%, $p < 0.01$, column 1), 9.3% more likely to sleep at least 7 hours (+16%, $p < 0.01$, column 2), and 5.6% more likely to sleep at least 8 hours (+20%, $p < 0.05$, column 3). There is instead no evidence of significant effects among other groups (Panel C).

Table A.8 reports the effects of SB 328 on wake times, bedtimes, and sleep outcomes for children aged 15–18, disaggregated for Hispanics and Whites, using ATUS data from 2003–2023.

Hispanic respondents exhibited significant declines in early wake times. The likelihood of being awake at 6am decreased by 44 percentage points ($p < 0.01$, column 1), the likelihood of being awake at 7am decreased by 67 percentage points ($p < 0.01$, column 2), and the likelihood of waking up at 8am also decreased by 11 percentage points ($p < 0.1$, column 3). The likelihood of sleeping at least 7 hours increased by 18 percentage points (+21%, $p < 0.01$ column 9), and the likelihood of sleeping at least 8 hours increased by 40 percentage points (+55%, $p < 0.01$, column 10).

White respondents also experienced significant declines in early wake times. The likelihood of being awake at 6am decreased by 30 percentage points ($p < 0.01$, column 1), and the likelihood of being awake at 7am decreased by 42 percentage points (-70%, $p < 0.01$, column 2). There is also a decline of 21 percentage point of the likelyhood in wakefulness at 8am (-29%, $p < 0.01$, column 3). The likelihood of bedtime after 10pm increased by 14 percentage points (+41%, $p < 0.01$ column 5) and after 11pm increased by 13 percentage point (+58%, $p < 0.01$ column 6), suggesting slightly later bedtimes. There was a 40 minutes increase in the overall sleep duration (+7%, $p < 0.01$ column 7), and the likelihood of sleeping at least 7 hours increased by 11 percentage points (+12%, $p < 0.01$, column 9).

We also find that the effects on math and English score are higher among Hispanics (column 4, Table A.9). These academic improvements mirror the patterns observed in sleep and mental health outcomes. Hispanic students—who experienced the largest increases in sleep duration and reductions in concentration difficulties—also saw the greatest academic gains. This reinforces the idea that improvements in foundational health behaviors like sleep can help advance educational equity. Consistent with this, Column 6 shows that economically disadvantaged students (as classified by eligibility for free or reduced-price lunch in SEDA) also benefited significantly from SB 328.

6 Conclusions

This study provides the first comprehensive evaluation of California's Senate Bill 328 (SB 328), a statewide mandate delaying school start times for middle and high schools, on adolescent sleep, mental health, and academic outcomes.

Our findings show that SB 328 significantly increased the proportion of students achieving sufficient sleep, better aligning student sleep patterns with CDC recommendations. Beyond sleep, we find suggestive evidence of mental health improvements—particularly among boys and Hispanic students—who exhibit statistically significant declines in reported sadness, hopelessness, and suicidal ideation. These results are consistent with the view that improved sleep may contribute to adolescent emotional well-being.

The policy also positively impacted academic performance. Younger students in grades 3–8 experienced meaningful gains in math and English scores. High school seniors also benefited, showing improvements in SAT scores across math and evidence-based reading and writing sections. These findings indicate that the policy not only enhances cognitive functioning but also better equips students for college admissions and long-term academic success.

The policy's impact varied across sociodemographic groups. Hispanic and disadvantaged students saw the largest academic gains, accompanied by improvements in sleep and mental health outcomes, such as better concentration and reduced sadness.

Future research could examine the policy's effects on family dynamics, extracurricular activities, and long-term health and economic outcomes. Furthermore, the post-implementation data may not fully capture long-term effects or potential unintended consequences. Future work should look into the potential effects on college enrollment. Furthermore, future studies may delve deeper into the effects the policy may have on commuting times and parental schedules. This study underscores the potential of systemic policies like SB328 in improving adolescent health and educational outcomes. By aligning school schedules with biological sleep patterns, the policy demonstrates how targeted reforms can lead to meaningful improvements in student well-being and performance across multiple dimensions. Our findings provide valuable insights for policymakers, particularly as other states prepare to implement similar initiatives.

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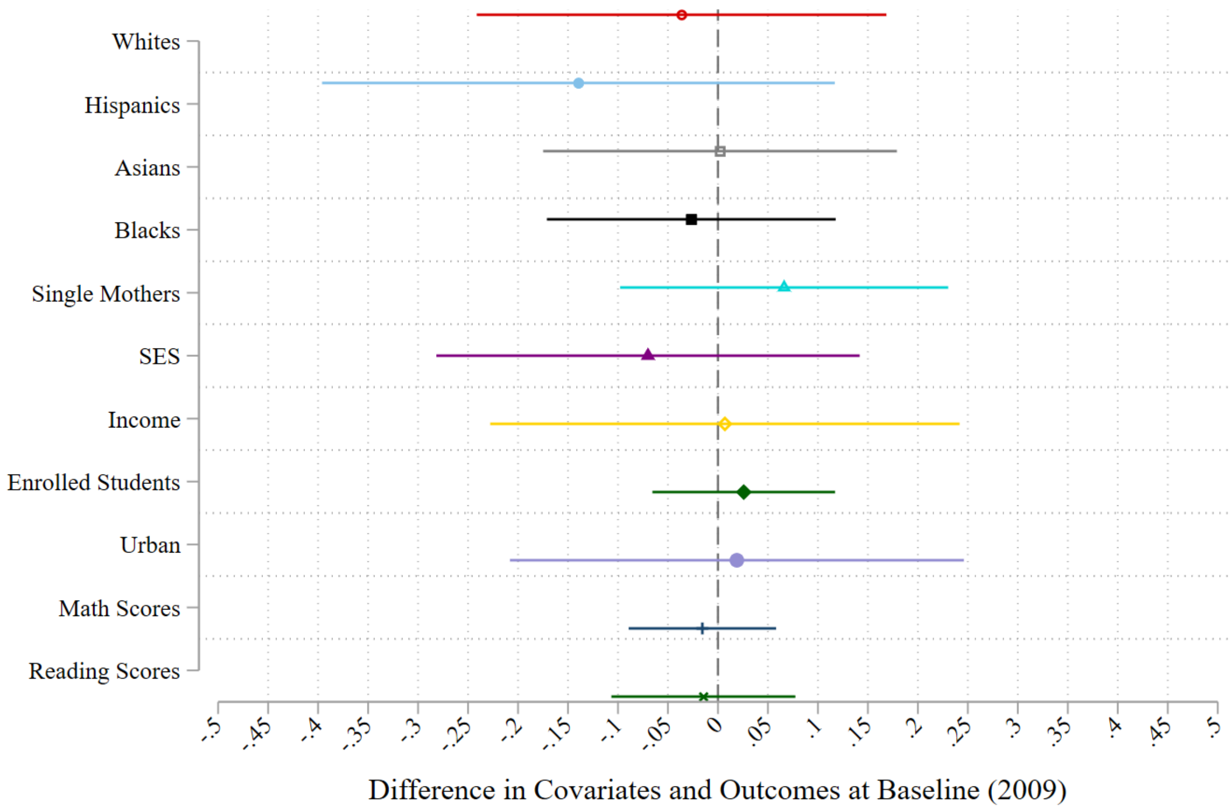
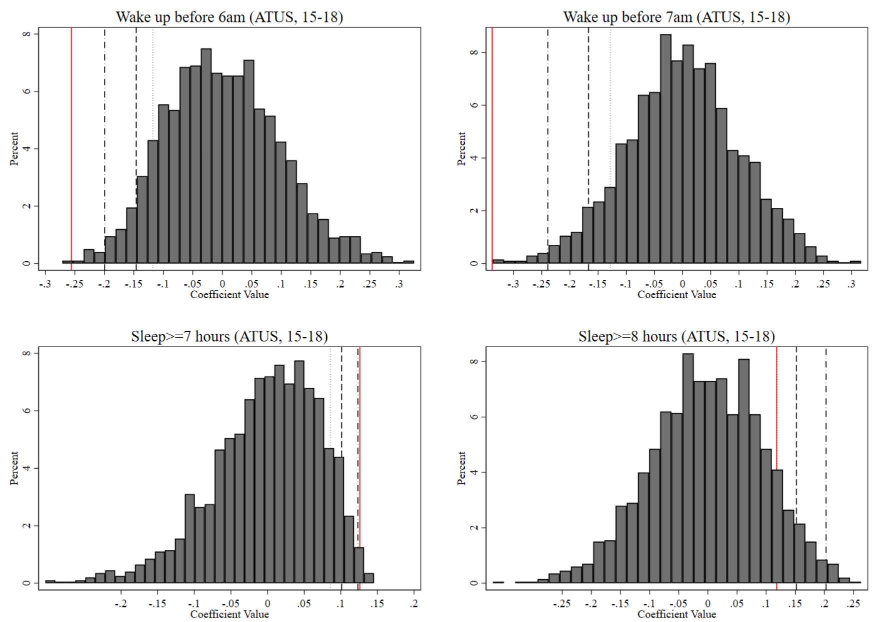
Appendix

Figure A.1: Balance, SEDA 2024, Covariates and Outcomes at Baseline, After Matching



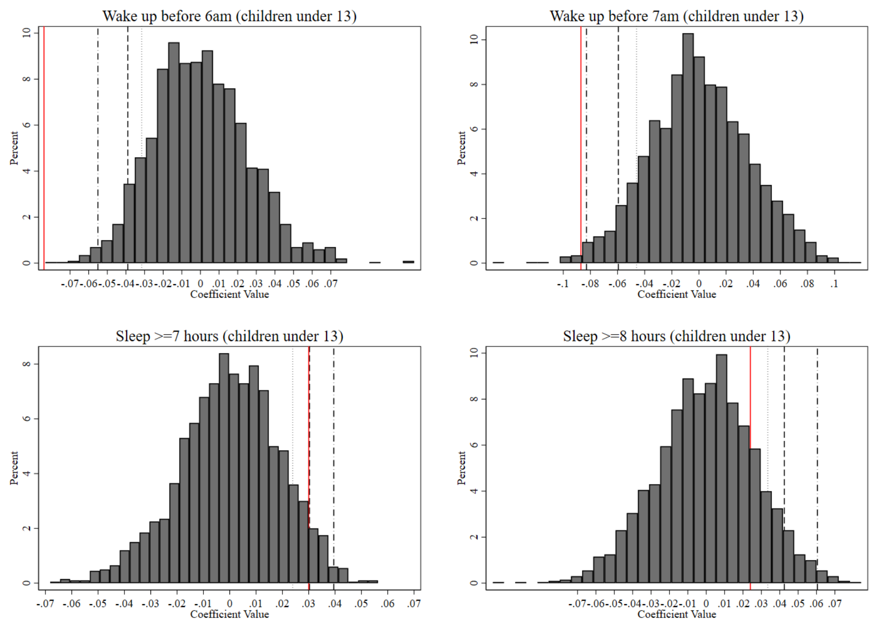
Notes: Data comes from the Stanford Education Data Archive (SEDA-2024). The figure illustrates the differences in covariates and outcomes from the SEDA 2024 data at baseline (2009) after matching as discussed in Section 3.2. All the variables are standardized.

Figure A.2: Permutation Tests, ATUS (2003-2023), Children Aged 15-18



Notes: The figure illustrates the results of permutation tests for various outcomes from ATUS respondents aged 15-18, where the policy adoption year was randomly reassigned to other states to create placebo scenarios. The red vertical line represents the observed treatment effect, while the dashed lines indicate the 1%, 5%, and 10% significance thresholds derived from the placebo distribution. By comparing the observed effect to the distribution of placebo effects, the test evaluates whether the observed policy effect is statistically significant or could plausibly arise by random chance. Outcomes with observed effects beyond the dashed lines suggest a significant and likely causal policy impact. For academic outcomes we use the SEDA 2024 district-level data. Standard errors are clustered at the state level.

Figure A.3: Permutation Tests, ATUS (2003-2023), Children Under 13



Notes: The figure illustrates the results of permutation tests for various outcomes from ATUS respondents under the age of 13, where the policy adoption year was randomly reassigned to other states to create placebo scenarios. The red vertical line represents the observed treatment effect, while the dashed lines indicate the 1%, 5%, and 10% significance thresholds derived from the placebo distribution. By comparing the observed effect to the distribution of placebo effects, the test evaluates whether the observed policy effect is statistically significant or could plausibly arise by random chance. Outcomes with observed effects beyond the dashed lines suggest a significant and likely causal policy impact. For academic outcomes we use the SEDA 2023 district-level data. Standard errors are clustered at the state level.

Table A.1: Summary Statistics - YRBS (2007–2023)

	Mean	Std. Dev.	N
Covariates			
Age categories	5.00	1.25	139,021
Female	0.50	0.50	139,703
Asian	0.04	0.20	139,703
Black	0.16	0.36	139,703
Hispanic	0.25	0.44	139,703
White	0.45	0.50	139,703
Outcomes			
Sleep $\geq$ 6 hours	0.79	0.41	120,919
Sleep $\geq$ 7 hours	0.56	0.50	120,919
Sleep $\geq$ 8 hours	0.27	0.44	120,919
Concentration difficulties	0.39	0.49	49,362
Sadness/hopelessness feelings	0.32	0.47	137,950
Suicidal intentions	0.18	0.39	122,451

Notes: Summary statistics reported for the full YRBS sample (2007–2023), including main covariates and mental health outcomes. Age categories are coded from 1 ($\leq$12 years) to 7 ($\geq$18 years). Outcomes are based on self-reported responses.

Table A.2: Summary Statistics - ATUS (2003–2023)

Panel A: Children aged 15–18	Mean	Std. Dev.	N
Wake up before 6am	0.28	0.45	5,823
Wake before 7am	0.59	0.49	5,823
Wake up before 8am	0.71	0.45	5,823
Bedtime after 10pm	0.70	0.46	5,823
Bedtime after 11pm	0.36	0.48	5,823
Bedtime after 12am	0.23	0.42	5,823
Sleep hours	9.13	2.34	5,823
Sleep more than 6 hours	0.94	0.23	5,823
Sleep more than 7 hours	0.86	0.34	5,823
Sleep more than 8 hours	0.70	0.46	5,823
Panel B: Children under 13			
Wake up before 6am	0.13	0.33	11,942
Wake before 7am	0.43	0.50	11,942
Wake up before 8am	0.76	0.43	11,942
Bedtime after 9pm	0.32	0.47	11,942
Bedtime after 10pm	0.14	0.34	11,942
Bedtime after 11pm	0.07	0.25	11,942
Sleep hours	9.65	2.00	11,942
Sleep more than 6 hours	0.96	0.19	11,942
Sleep more than 7 hours	0.94	0.24	11,942
Sleep more than 8 hours	0.88	0.33	11,942

Notes: Summary statistics reported for the full ATUS sample (2003–2023) for key sleep-related outcomes. Panel A shows results for children aged 15–18. Panel B presents both wake/bedtime patterns (N = 11,942) and sleep duration measures (N = 11,942) for children under 13, based on parental reports and linked child-level sleep data.

Table A.3: Wake-up Times and Sleep, Children Under 13, All Households, ATUS (2003–2023)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Wake-up time			Bedtime			Sleep			
	6am	7am	8am	after 9pm	after 10pm	after 11pm	sleep hours	sleep≥6	sleep≥7	sleep≥8
CA SB 328	-0.018	-0.014	0.007	0.048***	0.018	0.004	0.117**	0.029***	0.012	0.027**
	(0.011)	(0.026)	(0.021)	(0.017)	(0.012)	(0.009)	(0.048)	(0.004)	(0.015)	(0.011)
Observations	40,674	40,674	40,674	40,674	40,674	40,674	40,674	40,674	40,674	40,674
R-squared	0.014	0.047	0.077	0.066	0.040	0.025	0.036	0.013	0.015	0.021
Mean of dep. var.	0.144	0.508	0.812	0.374	0.155	0.0710	9.288	0.960	0.922	0.840
Std. dev. of dep. var.	0.352	0.500	0.391	0.484	0.362	0.257	1.969	0.197	0.268	0.367

Notes: Data comes from the 2003–2023 American Time Use Survey (ATUS). Observations are weighted by population weights obtained from the National Cancer Institute's SEER Program and assigned according to individual's state of residence, survey year, age, sex, and race. Estimation sample comprises children under 13 (including those from households with more than one child). All specifications control for state/year/month fixed effects, individual-level covariates (race/ethnicity of the parent) and state-level characteristics (population, % households with children, marital status & education-related variables, unemployment rate, median household income, and child poverty rate). The analysis is restricted to weekdays. Standard errors in parentheses, clustered at the state level. *** Significant at the 1% level ** Significant at the 5% level * Significant at the 10% level.

Table A.4: Robustness Check for SB 328, Wake-up Times and Sleep, Evidence from ATUS (2003–2023), No Outliers

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Wake-up time			Bedtime			Sleep			
	6am	7am	8am	after 9pm	after 10pm	after 11pm	sleep hours	sleep≥6	sleep≥7	sleep≥8
Panel A: Children aged 15–18										
CA SB 328	-0.254***	-0.345***	-0.145***	0.082*	0.142***	0.091**	0.448**	0.013	0.087***	0.083*
	(0.047)	(0.034)	(0.032)	(0.043)	(0.035)	(0.037)	(0.174)	(0.017)	(0.019)	(0.045)
Observations	5,718	5,718	5,718	5,718	5,718	5,718	5,718	5,718	5,718	5,718
R-squared	0.073	0.158	0.151	0.055	0.057	0.051	0.066	0.018	0.026	0.043
Mean of dep. var.	0.282	0.593	0.719	0.703	0.359	0.230	9.027	0.943	0.863	0.702
Std. dev. of dep. var.	0.450	0.491	0.450	0.457	0.480	0.421	2.117	0.232	0.344	0.457
Panel B: Children under 13										
CA SB 328	-0.074***	-0.091***	-0.038	0.078**	0.012	0.005	0.275**	0.051***	0.061***	0.106***
	(0.019)	(0.029)	(0.030)	(0.036)	(0.014)	(0.011)	(0.124)	(0.011)	(0.011)	(0.019)
Observations	11,788	11,788	11,788	11,788	11,788	11,788	11,788	11,788	11,788	11,788
R-squared	0.014	0.025	0.037	0.041	0.032	0.021	0.025	0.013	0.015	0.020
Mean of dep. var.	0.122	0.428	0.757	0.320	0.130	0.0601	9.682	0.972	0.945	0.882
Std. dev. of dep. var.	0.327	0.495	0.429	0.467	0.336	0.238	1.702	0.165	0.229	0.323

Notes: Data comes from the 2003–2023 American Time Use Survey (ATUS). Observations with sleep hours below 2 and above 15 are dropped as outliers. Observations are weighted by population weights obtained from the National Cancer Institute's SEER Program and assigned according to individual's state of residence, survey year, age, sex, and race. Panel A restricts the analysis sample to children aged 15–18. Panel B restricts the sample to children under the age of 13. All specifications control for state, year, and month fixed effects. Panel A regressions further control for individual-level covariates (age, sex, race/ethnicity) and state-level characteristics (% households with children, marital status & education-related variables, unemployment rate, and child poverty rate). Panel B regressions further control for individual-level covariates (race/ethnicity of the parent) and state-level characteristics (population, % households with children, marital status & education-related variables, unemployment rate, median household income, and child poverty rate). The analysis is restricted to weekdays. Standard errors in parentheses, clustered at the state level. *** Significant at the 1% level ** Significant at the 5% level * Significant at the 10% level.

Table A.5: SB 328, Wake-up Times and Sleep by Gender, Evidence from YRBS

	(1) Sleep ≥ 6	(2) Sleep ≥ 7	(3) Sleep ≥ 8	(4) Difficulty concentrating	(5) Felt sad/hopeless	(6) Suicidal intentions
Girls						
CA SB 328	0.069***	0.052**	0.032	-0.055*	-0.034	0.011
	(0.018)	(0.022)	(0.020)	(0.031)	(0.034)	(0.021)
Observations	59,288	59,288	59,288	24,144	67,424	59,782
R-squared	0.020	0.028	0.025	0.047	0.045	0.016
Mean of dep. var.	0.778	0.532	0.253	0.478	0.411	0.239
Std. dev. of dep. var.	0.416	0.499	0.435	0.500	0.492	0.426
Boys						
CA SB 328	0.068***	0.086***	0.041**	-0.056*	-0.023**	-0.038***
	(0.019)	(0.021)	(0.019)	(0.029)	(0.011)	(0.009)
Observations	58,747	58,747	58,747	24,055	66,972	59,501
R-squared	0.028	0.043	0.046	0.014	0.019	0.008
Mean of dep. var.	0.806	0.584	0.290	0.300	0.225	0.124
Std. dev. of dep. var.	0.395	0.493	0.454	0.458	0.418	0.329

Notes: Data comes from the 2007-2023 national Youth Risk Behavior Survey (YRBS). Observations are weighted by population weights obtained from National Cancer Institute's SEER Program and assigned according to individual's state of residence, survey year, age, sex, and race. All specifications control for individual-level covariates (grade, race/ethnicity) and state-level characteristics (population, population density, % households with children, marital status & education-related variables, unemployment rate, median household income, and child poverty rate). All regressions further include state and year fixed effects. Standard errors in parentheses, clustered at the state level. *** Significant at the 1% level ** Significant at the 5% level * Significant at the 10% level.

Table A.6: Wake up times and Sleep by Gender, Children Aged 15–18, Evidence from ATUS (2003–2023)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Wake-up time			Bedtime			Sleep			
	6am	7am	8am	after 9pm	after 10pm	after 11pm	sleep hours	sleep≥6	sleep≥7	sleep≥8
Girls										
CA SB 328	-0.333***	-0.248***	-0.130**	-0.144***	-0.066	-0.113***	1.004***	0.050*	0.052	0.395***
	(0.084)	(0.066)	(0.052)	(0.052)	(0.043)	(0.039)	(0.203)	(0.027)	(0.033)	(0.048)
Observations	2,883	2,883	2,883	2,883	2,883	2,883	2,883	2,883	2,883	2,883
R-squared	0.124	0.181	0.164	0.079	0.074	0.067	0.067	0.031	0.043	0.062
Mean of dep. var.	0.287	0.568	0.691	0.711	0.370	0.239	9.101	0.942	0.853	0.691
Std. dev. of dep. var.	0.452	0.495	0.462	0.453	0.483	0.426	2.353	0.234	0.354	0.462
Boys										
CA SB 328	-0.248***	-0.463***	-0.206**	0.215***	0.252***	0.212***	0.494	0.018	0.149***	-0.106
	(0.049)	(0.083)	(0.084)	(0.050)	(0.069)	(0.068)	(0.361)	(0.039)	(0.040)	(0.068)
Observations	2,939	2,939	2,939	2,939	2,939	2,939	2,939	2,939	2,939	2,939
R-squared	0.065	0.173	0.170	0.065	0.069	0.066	0.080	0.031	0.034	0.049
Mean of dep. var.	0.274	0.604	0.728	0.680	0.344	0.222	9.150	0.941	0.872	0.719
Std. dev. of dep. var.	0.446	0.489	0.445	0.466	0.475	0.415	2.333	0.235	0.334	0.450

Notes: Data comes from the 2003–2023 American Time Use Survey (ATUS). Observations are weighted by population weights obtained from the National Cancer Institute's SEER Program and assigned according to individual's state of residence, survey year, age, sex, and race. Estimation sample comprises children aged 15–18. All specifications control for state/year/month fixed effects, individual-level covariates (age, race/ethnicity) and state-level characteristics (% households with children, marital status & education-related variables, unemployment rate, and child poverty rate). The analysis is restricted to weekdays. Standard errors in parentheses, clustered at the state level. *** Significant at the 1% level ** Significant at the 5% level * Significant at the 10% level.

Table A.7: SB 328, Wake up times and Sleep by Race, Evidence from YRBS

	(1) Sleep $\geq$ 6	(2) Sleep $\geq$ 7	(3) Sleep $\geq$ 8	(4) Difficulty concentrating	(5) Felt sad/hopeless	(6) Suicidal intentions
Hispanics						
CA SB 328	0.057*	0.040***	0.012	-0.099***	-0.010	-0.026
	(0.030)	(0.014)	(0.009)	(0.027)	(0.021)	(0.018)
Observations	30,043	30,043	30,043	12,745	34,745	30,144
R-squared	0.021	0.037	0.030	0.057	0.065	0.030
Mean of dep. var.	0.799	0.569	0.286	0.404	0.343	0.179
Std. dev. of dep. var.	0.401	0.495	0.452	0.491	0.475	0.383
Whites						
CA SB 328	0.080***	0.093***	0.056**	-0.034	-0.031*	-0.016
	(0.023)	(0.026)	(0.026)	(0.034)	(0.018)	(0.012)
Observations	55,808	55,808	55,808	22,566	61,574	55,325
R-squared	0.020	0.034	0.038	0.053	0.068	0.030
Mean of dep. var.	0.818	0.590	0.281	0.379	0.307	0.183
Std. dev. of dep. var.	0.386	0.492	0.449	0.485	0.461	0.387
Others						
CA SB 328	0.018	-0.007	-0.009	-0.007	-0.016	0.020
	(0.021)	(0.019)	(0.016)	(0.019)	(0.028)	(0.017)
Observations	32,184	32,184	32,184	12,888	38,077	33,814
R-squared	0.023	0.032	0.033	0.062	0.064	0.037
Mean of dep. var.	0.740	0.491	0.241	0.391	0.316	0.181
Std. dev. of dep. var.	0.439	0.500	0.428	0.488	0.465	0.385

Notes: Data comes from the 2007-2023 national Youth Risk Behavior Survey (YRBS). Observations are weighted by population weights obtained from National Cancer Institute's SEER Program and assigned according to individual's state of residence, survey year, age, sex, and race. All specifications control for individual-level covariates (grade, sex) and state-level characteristics (population, population density, % households with children, marital status & education-related variables, unemployment rate, median household income, and child poverty rate). All regressions further include state and year fixed effects. Standard errors in parentheses, clustered at the state level. *** Significant at the 1% level ** Significant at the 5% level * Significant at the 10% level.

Table A.8: SB 328, Wake up times and Sleep by Race, Children Aged 15–18, Evidence from ATUS (2003–2023)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Wake-up time			Bedtime			Sleep			
	6am	7am	8am	after 9pm	after 10pm	after 11pm	sleep hours	sleep≥6	sleep≥7	sleep≥8
Hispanics										
CA SB 328	-0.443***	-0.669***	-0.112*	-0.072	0.014	0.055	1.752***	0.083	0.184***	0.404***
	(0.067)	(0.079)	(0.059)	(0.048)	(0.045)	(0.071)	(0.286)	(0.070)	(0.059)	(0.092)
Observations	1,052	1,052	1,052	1,052	1,052	1,052	1,052	1,052	1,052	1,052
R-squared	0.113	0.186	0.217	0.098	0.101	0.080	0.103	0.064	0.056	0.077
Mean of dep. var.	0.305	0.587	0.713	0.626	0.325	0.211	9.293	0.941	0.869	0.735
Std. dev. of dep. var.	0.461	0.493	0.453	0.484	0.469	0.408	2.421	0.236	0.338	0.442
Whites										
CA SB 328	-0.295***	-0.415***	-0.207***	0.043	0.144***	0.129***	0.669***	0.032	0.108***	0.063
	(0.053)	(0.034)	(0.032)	(0.041)	(0.041)	(0.044)	(0.220)	(0.031)	(0.029)	(0.048)
Observations	4,625	4,625	4,625	4,625	4,625	4,625	4,625	4,625	4,625	4,625
R-squared	0.071	0.155	0.148	0.054	0.055	0.049	0.061	0.020	0.027	0.043
Mean of dep. var.	0.279	0.596	0.720	0.693	0.350	0.221	9.054	0.943	0.865	0.704
Std. dev. of dep. var.	0.449	0.491	0.449	0.461	0.477	0.415	2.245	0.232	0.342	0.457
Others										
CA SB 328	-0.227**	-0.174*	-0.065	0.324***	0.056	-0.053	1.059***	0.011	0.027	0.238***
	(0.085)	(0.094)	(0.102)	(0.114)	(0.114)	(0.075)	(0.287)	(0.037)	(0.048)	(0.081)
Observations	1,124	1,124	1,124	1,124	1,124	1,124	1,124	1,124	1,124	1,124
R-squared	0.173	0.282	0.251	0.135	0.140	0.126	0.122	0.085	0.093	0.147
Mean of dep. var.	0.287	0.552	0.675	0.710	0.382	0.265	9.405	0.937	0.854	0.707
Std. dev. of dep. var.	0.453	0.497	0.468	0.454	0.486	0.442	2.678	0.243	0.353	0.455

Notes: Data comes from the 2003–2023 American Time Use Survey (ATUS). Observations are weighted by population weights obtained from the National Cancer Institute's SEER Program and assigned according to individual's state of residence, survey year, age, sex, and race. Estimation sample comprises children aged 15–18. All specifications control for state/year/month fixed effects, individual-level covariates (age, sex), and state-level characteristics (% households with children, marital status & education-related variables, unemployment rate, and child poverty rate). The analysis is restricted to weekdays. Standard errors in parentheses, clustered at the state level. *** Significant at the 1% level ** Significant at the 5% level * Significant at the 10% level.

Table A.9: CA SB 328 and School Performance, Heterogeneity By Sex/Race

	(1) All Students	(2) Female Students	(3) Male Students	(4) Hispanic Students	(5) White Students	(6) ECD Students
Panel A: Math Scores						
CA SB 328	0.169*** (0.027)	0.155*** (0.033)	0.168*** (0.031)	0.147*** (0.031)	0.088*** (0.023)	0.169*** (0.027)
Observations	8,405	7,707	7,684	5,867	6,901	7,414
Panel B: English (ELA) Scores						
CA SB 328	0.149*** (0.027)	0.134*** (0.038)	0.158*** (0.028)	0.162*** (0.027)	0.049** (0.020)	0.177*** (0.022)
Observations	8,470	7,735	7,765	5,964	6,899	7,508
District Pair FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Notes: Data comes from the Stanford Education Data Archive (SEDA-2024), with observations from 2009 to 2024. All specifications include controls for the share of Hispanics, share of Whites, and urban status of the district. Observations are weighted by the total population of students enrolled in the district. Standard errors in parentheses, clustered at the state level. *** Significant at the 1% level ** Significant at the 5% level * Significant at the 10% level.