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Early Birds in Elementary School? School Start Times and Outcomes for Younger Students

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While research supports later start times for secondary schools, there is little evidence regarding start times for elementary schools. We address this gap with a statewide examination of elementary schools and a quasi-experimental analysis of an urban district that recently changed its elementary start times. We find that earlier start times predict less sleep for students. Regarding academic outcomes, our estimates are small in magnitude and suggest that earlier elementary start times have near-zero effects. Earlier start times predict a slight increase in absences and modestly higher math scores, especially for traditionally disadvantaged students. In districts that need to stagger start times, it may be advisable for elementary schools to start earlier to accommodate later secondary school start times.

Keywords: *educational policy, elementary schools, school/teacher effectiveness, econometric analysis, regression analyses*

Introduction

Many states and school districts are seeking low-cost, evidence-based approaches to improve student achievement and engagement with school. One solution for secondary schools may be delaying school start times. Later secondary school start times are supported by research on adolescent sleep patterns (Carskadon, 2011; Carskadon et al., 2001, 2004) and studies connecting chronic sleep loss to adverse physical and mental health outcomes (Alfano et al., 2009; Landhuis et al., 2008; Ludden & Wolfson, 2010). Furthermore, education research indicates that later secondary school start times are associated with improvements in student attendance, course grades, disciplinary incidents, and test scores (Bastian & Fuller, 2018; Carrell et al., 2011; Cortes et al., 2012; Edwards, 2012; Groen & Pabilonia, 2019; Heissel & Norris, 2018; Lenard et al., 2020; Wahlstrom et al., 2014). Economic projections suggest that the benefits to delaying secondary school start times far outweigh the costs (Jacob & Rockoff, 2011) and that later secondary school start times could add $83 billion to the United States economy over the next decade (Hafner et al., 2017). With this evidence, states and school districts across the United States are debating and making school start time changes. Most notably, California recently enacted legislation requiring public middle schools to start no earlier than 8:00 a.m. and public high schools to start no earlier than 8:30 a.m. (Luna, 2019).

Understandably, the attention given to school start times has largely focused on high schools, and to a lesser extent, on middle schools. These are the school levels at which biological changes in adolescent sleep support later start times (Carskadon et al., 2001). These are also the school levels at which education research has shown benefits to later start times (Bastian & Fuller, 2018, 2022; Edwards, 2012; Groen & Pabilonia, 2019; Heissel & Norris, 2018; Lenard et al., 2020; Wahlstrom et al., 2014). However, this attention to secondary schools ignores the broader structure of school districts. Many districts, particularly in urban areas, stagger start times for elementary, middle, and high schools to allow for multiple busing runs, to lessen traffic congestion, and to allow parents to drop off children at different schools. These staggered start times make it difficult for school districts, especially those with tiered busing schedules,[1] to delay high school start times without adjusting start times for other school levels. In response, school districts often pair delays in high school start times with earlier start times for elementary and/or middle schools (Owens, Drobnich, et al., 2014).

There are few studies on elementary school start times. What evidence that does exist suggests that earlier start times are associated with a greater number of disciplinary incidents (Keller et al., 2017) and student absences (Heissel & Norris, 2018). Likewise, earlier elementary school start times are associated with lower test proficiency rates (Keller et al., 2015) and reading achievement (Heissel & Norris, 2018). While suggestive, this previous research has limitations, including methods that may not isolate the impact of elementary school start times (Keller et al., 2015, 2017) and an assumption that daylight, rather than clock time, is a primary driver of sleep–wake cycles for elementary school students (Heissel & Norris, 2018). As such, continuing to build on this emerging research is critical to the decision-making of states and school districts. If earlier elementary school start times are neutral or beneficial for student outcomes, then states and school districts may view delayed secondary school start times as a low-cost, promising school improvement strategy. Conversely, if the benefits of later secondary school start times come at a cost to elementary school students, then states and school districts must balance these competing priorities. To provide states and school districts with a richer body of evidence to inform school start time decisions, we ask the following questions:

1. Do elementary school start times influence self-reported measures of student sleep?
2. Do elementary school start times predict measures of student engagement with school?
3. Do elementary school start times predict student achievement?

We answer these questions with two studies on elementary schools in North Carolina. Our first study leverages statewide start time data to assess how changes in elementary school start times are associated with student achievement and engagement outcomes. Our second study focuses on an urban school district that recently delayed its high school start times, and in response, moved the start times for many of its elementary schools earlier. Together, these studies have complementary strengths and limitations. In particular, our statewide study includes a larger and more generalizable sample of schools and students. With this sample we have sufficient statistical power to detect meaningful effects. However, with the statewide study, we do not know why schools changed start times nor do we have data on student sleep. With our district-focused study, we know why schools changed start times and there are a set of elementary schools that retained later start times (to serve as a comparison group). Furthermore, with our district-focused study, we possess data on student bed and wake times. These sleep data add to the richness of our analyses. Unfortunately, our district sample is much smaller and as a result the analyses are underpowered. Given these tradeoffs, we lead with our statewide analyses and consider estimates from both studies, in tandem, to better understand the relationships between start times and outcomes for elementary grade students.

We find that 5th grade students in our focal district report getting less sleep when their school switches to an earlier start time. Regarding academic outcomes, our start time estimates are small in magnitude and suggest that earlier elementary start times have near-zero effects. Our analyses indicate that earlier start times predict a slight increase in absences. With a few exceptions, our remaining estimates are either statistically insignificant or suggestive of modest benefits to earlier elementary school start times. In math, our statewide school fixed effect analyses show that earlier start times predict slightly higher test scores, especially for economically disadvantaged students, students of color, and students in rural communities. Our reading estimates are generally small and statistically insignificant. Moving forward, our work suggests that, in some districts, it may be advisable for elementary schools to start earlier to accommodate later secondary school start times. Further research should continue to rigorously assess the relationships between start times and student outcomes, especially for students in earlier grades.

Research on Adolescent Sleep, School Start Times, and Academic Outcomes

In 2014, the American Academy of Pediatrics (AAP) issued a policy statement recommending that middle and high schools start no earlier than 8:30 a.m. (Owens, Au, et al., 2014). Research on adolescent sleep, health, and education support this recommendation. Many adolescents experience biological changes around the onset of puberty that result in a phase delay affecting the timing of their sleep. Although adolescents still need 8.5 to 9.5 hours of sleep a night, the phase delay in adolescents' sleep–wake cycle makes it difficult for them to fall asleep before 11:00 p.m. and wake before 8:00 a.m. (Carskadon et al., 2001). Early school start times may make it challenging for adolescents to get the sleep they need, and consequently, fatigued students may be less engaged with and successful in school (Lufi et al., 2011).[2]

Education research—primarily conducted at the secondary school level—indicates that later school start times predict a range of student engagement and achievement outcomes. Regarding engagement with school, multiple studies show that students are absent less often and have higher grades when their high school starts later (Cortes et al., 2012; Dunster et al., 2018; Lenard et al., 2020; Wahlstrom, 2002; Wahlstrom et al., 2014). Likewise, statewide data from North Carolina show that students are less likely to be suspended when their high school starts later, with the largest reduction in the probability of being suspended for high schools starting at 8:30 a.m. or later (Bastian & Fuller, 2018).

Regarding student achievement, a random assignment study from the Air Force Academy shows that freshman placed into early classes (starting before 8:00 a.m.) performed significantly worse on standardized course examinations. This negative effect held for first period and for subsequent periods throughout the day (Carrell et al., 2011). In the Florida panhandle, Heissel and Norris (2018) find that delaying start times 1 hour, relative to sunrise, increases test scores for high school students in math and reading. In North Carolina, both a statewide study of middle schools and a study focused on Wake County middle schools show that a 1-hour delay in start times was associated with test score increases in mathematics and reading (Bastian & Fuller, 2022; Edwards, 2012). The middle school results in Wake County were particularly strong for low-performing students (Edwards, 2012). This finding is important from an equity perspective and fits with research showing that disadvantaged students are more vulnerable to a lack of sleep and its effects (El-Sheikh et al., 2010). While research generally supports later secondary school start times, there are studies that return insignificant or mixed results (Bastian & Fuller, 2018; Groen & Pabilonia, 2019; Hinrichs, 2011; Wahlstrom et al., 2014). These findings highlight the need for continued research on the conditions in which later start times benefit secondary school students.

Relative to secondary schools, there has been less attention on elementary school start times. The AAP did not issue a recommendation for elementary school start times in its 2014 report, and most elementary school students are too young to have experienced a phase delay in their sleep–wake cycle. Sleep research indicates that elementary school students have relatively high sleep needs—between 9 and 11 hours of sleep per night (Hirshkowitz et al., 2015). However, one study finds that moving to an earlier start time does not significantly reduce elementary school students' sleep time (Appleman et al., 2015).

Extant research has limitations but raises some concerns about early start times for elementary schools. Two studies from Kentucky show that earlier elementary school start times are associated with greater behavioral problems (i.e., in-school removals, suspensions, and expulsions) and lower test proficiency rates (Keller et al., 2015, 2017). These analyses are comprehensive in scope—that is, covering all Kentucky elementary schools—but are limited in several ways, including the use of school-level data (from only one academic year), few statistical controls, and analytical approaches that do not convincingly isolate start time effects.

In more rigorous analyses of student-level data, Edwards (2012) finds no relationship between start times and the math and reading scores of elementary school students in Wake County, North Carolina. However, the generalizability of these test score estimates may be limited as more than half of the elementary schools in the sample started at 9:15 a.m. and almost all of the remaining schools started at 8:15 a.m. Earlier elementary school start times still may impact student engagement and achievement. Finally, Heissel and Norris (2018) use the time zone boundary in the Florida panhandle to instrument for daylight before school and estimate start time effects for students moving across the time zone boundary. For prepubescent students, they find that advancing start times 1 hour earlier, relative to sunrise, predicts a 1 percentage point increase in absences and significantly lower reading scores. While Heissel and Norris (2018) use a novel identification strategy, they do not assess actual start time changes in schools. Furthermore, they rely on an assumption that daylight, rather than clock time, is the primary driver of sleep–wake cycles for students. This assumption may be problematic for elementary school students whose sleep cycles are more regulated by their parents.

We add to the emerging evidence on elementary school start times with two complementary studies. Our analyses consider a diverse range of elementary schools across North Carolina that changed their start times during our study period and an urban district that recently made large changes to its elementary school start times. We examine student sleep, engagement, and achievement outcomes and use several analytical approaches to better isolate start time effects. We estimate start time effects for all students and extend prior work from middle and high school grades by assessing whether elementary school start times particularly influence certain student subgroups—for example, economically disadvantaged students, students of color, and students attending rural versus urban schools. These subgroup analyses are especially salient as school start times may represent a low-cost approach to narrowing school engagement and achievement gaps. Most importantly, our focus on elementary schools recognizes the realities of staggered start times and the tradeoffs that school districts make when implementing start time changes. Many districts, including Cherry Creek, Colorado; Saint Paul, Minnesota; and Seattle, Washington, have already advanced elementary school start times to accommodate later high school start times.[3] Our focus on elementary schools allows us to test for unintended consequences of decisions to implement later high school start times and to provide states and districts with a more complete body of evidence to inform school start time decisions.

Study 1: Across All North Carolina Elementary Schools

Research Sample

Our first study is broad in scope, covering all public (noncharter) elementary schools in North Carolina from 2011–2012 through 2016–2017. While our sample includes all elementary schools, we are most interested in the schools experiencing a start time change during our study period (see the “Analyses” section). Table 1 presents school-level characteristics for all elementary schools and for elementary schools starting at (a) 7:10 a.m. to 7:59 a.m., (b) 8:00 a.m. to 8:44 a.m., or (c) 8:45 a.m. or later. Across all North Carolina elementary schools—1,417 unique schools—the average start time is 8:06 a.m. Approximately 62% of students are economically disadvantaged and 50% are a student of color. Test proficiency rates are at 58% and nearly 80% of schools meet or exceed expected student achievement growth. The largest category of elementary schools are those starting from 8:00 a.m. to 8:44 a.m. (50.5% of the school-year observations); the smallest category of schools are those starting at 8:45 a.m. or later (11.7% of the school-year observations).

We use t tests to assess whether later-starting elementary schools (8:45 a.m. or later) significantly differ from elementary schools starting from 7:10 a.m.–7:59 a.m. and from 8:00 a.m.–8:44 a.m. Given our large analytical sample, nearly all of these differences are statistically significant. As such, we highlight differences that are particularly large. Late-starting elementary schools enroll many more students and are much more likely to be located in a city/suburb. This concentration likely reflects the need for urban school districts to have tiered busing schedules. Elementary schools starting at 8:45 a.m. or later enroll fewer economically disadvantaged students and more students of color. These late-starting elementary schools have higher test proficiency rates; however, a higher percentage of these schools do not meet expected growth. Finally, late-starting elementary schools have lower short-term suspension rates.

Outcome Measures

In each of our elementary school studies, we assess student engagement with school and student achievement on standardized exams. Our engagement outcomes are student absences and suspensions from school. Absences are the percentage of days that a student did not attend school—for excused or unexcused reasons—during the school year. For suspensions, we created an indicator equal to "1" if a student received an in-school or out-of-school suspension during the year and equal to "0" if a student was not suspended. Our achievement outcomes are test scores on statewide end-of-grade (EOG) exams in mathematics and reading. Students take these exams in Grades 3 to 5 and we standardized scores within subject, grade, and year. Across outcomes, our primary analyses focus on Grades 3 to 5, as these are the grade levels at which all our engagement and achievement measures are available. To examine start time effects for a larger group of students, we also estimate separate absence and suspension models for K–5 students.

Online Supplementary Table 1 presents descriptive (unadjusted) data on these engagement and achievement measures. Across North Carolina, 3rd to 5th grade students are absent 3.5% of school days and 6.5% of these students receive an in-or out-of-school suspension in a given year. There are sizable differences in these engagement and achievement measures by student characteristics. For instance, economically disadvantaged students (i.e., those qualifying for subsidized school meals) and students of color (i.e., Black, Hispanic, American Indian, Asian, or multiracial) are far more likely to be suspended and have lower math and reading scores than their noneconomically disadvantaged and White peers. When examining these descriptive data by urbanicity, we find that students attending elementary schools in urban areas are absent less often, less likely to be suspended, and have higher test scores than peers in rural environments. These descriptive data help motivate our subgroup analyses and provide a benchmark to gauge the magnitude of our start time estimates.

Analyses

We aim to isolate the causal relationship between school start times and student engagement and achievement outcomes. Toward this end, we begin our statewide start time analyses with an event study of student engagement and achievement in upper elementary grades (3–5). The event study is a variation of a difference-in-difference model that allows us to examine nonparametric trends in elementary schools changing their start time relative to those retaining their start time. Specifically, the event study replaces the interaction between treatment and post with a vector of indicators interacting treatment with the individual years immediately before and after implementation. This approach informs model selection by assessing whether pretreatment trends in schools changing their start time—relative to those retaining their start time—violate the parallel trends assumption.

Equation 1 displays our event study model. Here, Y_{ist} is a school engagement or achievement outcome for student i in school s at time t. The coefficients of interest are the interactions between "earlier" (i.e., elementary schools shifting to an earlier start time) and "later" (i.e., elementary schools shifting to a later start time) and the year indicators. $Student_{ist}$ is a vector of student characteristics, including indicators for grade level, gender, race/ethnicity, economic disadvantage, limited English proficiency (current and former), special education, and gifted education. $School_{st}$ is a vector of time-varying school covariates, including enrollment, per-pupil expenditures, average teacher salary supplements, and the percentages of economically disadvantaged students and students of color. $Year_t$ is a vector of year fixed effects, where we specify the year before a school's start time change as the

TABLE 1.

Characteristics of All North Carolina Elementary Schools (2011–2012 to 2016–2017)

School Characteristics	All elementary schools	7:10 a.m. to 7:59 a.m.	8:00 a.m. to 8:44 a.m.	8:45 a.m. or later
School start time	8:06	7:44	8:08	9:05
School enrollment	501.27	**477.68****	**483.71****	653.61
City/suburb	41.31	**34.77****	**34.44****	92.16
Rural/town	58.69	**65.23****	**65.56****	7.84
% Economically disadvantaged students	61.69	**62.19****	**64.21****	49.17
% Students of color	50.68	**49.89****	**48.70****	61.75
Test proficiency rates	58.14	**57.42****	**57.53****	62.97
% Exceeded student growth	26.40	**26.75**†	**26.76**†	23.83
% Met student growth	51.88	**53.53****	**51.53**†	48.16
% Not met student growth	21.72	**19.72****	**21.72****	28.01
Short-term suspension rates (per 100 students)	8.19	**8.14****	**8.90****	5.29
% Novice teachers	20.84	**21.50***	**19.99****	22.44
% Nationally board-certified teachers	15.28	15.30	15.37	14.85
Unique school counts	1,417	598	771	188
School-by-year counts	8,306	3,138	4,198	970

Note. This table displays school-level characteristics for all public (noncharter) elementary schools in North Carolina from 2011–2012 through 2016–2017. We test for statistically significant differences between (a) schools starting from 7:10 a.m. to 7:59 a.m. versus 8:45 a.m. or later and (b) schools starting from 8:00 a.m. to 8:44 a.m. versus 8:45 a.m. or later.
†,*, and ** indicate statistical significance at the .10, .05, and .01 levels, respectively.

omitted category. μ_S is a school fixed effect to adjust for time-invariant school characteristics that may be associated with start times and student outcomes.

$$Y_{ist} = \alpha + \sum_{j=-3}^{2} \beta_j * Earlier * Year_{isjt} + \sum_{j=-3}^{2} \beta_j * Later * Year_{isjt} + \delta Student_{ist} + \omega School_{st} + Year_t + \mu_S + \varepsilon_{ist} \quad (1)$$

Figure 1 displays these statewide event study results. Here, we are particularly interested in the estimates for schools shifting to an earlier start time, as this aligns with policy (i.e., earlier start times to accommodate later start times for secondary schools) and is consistent with the analyses in our focal district (Study 2). Overall, the event study results support the parallel trends assumption for schools shifting to an earlier start time. In particular, the pretreatment estimates for schools that advance their start times are statistically insignificant and generally do not show consistent trends. One potential exception is reading, where there is a small—2% of a standard deviation—upward trend in the years before a shift to earlier start times.

Given these findings, we proceed with two approaches for our statewide analyses. In our preferred approach, we estimate regression models that include a rich set of student characteristics, time-varying school characteristics, year fixed effects, and a school fixed effect. The inclusion of a school fixed effect allows us to adjust for time-invariant school characteristics that are associated with start times and our outcome measures. These fixed effects may be particularly relevant given the descriptive results in Table 1 showing that late-starting elementary schools (8:45 a.m. or later) differ from schools starting earlier. With a school fixed effect, the effect of start times on student engagement and achievement is identified based on within-school changes in start times.

$$Y_{ist} = \alpha + \beta StartTime_{ist} + \delta Student_{ist} + \omega School_{st} + Year_t + \mu_S + \varepsilon_{ist} \quad (2)$$

Equation 2 displays our school fixed effect model. Y_{ist} is a school engagement or achievement outcome for student i in school s at time t. $StartTime_{ist}$ is either a continuous measure or a set of indicators that allow us to test for nonlinear start time effects. Our continuous measure is the number of hours *before* midnight that a school starts (e.g., an elementary school starting at 8:00 a.m. would have a value of 16).[4] Coefficients from these models express how advancing start times 1 hour earlier predict student engagement and achievement. Our indicator measures include elementary schools starting at 7:10 a.m. to 7:59 a.m. and 8:00 a.m. to 8:44 a.m. in reference to elementary schools starting at 8:45 a.m. or later. Specifying our start time variables in this way—with a focus on earlier elementary school start times—aligns with the tradeoffs that many districts (including our focal district) face when considering later start times for secondary schools. Furthermore, by specifying our start time variables in this way, the estimates from our statewide analyses and focal district are more comparable. $Student_{ist}$ and $School_{st}$ represent the same vector of covariates used in Equation 1. μ_S is a school fixed effect and $Year_t$ is a year fixed effect. We cluster standard errors at the school level in these analyses.

While a school fixed effect is our preferred model—given that it assesses within-school variation over time—there are limitations to this approach. It is difficult to estimate start time impacts if few elementary schools change start times and/or if start time changes are small in magnitude. Therefore, we identified the number of elementary schools that changed start times during our study period, the magnitude of those changes, and the characteristics of schools that change start times. As shown in the top panel of Online Supplementary Table 2, a large majority of elementary schools (approximately 85%) did not make a start time change during our study period. Of the 220 elementary schools that changed start times during our study period, 143 switched to an earlier start time and 77 switched to a later start time. Among those switching to an earlier start time, the average start time change was 27.10 minutes. Most of these schools (97 of 143) made a change of 15 to 30 minutes; 29 of these schools made a change greater than 30 minutes. Among those switching to a later start time, the average start time change was 33.44 minutes. Roughly half of these schools (39 of 77) made a change of 15 to 30 minutes; 30 of these schools made a change greater than 30 minutes. Because elementary schools in our focal district (from Study 2) make up 13% of the elementary schools changing start times during our study period (and nearly 30% of the elementary schools changing start times by more than 30 minutes), we run an additional set of statewide analyses that exclude focal district elementary schools. This lets us examine all elementary schools that changed start times and all elementary schools that changed start times outside of our focal school district.

The bottom panel of Online Supplementary Table 2 displays school-level characteristics for elementary schools that did not make a start time change and for schools that switched to an earlier or later start time. Overall, we find that elementary schools switching start times differ from those that retain their start time. Specifically, schools switching to an earlier start time enroll fewer students, are less likely to be in a city/suburb, have a higher percentage of economically disadvantaged students, and have lower test proficiency rates. Those switching to a later start time enroll more students, have more economically disadvantaged students and students of color, have lower test proficiency rates, are more likely to have not met expected achievement growth, and have higher short-term suspension rates.[5]

An additional concern with a school fixed effect model is that compositional changes in the student body may influence start time estimates. As such, our second analytical approach is a student-by-school fixed effect model. In these analyses, we substitute a student-by-school fixed effect for the school fixed effect, include the same covariates as in Equations 1 and 2, and cluster standard errors at the school level.[6] We estimate a student-by-school fixed effect model, rather than a student fixed effect model, because it lets us better isolate the treatment of interest. In particular, there are two potential sources of within-student variation in these analyses—that is, when a student's school changes its start time and when a student moves to a new school with a different start time. By estimating a student-by-school fixed effect model, we focus on within-student variation in outcomes when their existing elementary school changes its start time.[7] Relative to a school fixed effect, we note that our student-by-school fixed

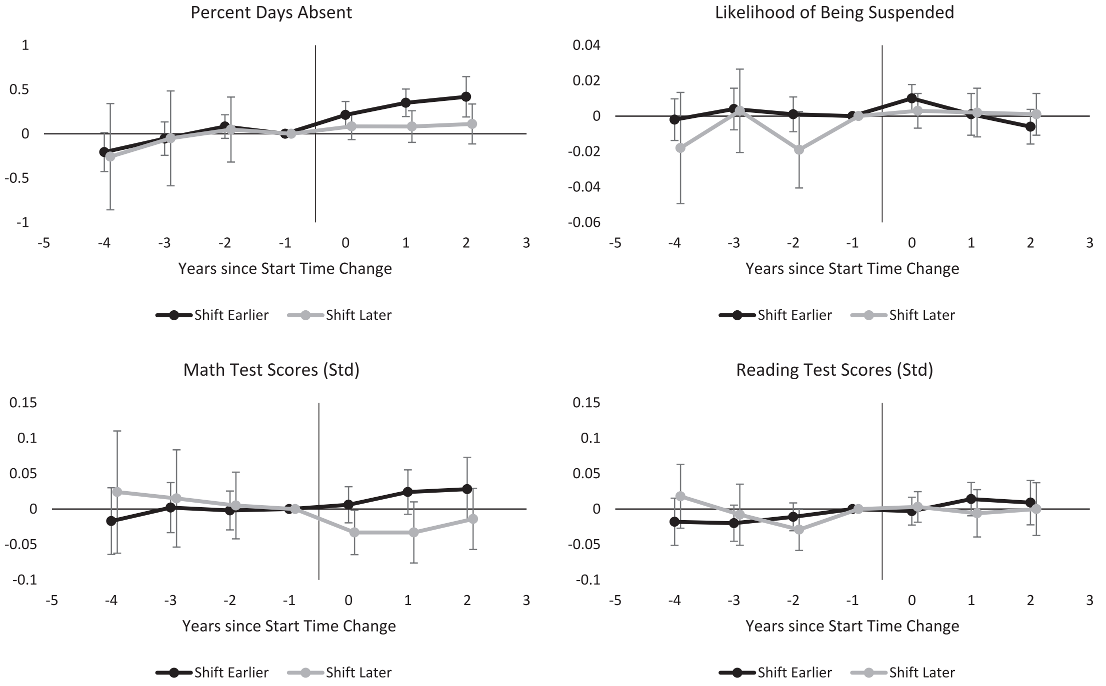

FIGURE 1. *Statewide event study results (Grades 3–5).*
Note. These figures display results from statewide event study analyses examining trends in student engagement and achievement outcomes for elementary schools switching to an earlier start time and elementary schools switching to a later start time. Error bars represent the 95% confidence intervals around the estimated coefficient.

effect model parses variation over a shorter time period (for students in Grades 3–5 in our primary specification), meaning that coefficients capture more immediate start time impacts. This is of potential significance given recent scholarship suggesting a start time disruption effect—that is, after a start time change, student outcomes may temporarily worsen before improving (Fuller & Bastian, 2022).

Results

Table 2 presents student engagement and achievement results for 3rd to 5th grade students in North Carolina. Considering attendance, we find some evidence that earlier start times are associated with a small increase in absences. Comparing within elementary schools, we find that starting school 1 hour earlier is associated with an increase in absences of nearly 0.25 percentage points. This fits with the results from our statewide event study (Figure 1) and corresponds to 3rd to 5th grade students averaging nearly 0.50 more days absent each year. The student-by-school fixed effect estimates for 3rd to 5th grade students are generally smaller than the school fixed effect estimates and are statistically insignificant. Considering all K–5 students—see the top panel of Online Supplementary Table 4—we find that starting school 1 hour earlier is associated with a significant increase in absences in both our school and student-by-school fixed effect models. These estimates correspond to approximately 0.60 and 0.30 more days absent each year. However, when we estimate models that exclude students enrolled in our focal district, the coefficients are often reduced in magnitude and statistically insignificant, especially in upper elementary grades (3–5).

Regarding suspensions, we find little evidence that earlier elementary school start times predict exclusionary discipline. For 3rd to 5th grade students, estimates from our school and student-by-school fixed effect models are largely insignificant (Table 2). These insignificant results also hold across all K–5 students (Online Supplementary Table 4). However, it is worth noting that for elementary schools switching to an earlier start time, Figure 1 shows an immediate (small) increase in

TABLE 2

Statewide Student Engagement and Achievement Results (Grades 3–5)

	% Days absent		Suspended		Math		Reading	
Focal Start Time Measures	School FE	Student-by-school FE	School FE	Student-by-school FE	School FE	Student-by-school FE	School FE	Student-by-school FE
All elementary schools								
School start time	0.226**	0.142	0.004	0.009	0.034*	0.013	0.015	−0.001
	(0.080)	(0.116)	(0.005)	(0.009)	(0.016)	(0.034)	(0.011)	(0.017)
Start time: Before 8:00	0.192*	0.040	0.002	0.014	0.028	0.010	0.019	0.002
	(0.097)	(0.111)	(0.007)	(0.011)	(0.020)	(0.042)	(0.015)	(0.022)
Start time: 8:00–8:44	−0.094	−0.045	0.001	0.004	−0.001	−0.007	0.003	−0.004
	(0.098)	(0.106)	(0.006)	(0.009)	(0.019)	(0.038)	(0.014)	(0.019)
Observation count	1,983,739	1,894,578	2,001,160	1,911,215	1,910,138	1,875,946	1,900,454	1,866,692
Excluding the focal district								
School start time	0.153	0.151	−0.006	0.002	0.044*	0.025	0.018	0.011
	(0.107)	(0.170)	(0.006)	(0.008)	(0.021)	(0.050)	(0.014)	(0.024)
Start time: Before 8:00	0.017	−0.048	−0.013*	0.005	0.036	0.023	0.023	0.018
	(0.128)	(0.146)	(0.006)	(0.009)	(0.027)	(0.063)	(0.020)	(0.031)
Start time: 8:00–8:44	−0.232*	−0.110	−0.011*	−0.003	0.007	0.006	0.007	0.007
	(0.117)	(0.131)	(0.004)	(0.007)	(0.024)	(0.052)	(0.018)	(0.025)
Observation count	1,938,108	1,850,840	1,955,154	1,867,121	1,866,525	1,833,234	1,857,369	1,824,489

Note. This table presents results from regression models controlling for a rich set of student and school covariates. Standard errors clustered at the school level are in parentheses. FE = fixed effect.

†, *, and ** indicate statistical significance at the .10, .05, and .01 levels, respectively.

TABLE 3

Statewide Student Subgroup Analyses for Engagement and Achievement (Grades 3–5)

	% Days absent		Suspended		Math		Reading	
Focal Start Time Measures	School FE	Student-by-school FE	School FE	Student-by-school FE	School FE	Student-by-school FE	School FE	Student-by-school FE
All elementary schools								
Start time: EDS	0.199*	0.142	0.007	0.011	0.056**	0.014	0.034**	0.002
	(0.081)	(0.110)	(0.006)	(0.009)	(0.017)	(0.034)	(0.012)	(0.017)
Start time: Non-EDS	0.262**	0.143	0.000	0.007	0.005	0.012	−0.009	−0.005
	(0.083)	(0.137)	(0.005)	(0.009)	(0.017)	(0.034)	(0.012)	(0.017)
Start time: Students of color	0.117	0.056	0.007	0.016	0.057**	0.001	0.033**	0.001
	(0.082)	(0.135)	(0.006)	(0.013)	(0.017)	(0.032)	(0.012)	(0.017)
Start time: White	0.382**	0.268	−0.002	−0.001	0.008	0.031	−0.006	−0.005
	(0.081)	(0.174)	(0.005)	(0.006)	(0.017)	(0.047)	(0.012)	(0.024)
Start time: Urban schools	0.101	0.039	0.006	0.013	0.022	−0.025	−0.001	−0.017
	(0.105)	(0.131)	(0.007)	(0.012)	(0.019)	(0.033)	(0.013)	(0.016)
Start time: Rural schools	0.426**	0.365	−0.000	0.002	0.053†	0.098	0.042*	0.032
	(0.118)	(0.248)	(0.008)	(0.010)	(0.028)	(0.070)	(0.018)	(0.037)
Excluding the focal district								
Start time: EDS	0.122	0.140	−0.004	0.004	0.069**	0.028	0.037*	0.015
	(0.108)	(0.160)	(0.006)	(0.008)	(0.021)	(0.051)	(0.015)	(0.024)
Start time: Non-EDS	0.192†	0.160	−0.009	0.001	0.012	0.022	−0.005	0.007
	(0.110)	(0.187)	(0.006)	(0.008)	(0.021)	(0.051)	(0.015)	(0.025)
Start time: Students of color	0.007	0.003	−0.003	0.004	0.072**	0.008	0.038*	0.022
	(0.106)	(0.210)	(0.006)	(0.012)	(0.022)	(0.053)	(0.016)	(0.028)
Start time: White	0.293**	0.286	−0.010†	0.001	0.023	0.041	0.003	0.000
	(0.104)	(0.213)	(0.006)	(0.007)	(0.021)	(0.058)	(0.015)	(0.028)
Start time: Urban schools	−0.207	−0.071	−0.014†	0.003	0.032	−0.047	−0.012	−0.011
	(0.169)	(0.228)	(0.008)	(0.012)	(0.031)	(0.059)	(0.021)	(0.029)
Start time: Rural schools	0.428**	0.368	−0.000	0.002	0.053†	0.097	0.043*	0.033
	(0.119)	(0.249)	(0.008)	(0.010)	(0.028)	(0.070)	(0.018)	(0.037)

Note. This table presents results for student subgroups from regression models controlling for a rich set of student and school covariates. Standard errors clustered at the school level are in parentheses. EDS = economically disadvantaged students.

†, *, and ** indicate statistical significance at the .10, .05, and .01 levels, respectively. Cells shaded in gray denote statistically significant differences between the subgroups.

the likelihood of students being suspended. This increased probability of suspension goes back down in subsequent years. The exception to these null results are the estimates from our school fixed effect models that exclude our focal district. In these analyses, we find that elementary grade students are less likely to be suspended—by approximately 1 percentage point—when their school switches to a start time before 8:45 a.m.

Turning to student achievement, estimates from our school fixed effect models show positive but modest associations between earlier start times and math test scores. For example, advancing start times by 1 hour predicts increases in math scores of nearly 3.5% of a standard deviation. These positive math results appear to be concentrated among elementary schools starting before 8:00 a.m. and are consistent across models that include/exclude our focal district. Math estimates from our student-by-school fixed effect models are generally positive in direction but are smaller in magnitude and not statistically significant. Given that our student-by-school fixed effect models parse variation over a shorter period, these within-student estimates align with the event study in Figure 1, where positive math results develop in the year after the shift to earlier start times. In reading, our school and student-by-school fixed effect analyses return statistically insignificant results. These null results are consistent across models that that include/exclude our focal district.

To examine start time effects for student subgroups, we estimated separate models in which we interacted our continuous start time measure with indicators for the following pairs of students: (a) economically disadvantaged versus noneconomically disadvantaged students, (b) students of color versus White students, and (c) students attending schools in urban versus rural areas.[8] These interaction models provide direct tests as to whether the start time estimate for a given subgroup differs from zero. We supplemented these results with post-estimation tests (*F* tests) to determine whether the start time estimates differ from each other (i.e., whether the start time estimate for students of color differs from the estimate for White students). These models include the same set of student and school covariates as in Equations 1 and 2 and also include a school or student-by-school fixed effect.

Table 3 presents our subgroup results for 3rd to 5th grade students in North Carolina. Regarding absences, we find that White students and students in rural areas miss more school after a shift to earlier start times. This is evident based on the magnitude of coefficients in our school and student-by-school fixed effect models and by the statistical significance in our school fixed effect models. Furthermore, our postestimation tests for school fixed effect analyses indicate that White and rural students are more adversely impacted by a shift to earlier start times than students of color or students in urban environments. Examining suspensions, very few of the subgroup estimates are statistically different than zero. However, there is modest evidence from our school fixed effect models that subgroup estimates based on student economic status or race/ethnicity differ from each other. Finally, regarding achievement, our school fixed effect models return positive results in math and reading for economically disadvantaged students, students of color, and students in rural communities. In many instances, postestimation tests indicate that these estimates for traditionally marginalized and rural students are significantly different than those for the paired subgroup. Like the main achievement results in Table 2, subgroup estimates for math and reading from our student-by-school fixed effect models are statistically insignificant.

Study 2: Within an Urban School District in North Carolina

Research Sample

Our second study focuses on an urban district in North Carolina that recently changed its elementary and high school start times.[9] Beginning in the 2016–2017 school year, our focal district delayed high school start times from 7:30 a.m. to 9:00 a.m. To facilitate this start time change, the district advanced the start time for many of its elementary schools. Specifically, elementary schools across the district were assigned to three different start times to enable buses to run routes for multiple schools in succession. Prior to the start time change, district elementary schools primarily started at 9:00 a.m.[10] After the start time change, 15 elementary schools switched to a 7:45 a.m. start time; one school switched to a 7:25 a.m.

TABLE 4

Characteristics of Focal District Elementary Schools (2012–2013 Through 2015–2016)

School Characteristics	All elementary schools	Retained later start time	Switched to an earlier start time	Early start time	Middle start time
School enrollment	532.90	450.14	560.49**	535.88*	639.25**
% Economically disadvantaged students	66.20	65.47	66.43	65.19	70.43
% Students of color	79.49	80.63	79.11	77.44	84.44
Test proficiency rates	44.70	48.66	43.38	44.37	40.23†
% Exceeded student growth	25.00	28.57	23.81	20.31	35.00
% Met student growth	52.68	60.71	50.00	56.25	30.00*
% Not met student growth	22.32	10.71	26.19†	23.44	35.00*
Short-term suspension rates (per 100 students)	7.04	9.93	6.07*	5.87†	6.72
% Novice teachers	26.49	24.08	27.28	28.52†	23.36
% Nationally board-certified teachers	11.77	11.74	11.78	11.75	11.89
Unique school count	28	7	21	16	5

Note. This table displays school-level characteristics for the elementary schools in our focal school district in the years prior to the start time change (2012–2013 through 2015–2016). We use *t* tests to test for statistically significant differences between (a) retained versus switched to any earlier start time, (b) retained versus early start time, and (c) retained versus middle start time. †,*, and ** indicate statistical significance at the .10, .05, and .01 levels, respectively.

start time.[11] We label these schools as "early start time" in Table 4. Five elementary schools advanced their start times from 9:00 a.m. to 8:30 a.m. We label these schools as "middle start time" in Table 4. Finally, seven elementary schools retained a later start time—six of these schools shifted from a 9:00 a.m. to 9:15 a.m. start time, one shifted from an 8:45 a.m. to 9:00 a.m. start time. We label these schools as "retained later start time" in Table 4. In interpreting results, we place a greater emphasis on the estimates for schools that shifted to an early start time (7:45 a.m. or earlier), as there are more of these schools and they made a larger start time change (i.e., 75 vs. 30 minutes). We analyze data on elementary school students in the focal district from 2012–2013 through 2018–2019. This provides 4 years of student data before and 3 years of data after the start time change.

Table 4 displays descriptive data on the elementary schools in our focal district in the 4 years *prior to* the start time change. Across all district elementary schools, approximately 66% of students are economically disadvantaged and nearly 80% are students of color. Students pass nearly 45% of their state assessments (proficiency rate) and more than 75% of schools meet or exceed expected student achievement growth. We use *t* tests to assess whether the schools advancing their start times differ from those retaining a later start time. Table 4 shows that elementary schools switching to an earlier start time enroll more students than schools retaining their later start time. While the percentage of economically disadvantaged and students of color is comparable across school groups, there are several significant differences in school achievement and discipline measures. Specifically, schools switching to an earlier start time—especially the middle start time category of 8:30 a.m.—have lower levels of achievement (proficiency rates and percent not meeting expected growth). Schools switching to an earlier start time also have lower short-term suspension rates.

Outcome Measures

Our study of elementary school start times in our focal school district considers the same student engagement and achievement outcomes as in our statewide analyses. These outcome measures are the percent days absent (for excused or unexcused reasons), whether a student was suspended (in-school or out-of-school) in a respective year, and standardized scores from EOG exams in mathematics and reading (standardized across the entire state). As with our statewide models, the primary analyses for our focal district focus on Grades 3 to 5; we also estimate separate absence and suspension models for K–5 students.

Online Supplementary Table 5 displays descriptive data on these student engagement and achievement measures from our focal district. We present these data for all students and by students' economic and student of color status. Overall, 3rd to 5th grade students in our focal district are absent 4% of school days. Nearly 8% of these students are suspended in a given academic year and their math and reading scores are approximately 25% of a standard deviation below the statewide mean. We find sizable differences in these engagement and achievement outcomes by students' economic status and race/ethnicity. For example, students of color in our focal district are 3.7 times more likely to be suspended than their White peers and score approximately one standard deviation lower on tests in math and reading.

Analyses

To isolate the relationship between school start times and student engagement and achievement outcomes, our second study leverages a natural experiment: In 2016–2017, our focal school district advanced the start times for many of its elementary schools. This policy change suggests a difference-in-differences analytical framework. However, the significant differences in observables between schools with different start times—see Table 4—highlight the importance of testing the parallel trends assumption underlying the difference-in-differences model. As such, like our statewide analyses, we begin our focal district analyses with an event study to test this assumption and inform our model selection.

$$\begin{aligned} Y_{ist} = \alpha + \sum_{j=-3}^{2} \beta_j {*Early*Year}_{isjt} \\ + \sum_{j=-3}^{2} \beta_j {*Middle*Year}_{isjt} + \delta Student_{ist} \\ + \omega School_{st} + Year_t + \mu_s + \varepsilon_{ist} \end{aligned} \quad (3)$$

TABLE 5

Student Sleep and School Start Times in the Focal School District (5th Grade)

Survey item	Early start time	Middle start time	Late start time
On a typical school night what time do you go to bed?	9:11 p.m.*	9:20 p.m.*	9:15 p.m.
On a typical school day what time do you wake up?	6:10 a.m.**	6:38 a.m.**	7:00 a.m.
Total hours of sleep	8:59**	9:19**	9:45
The time that my school starts in the morning is about right?	40.36**	59.95**	74.22
Survey responses	2,200	839	869

Note. This table displays survey response data from a district-wide survey of 5th grade students in our focal district.
* and ** indicate statistical significance at the .05 and .01 levels, respectively.

Equation 3 displays our event study model for our focal district. Here, Y_{ist} is a school engagement or achievement outcome for student *i* in school *s* at time *t*. The coefficients of interest are the interactions between "early" (i.e., elementary schools that switched to an early start time) and "middle" (i.e., elementary schools that switched to a middle start time) and the year indicators. $Student_{ist}$ and $School_{st}$ represent vectors of the same student and school covariates included in Equations 1 and 2. $Year_t$ is a vector of year fixed effects where the year before the start time change is the omitted category. μ_S is a school fixed effect to adjust for time-invariant school characteristics that may be associated with start times and student outcomes.

Figure 2 displays the event study results for absences, suspensions, and test scores in our focal district. For absences and suspensions, the event study results largely support the assumption of parallel trends. The coefficients on the years prior to the start time change are not statistically different from zero and do not show a consistent positive or negative trend. For math and reading scores, the results, particularly for schools switching to an early start time—the group in which we are most interested—show evidence of a positive trend prior to the start time change. For instance, the math coefficients for early start schools increase by approximately 15% of a standard deviation in the 4 years before the start time change. The rise in reading scores was nearly 7% of a standard deviation.

Given these pretreatment trends, we estimate a comparative interrupted time series (CITS) model in our focal district. This approach includes controls for time trends both pre- and posttreatment for schools in our "early" and "middle" start time categories. With these analyses, we adjust for the possibility that treatment schools have different trends in outcomes than schools that retained their start time. Furthermore, with 3 years of data post start time change, the CITS model allows us, albeit in a somewhat limited fashion, to assess whether there were immediate effects of the start time change and/or whether effects intensified or dissipated with time. This feature of the CITS model is particularly important given suggestive evidence of a short-term disruption effect after a start time change (Fuller & Bastian, 2022).

$$\begin{aligned} Y_{ist} = {} & \alpha + \beta_1 Post_{ist} + \beta_2 Post_{ist} * Time \\ & + \beta_3 Early * Time + \beta_4 Middle \\ & * Time + \beta_5 Early * Post_{ist} \\ & + \beta_6 Early * Post_{ist} * Time \\ & + \beta_7 Middle * Post_{ist} + \beta_8 Middle * Post_{ist} \\ & * Time + \delta Student_{ist} + \omega School_{st} + \mu_s + \varepsilon_{ist} \end{aligned} \tag{4}$$

Equation 4 presents our main CITS model. Here, Y_{ist} is a school engagement or achievement outcome for student *i* in school *s* at time *t*. We center the *Time* variable on the first year of the new start times, such that the estimates $Early * Post_{ist}$ and $Middle * Post_{ist}$ capture the one time increase or decrease in outcomes in the year of the start time change. Relative to the preexisting trends, $Early * Post_{ist} * Time$ and $Middle * Post_{ist} * Time$ capture the change in trends for the treatment groups after the implementation of the start time change. $Student_{ist}$ and $School_{st}$ are the same vectors of covariates

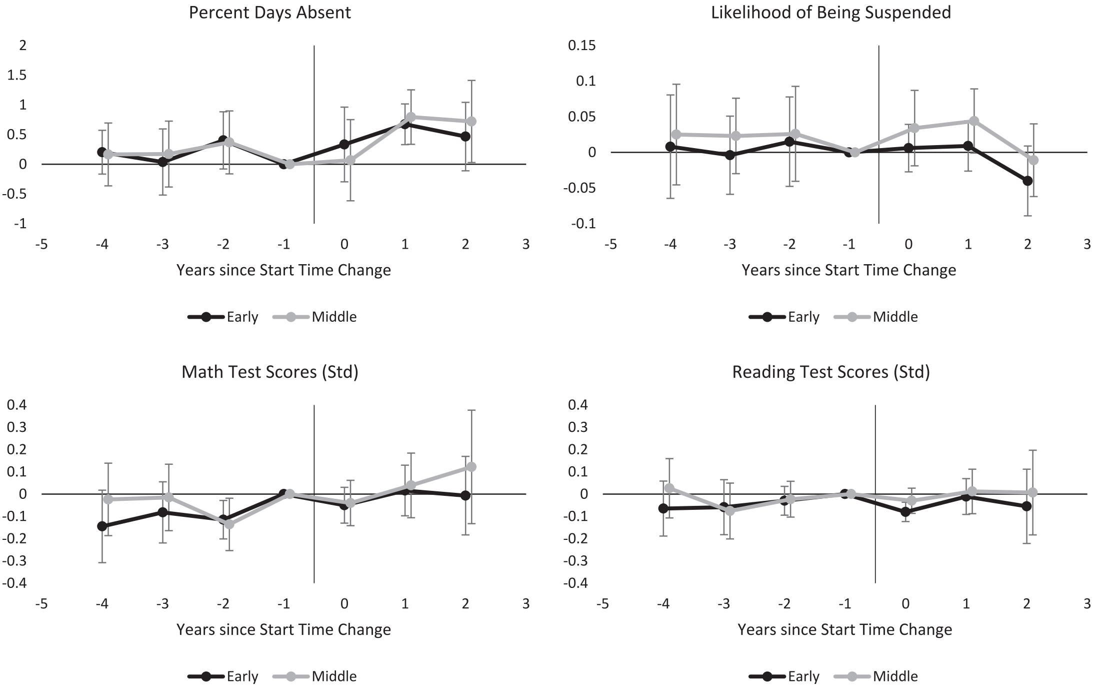

FIGURE 2. *Event study results from our focal school district (Grades 3–5).*
Note. These figures display results from event study analyses examining trends in student engagement and achievement outcomes for early- and middle-starting schools (relative to schools that retained their later start time). Error bars represent the 95% confidence intervals around the estimated coefficient.

as described in Equations 1 to 3. $\boldsymbol{\mu}_S$ is a school fixed effect. Because start times are a school-level treatment, we estimate CITS models with standard errors clustered at the school level. With only 28 elementary schools in our focal district, clustering at the school level may make it difficult to detect statistically significant effects, even for effect sizes with meaningful policy implications. As such, we prioritize the reporting of statistically significant estimates but also consider the magnitude of estimates, regardless of their significance.[12]

In addition to differences in pretreatment trends, another threat to our estimates is that students/families in our focal district could switch schools for their preferred start time. To examine this we (a) identified the number of students who moved to an elementary school in a different start time category and (b) examined changes in student-level characteristics in elementary schools that shifted to an "early" or "middle" start time. Using data from 2015–2016 through 2018–2019, we find that 94% of K–5 students in our focal district did not change start time categories (i.e., always in a school that would have/has an "early," "middle," or "late" start time). Three percent of K–5 students switch to an elementary school in an earlier start time category; the remaining 3% switch to an elementary school in a later start time category. Online Supplementary Table 6 shows that student-level characteristics are generally similar before and after the start time change. Post start time change there is a lower percentage of economically disadvantaged students in treatment schools. This corresponds to changes in reporting economic disadvantage due to the Community Eligibility Provision. Elementary schools in the "middle" start time category experienced a modest decrease in the percentage of Black students and an increase in the percentage of limited English-proficient students.[13]

Results

Before presenting our student engagement and achievement results, we focus on student sleep. Sleep is a proximal outcome for start time

TABLE 6

Student Engagement and Achievement Results for Elementary Schools in our Focal District (Grades 3–5)

Focal Start Time Measures	% Days absent	Suspensions	Math	Reading
Comparative interrupted time series				
Early*Post	0.342	0.010	−0.049	−0.078†
	(0.385)	(0.024)	(0.058)	(0.043)
Early*Post*Time	0.146	−0.021	−0.025	−0.013
	(0.258)	(0.020)	(0.062)	(0.050)
Middle*Post	0.230	0.045	0.002	−0.003
	(0.421)	(0.030)	(0.065)	(0.055)
Middle*Post*Time	0.456	−0.013	0.073	0.016
	(0.274)	(0.023)	(0.081)	(0.057)
Early*Time	−0.038	−0.000	0.040	0.022
	(0.063)	(0.011)	(0.030)	(0.023)
Middle*Time	−0.055	−0.007	−0.003	−0.003
	(0.076)	(0.011)	(0.028)	(0.024)
Post	1.398**	0.029*	0.035	0.034
	(0.363)	(0.014)	(0.045)	(0.029)
Time	−0.548**	−0.005	−0.011	0.007
	(0.080)	(0.010)	(0.025)	(0.020)
Observation count	50,510	50,716	48,474	48,148

Note. This table presents results from comparative interrupted time series (CITS) models with a school fixed effect. Standard errors clustered at the school level are in parentheses.

†, *, and ** indicate statistical significance at the .10, .05, and .01 levels, respectively.

changes, and as such, we test whether elementary school students with earlier start times report getting less sleep. Specifically, we incorporated a limited number of items on sleep and school start times into our focal district's district-wide survey of 5th grade students.[14] These data come from survey administrations in November 2018 and November 2019. In analyses, we test whether the responses of 5th grade students attending elementary schools with early or middle start times differ from those of students attending elementary schools with late start times.

Although the differences are statistically significant, Table 5 indicates that 5th grade students in our focal district go to bed around the same time, regardless of their school start time. For instance, those with early start times report going to bed at 9:11 p.m., whereas those with middle and late start times report going to bed at 9:20 p.m. and 9:15 p.m., respectively. There are much larger differences regarding when 5th grade students report waking up on a school day—6:10 a.m., 6:38 a.m., and 7:00 a.m. across the early, middle, and late start time categories. Given these differences, we calculate that 5th grade students with early start times average 45 minutes less sleep, per school night, than peers with late start times. Likewise, those starting school at 8:30 a.m. average 26 minutes less sleep, per school night, than peers with late start times. These findings differ from prior work on start times and sleep duration in elementary schools (Appleman et al., 2015) but are consistent with findings from middle and high school (Minges & Redeker, 2016; Wolfson et al., 2007). Finally, Table 5 shows that nearly 75% of 5th grade students with late start times think that their school starts at about the right time (relative to starting too early or too late). By comparison, only 60% of those starting at 8:30 a.m. and 40% of those starting at 7:45 a.m. feel similarly.

Turning to student engagement and achievement, Table 6 presents results from CITS models for 3rd to 5th grade students in our focal district. Here, we display coefficients for our start time measures, the pretreatment trends, and the post period. Overall, very few of our start time estimates are statistically significant. This suggests that start time changes in our focal district are unrelated to student engagement and achievement. However, it is important to note the magnitude of estimates, especially with only 28 elementary schools in the district. From this perspective, several coefficients warrant further attention.

Regarding student engagement, estimates show that after our focal district changed start times, 3rd to 5th grade students across the district were absent more often and were more likely to be suspended. In particular, the "post" estimates for absences and suspensions are statistically significant and indicate that upper elementary grades students missed nearly 1.5% more days of school and were 3 percentage points more likely to be suspended after the start time change. The start time coefficients for absences (e.g., "Early*Post" and "Early*Post*Time") are not statistically significant; however, they suggest that absences may have increased more at elementary schools shifting to an earlier start time. For example, the coefficient for early start students shows an immediate increase in absences of approximately 0.34 percentage points and a positive trend in absences of approximately 0.15 percentage points in successive years. This suggests that by the second year after the start time change, students attending early-start elementary schools missed nearly one more day of school than peers with a late start time. The absence estimates in Table 6 corroborate the event study findings in Figure 2 and are consistent with both the K–5 absence results for our focal district (see Online Supplementary Table 8) and the statewide absence findings. The start time coefficients for suspensions are statistically insignificant, small in magnitude, and do not show a consistent trend in direction after the focal district implemented the start time change.

For student achievement, Table 6 shows that students attending early-start schools experience a statistically significant reduction in reading scores—of nearly 8% of a standard deviation—at the time of the start time change.[15] Posttreatment trends for early-start schools in reading are small in magnitude and nonsignificant. Math results for early-start schools are not statistically significant; however, the estimate of the initial change in math scores is negative (by nearly 5% of a standard deviation) and there is a negative trend in successive years. Relative to late-starting schools, these results suggest that math scores may have decreased after the switch to an early (7:45 a.m.) start time. Finally, we note that trend estimates in math increase sharply for schools with middle start times (Middle*Post*Time).

Given prior work in middle and high school grades showing that disadvantaged students benefit from later start times (Bastian & Fuller, 2018; Edwards, 2012), we also estimated subgroup models for the 3rd to 5th grade students in our focal district. Specifically, we estimated separate CITS models for economically disadvantaged students and for students of color. Table 7 presents these subgroup estimates. As our focal district enrolls a large percentage of economically disadvantaged students and students of color, many of these subgroup results are comparable to the main results in Table 6. Of particular note, however, we find that absences significantly increase for economically disadvantaged students attending schools that advanced their start time to 7:45 a.m. or 8:30 a.m. For example, relative to economically disadvantaged students at late-start schools, the coefficient for economically disadvantaged students at early-start schools shows an immediate increase in absences of 0.60 percentage points. There are no statistically significant subgroup results for suspensions. Achievement results show a statistically significant and immediate decrease in reading scores for economically disadvantaged students in early-start schools. Although statistically insignificant, reading estimates are also negative for students of color in early-start schools and economically disadvantaged students in middle-start schools (at the implementation of the start time change).

Discussion

Providing adolescents with more time to sleep is a low-cost, evidence-based approach that may improve student engagement and achievement, especially for low-income students and students of color (Carrell et al., 2011; Edwards, 2012; El-Sheikh et al., 2010; Jacob & Rockoff, 2011). Given this research, states and school districts across the country are delaying high school start times. As momentum builds for these delays, it is important to remember the broader, interconnected structure of school systems. Many school districts

TABLE 7

Student Subgroup Analyses for Elementary Schools in Our Focal District (Grades 3–5)

	% Days absent		Suspensions		Math		Reading	
Focal Start Time Measures	EDS	Students of color	EDS	Students of color	EDS	Students of color	EDS	Students of color
Comparative interrupted time series								
Early*Post	0.606*	0.300	0.001	0.010	−0.040	−0.040	**−0.078**†	−0.067
	(0.250)	(0.464)	(0.033)	(0.028)	(0.064)	(0.062)	(0.042)	(0.046)
Early*Post*Time	−0.050	0.133	−0.023	−0.028	0.004	−0.028	−0.011	−0.019
	(0.188)	(0.307)	(0.028)	(0.023)	(0.058)	(0.064)	(0.060)	(0.053)
Middle*Post	0.436†	0.219	0.045	0.040	−0.002	0.023	−0.066	0.002
	(0.253)	(0.495)	(0.043)	(0.032)	(0.065)	(0.066)	(0.059)	(0.058)
Middle*Post*Time	0.190	0.478	−0.009	−0.015	0.133	0.055	0.038	−0.000
	(0.213)	(0.323)	(0.031)	(0.026)	(0.085)	(0.078)	(0.067)	(0.061)
Early*Time	−0.034	−0.046	0.001	0.001	0.034	0.042	0.020	0.022
	(0.077)	(0.061)	(0.016)	(0.013)	(0.027)	(0.032)	(0.022)	(0.024)
Middle*Time	0.005	−0.079	−0.009	−0.008	−0.023	0.000	−0.005	0.004
	(0.080)	(0.078)	(0.015)	(0.013)	(0.027)	(0.030)	(0.023)	(0.025)
Post	1.234**	1.504**	0.042†	0.038*	0.012	0.017	0.044	0.033
	(0.205)	(0.447)	(0.024)	(0.018)	(0.050)	(0.045)	(0.028)	(0.025)
Time	−0.611**	−0.489**	−0.005	−0.006	0.003	−0.013	0.013	0.004
	(0.091)	(0.087)	(0.015)	(0.012)	(0.023)	(0.027)	(0.020)	(0.019)
Observation count	28,736	40,807	28,769	40,969	27,316	39,029	27,063	38,745

Note. For student subgroups—economically disadvantaged students and students of color—this table presents results from comparative interrupted time series models with a school fixed effect. Standard errors clustered at the school level are in parentheses. EDS = economically disadvantaged students.
†, *, and ** indicate statistical significance at the .10, .05, and .01 levels, respectively.

stagger start times for elementary, middle, and high schools, and as such, delays in high school start times are often accompanied by earlier start times for elementary schools (Owens, Drobnich et al., 2014). If districts can make this tradeoff without adverse impacts for elementary school students, then efforts to delay high school start times may be strengthened. Conversely, if this tradeoff creates unintended consequences for elementary school students, then delays to high school start times become more challenging. We address this tradeoff by assessing whether elementary school start times predict student sleep, engagement, and achievement outcomes. Our study is unique because we consider elementary school start times in two ways: a statewide analysis of start times in North Carolina and an examination of an urban school district that recently advanced its elementary school start times.

Regarding the most proximal outcome for start time changes—student sleep—we find that 5th grade students with earlier start times report getting less sleep than peers attending later-starting elementary schools. This result is due to differences in self-reported wake times, suggesting that students kept similar bedtimes but adjusted their wake times after the start time change. This finding is consistent with prior work on sleep and start times for older students (Dunster et al., 2018; Minges & Redeker, 2016) and is important as sleep duration and quality are related to a range of physical and mental health outcomes (Alfano et al., 2009; Landhuis et al., 2008; Ludden & Wolfson, 2010). As such, this sleep result is worth further consideration as states and districts consider start time changes.

Considering academic outcomes, our start time estimates are generally small in magnitude and statistical significance is not consistent across models, samples, or studies. In particular, in our statewide analyses, there are multiple instances in which an estimate is statistically significant in our school fixed effect models and insignificant in our student-by-school fixed effect models. This is due to both smaller coefficients and larger standard errors in our student-by-school fixed effect analyses. This difference may also be related to differences in the variation parsed by the fixed effect approaches and by the amount of time it takes for start time effects to develop (Fuller & Bastian, 2022).

While our analyses indicate that earlier elementary start times have modest impacts on academic outcomes, there are several results worth further attention. First, our analyses suggest that elementary school students are absent more often when their school switches to an earlier start time. This finding aligns with prior work showing that earlier start times are associated with increased absences for prepubescent students (Heissel & Norris, 2018). In our statewide school fixed effect analyses, estimates show a slight increase in absences with a shift to earlier start times. These results are larger in magnitude for White students and students living in rural areas. In our focal district, absence estimates are positive but often statistically insignificant. However, relative to economically disadvantaged students in late-starting schools, we find that economically disadvantaged students are absent more often after their school shifted to an earlier start time. Second, our statewide school fixed effect analyses indicate that earlier start times predict significantly higher math test scores. These results are particularly strong for economically disadvantaged students, students of color, and students in rural communities. These student subgroups benefit more—relative to the paired subgroup—from earlier start times. While not statistically significant, the results from Edwards (2012) also suggested that earlier elementary school start times were associated with higher math scores. In reading, most of our statewide and focal district estimates are statistically insignificant. However, statewide subgroup analyses (school fixed effect) indicate that earlier start times are associated with modest increases in the reading scores of economically disadvantaged students, students of color, and students in rural communities.

Before considering the implications of our work, it is useful to recognize its limitations. Across both of our studies, there are potential challenges to the validity and generalizability of our estimates. Regarding validity, it is possible that unobserved school and student characteristics that are correlated with decisions to change start times bias our estimates. Regarding generalizability, it is possible that elementary schools advancing their start times differ from those that retained later start times. If so, our results may not generalize to a broader set of schools and students. We attempt to alleviate these concerns by estimating models that parse variation within schools and students, include a range of covariates, and control for differences in trends. Given the small number of schools in our focal district and the clustering of standard errors at the school level, we also have limited power to detect small to moderate effects in our second study. We address this concern by leading with our statewide analyses and by considering both statistical significance and the magnitude of coefficients.

Overall, our study does not identify when elementary schools should start. However, if a school level needs to start earlier, our study, combined with other sleep, health, and education research, suggests that it may be advisable for elementary schools to start earlier to accommodate later secondary school start times. Earlier elementary school start times are likely preferable to earlier start times for middle or high schools. Heissel and Norris (2018) start to address the ordering of start times by showing that if districts kept their current start times but reallocated the distribution so that elementary schools have the earliest start times and high schools the latest that high school achievement increases in math and reading. Conversely, the reading scores of elementary school students, particularly students of color, are adversely impacted. We recently completed a separate study focused on high school outcomes in our focal district. There, we found that delays to high school start times resulted in secondary students getting more sleep and earning higher course grades, especially in first period classes. The later start times did not predict higher test scores on end-of-course exams or the ACT (Fuller & Bastian, 2022).

Moving forward, our study calls for continued research to assess the relationship between start times and outcomes for elementary school students. Districts that recently enacted or will soon enact earlier elementary school start times need to rigorously evaluate these efforts. It is important to know whether later start times benefit secondary school students and to further develop an understanding of start time effects for younger students. This deeper understanding can help school officials make start time decisions that balance the health, engagement, and achievement outcomes of all students.

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Notes

1. In a tiered busing schedule, districts assign one bus to multiple schools/school levels to transport students to and from school each day. Districts must coordinate school instructional times so that buses have sufficient time to make multiple runs each morning and afternoon.

2. Several studies indicate that high school students get more sleep and report feeling more rested when their schools start later (Dunster et al., 2018; Wahlstrom, 2002; Wahlstrom et al., 2014).

3. To accommodate later-starting high schools: (a) Cherry Creek, Colorado, moved its elementary school start times from 9:00 a.m. to 8:00 a.m.; (b) Saint Paul, Minnesota, advanced its elementary school start times from 8:30 a.m. to 7:30 a.m.; and (c) Seattle, Washington, moved many elementary schools to a 7:55 a.m. start.

4. This is contrary to how start time is usually defined in studies for middle and high schools, where start times are usually measured as hours *after* midnight.

5. As another approach to assess student compositional changes in schools, we estimated predicted outcomes for percent absent, likelihood of being suspended, and test scores from a first-stage model that included student-level covariates but excluded our focal start time measure and school-level covariates. In our second-stage model, we regressed the predicted outcomes (from Stage 1) on the school start time, school covariates, and a school fixed effect. Results in Online Supplementary Table 3 are statistically insignificant for math, reading, and suspensions. Results for absences are positive, suggesting that students who are less likely to be absent shifted away from elementary schools moving to an earlier start time. It is worth noting, however, that the R^2 value in our first-stage regression for absences was only .028. As such, our predicted absence outcome comes from a model that explained very little of the variation in absences.

6. Our primary student-by-school fixed effect models exclude students who have been retained in grade. Models that include these retained students return comparable results.

7. We also estimated a student fixed effect model where we dropped observations for students who switched schools during the study period. Start time estimates from these student fixed effect models are comparable to the student-by-school fixed effect estimates we display in this article.

8. These analyses do not include a main effect for school start time.

9. The district did not change its middle school start times. Middle schools in the focal school district start between 7:20 a.m. and 7:40 a.m.

10. Twenty-six elementary schools started at 9:00 a.m., one started at 8:45 a.m., and one started at 9:15 a.m.

11. Fourteen schools switched from a 9:00 a.m. start time to a 7:45 a.m. start time, one school switched from a 9:15 a.m. to 7:45 a.m. start time, and one school switched from a 9:00 a.m. start time to a 7:25 a.m. start time.

12. For the comparative interrupted time series (CITS) models, our primary specification has separate treatment variables for "early" and "middle" starting elementary schools. We prefer this approach because it allows us to focus on early-starting schools and assess whether there are differences in larger versus smaller start time changes. We also estimate CITS models with a single treatment group—that is, schools starting at 7:45 a.m. or 8:30 a.m. Given space limitations, these results are available upon request.

13. As in our statewide analyses, we also assessed student compositional changes in focal district elementary schools through a two-stage regression approach. In our first-stage model, we regressed our student outcomes on student covariates only. In our second-stage model, we regressed predicted outcomes (from Stage 1) on our focal start time measures, school covariates, and a school fixed effect. Results in Online Supplementary Table 7, from our second-stage model, show that our focal start time estimates are statistically insignificant for absences and suspensions. In math and reading, there is modest evidence of student compositional changes in early-start elementary schools.

14. The focal district administers a district-wide survey to 5th, 7th, and 11th grade students each school year.

15. While not statistically significant, the pretreatment trends for early-start schools in math and reading are positive and meaningful in magnitude. The pretreatment trend estimates for middle-start schools (Middle*Time) are statistically insignificant and near zero in our test score analyses.

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