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Snooze or Lose: High School Start Times and Academic Achievement

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Snooze or Lose:
High School Start Times and Academic Achievement*

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Abstract: Many U.S. high schools start classes before 8:00 A.M., yet research on circadian rhythms suggests that teenagers' biological clocks shift to later in the day. This paper conducts the first study using a nationally representative dataset to examine the effect of high school start times on longer-run academic outcomes, including college-entrance exam scores and college attendance. Results indicate that female students who attend schools with later start times get more sleep and score higher on the SAT. Male students also get more sleep when their schools start later, but they are less likely to attend a four-year college.

Keywords: Academic achievement, School start times, Sleep, Time allocation

JEL classification: I2, J22

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I. Introduction

Over the past decade, many U.S. school districts have pushed their high school morning bell times later in response to surveys suggesting that teens are not getting enough sleep and evidence from sleep scientists suggesting that children's circadian rhythms shift to later in the day as they enter adolescence.[1] Poor or inadequate sleep is correlated with higher rates of obesity, lower cognitive performance, and higher rates of depression. Therefore, shifting to later start times has the promise of increasing both sleep and academic achievement.

However, changing bell times often occurs with much disruption to local communities' schedules, because many districts originally set early schedules for high schools to implement less-expensive multiple-tiered busing schedules. Opponents of later start times argue that, in addition to raising busing costs, later start times would negatively affect students' participation in team sports, after-school jobs, and other extracurricular activities (Sleep in Fairfax 2013). Early start times, however, may not be detrimental to learning if students are able to adapt to waking up early or if teachers are more productive with early schedules.

The link between school start times and achievement has received much attention in the popular press, by the health community, and even by Congress. House Concurrent Resolution 176, introduced to Congress in 2007 as the "Zzz's to A's Resolution" but not passed, called for secondary schools nationwide to begin the school day after 9:00 A.M. Recently, the American Academy of Pediatrics (2014) recommended that "in most districts, middle and high schools should aim for a starting time of no earlier than 8:30 A.M." If delaying start times causes students to get more sleep, students may experience increases in health outcomes and cognitive performance—and ultimately academic achievement. Some recent papers (Carrell, Maghakian, and West 2011; Edwards 2012; Hinrichs 2010; Wong 2011) have examined whether changing school start times results in a positive effect on measurable academic outcomes, with mixed results.

The primary goals of this paper are to examine whether school start times affect (1) students' decisions to pursue a college degree and the type of college and (2) student learning as measured by college-entrance exam scores and achievement test scores obtained while in high school. This paper differs from previous studies because we use data from a nationally representative sample of high school students (the Child Development Supplement to the Panel

[1] Some of these changes in school start times have been documented by Start School Later, Inc. (2015).

Study of Income Dynamics [PSID-CDS] and its follow-up, the Transition to Adulthood [TA] study) and examine several longer-term measures of academic achievement. We also use the CDS time diaries to explore the effects of high school start times on students' time allocation, which could help to explain any observed effects on academic achievement beyond a disturbance in natural sleep cycles. Results indicate that female students who attend schools with later start times get more sleep but do not have better college attendance, although they score higher on the SAT. Male students also get more sleep, but we observe negative effects on their attendance at four-year colleges.

II. Background and Literature Review

A. Sleep Patterns and Sleep Science

A sleep-laboratory study among adolescents given a 10-hour sleep opportunity suggested that adolescents need on average 9.2 hours of sleep each night (Carskadon et al. 1980). Recently, the National Sleep Foundation recommended that teenagers (ages 14-17) sleep between 8 and 10 hours each night (Hirshkowitz et al. 2015). However, a national survey of adolescents found that adolescents in high school reported sleeping on average only 7.2 hours on the typical school night (National Sleep Foundation 2006).[2] About 40 percent of U.S. public high schools started the school day before 8:00 A.M. in 2007-08, and about 85 percent started before 8:30 A.M. (U.S. Department of Education 2013). Advocates of later bell times argue that delaying bell times would allow students to get more sleep, which would promote cognitive functioning during the school day and improve academic achievement (e.g., Jacob and Rockoff 2011; National Sleep Foundation 2013).

These claims have a basis in sleep science. Sleep scientists postulate that sleep/wake behavior in humans is coordinated by two processes: a circadian timing system and a homeostatic system (Borbely 1982). The circadian system is associated with the hormone melatonin, is influenced by light and darkness, and tends to make humans tired during the nighttime hours. The homeostatic system provides sleep pressure that increases the longer a person is awake and decreases with sleep. There is some evidence that the circadian system of humans undergoes a phase shift in adolescence (associated with puberty) toward later bedtimes

[2] Estimates from time diaries suggest that adolescents actually sleep slightly longer than estimates from surveys about usual hours (e.g., Kalenkoski and Pabilonia 2012). The time-diary estimates from the PSID-CDS and ATUS both fall close to the lower bound of the appropriate sleep-duration range for adolescents as specified in the National Sleep Foundation's recommendations (Hirshkowitz et al. 2015).

and later wake-up times (Carskadon, Vieira, and Acebo 1993). A later sleep/wake cycle may also be promoted by a slower accumulation of homeostatic sleep pressure, allowing adolescents to stay awake longer (Crowley, Acebo, and Carskadon 2007).

In addition to biological factors, environmental factors appear to contribute to the later sleep/wake cycle of adolescents. These factors include reduced parental influence on bedtimes, increased homework, and extracurricular activities such as sports, music, and part-time employment (Carskadon 1990). In short, the evidence from sleep science argues that early start times are in conflict with the desired sleep patterns of adolescents. Environmental influences and changes in biological systems may limit the ability of students to make adequate adjustments to early start times.

B. Start Times and Academic Achievement

Our paper investigates the relationship between starting times in high school and academic achievement. A small number of papers have investigated this relationship, and the evidence is mixed. The earliest research in this area used data from the Minneapolis–St. Paul (Minnesota) metropolitan area, where Minneapolis and several suburban districts shifted to later bell times for their high schools (starting in 1997-98) but St. Paul and other suburban districts maintained early schedules. Wahlstrom (2002) examined Minneapolis high schools before and after the change and found that attendance rates increased and grades improved slightly. However, Hinrichs (2010) found no effect of starting times on achievement in an analysis that involved data from both schools that changed schedules and those that did not change schedules. Using individual-level ACT test-score data for students in the region who took the test for several years before and after the policy change, Hinrichs found that students who attended high schools with later start times did no better on the ACT than students who attended high schools with earlier start times. Hinrichs obtained similar results using school-level data on starting times and scores on statewide standardized tests from Kansas and Virginia.

In contrast, Wong (2011) found positive effects of later school start times on school-level student performance on state standardized tests. He primarily used a nationally representative cross-sectional sample of high schools from the National Center for Education Statistics (NCES) 2007-08 Schools and Staffing Survey (SASS) combined with scale scores on standardized tests obtained from state departments of education. In a study of middle school students in Wake County, North Carolina, Edwards (2012) also found positive effects of starting times on short-run achievement. In this county during the 1999-2006 period, there was substantial variation in starting times both across schools and within schools over time. Edwards found that later start times were associated with greater scores on standardized tests in math and reading. Carrell, Maghakian, and West (2011) also provide evidence that suggests a positive effect of later start times, at least for older teenagers. They examined college students in their first year at the U.S. Air Force Academy, where freshmen are randomly assigned to courses and schedules. They found that students who began the school day later in the morning performed better in all of their courses taken that day compared with students who began the day earlier in the morning.

Related literature addresses whether the time of day that students attend a class affects their performance. Cortes, Bricker, and Rohlfs (2012) found that high school students in Chicago Public Schools received lower grades and were more likely to be absent from a class when it met in first period than when it met later in the day. Dills and Hernandez-Julian (2008) found that college students at Clemson University received higher grades in a class if it met later in the day. High school students performed better on cognitive tests given in the afternoon than in the morning (Hansen et al. 2005).

C. Mechanisms

According to several strands of literature, the primary mechanism connecting high school start time and academic achievement is sleep. There is general evidence that school attendance is associated with sleep loss. Students sleep less on weekdays during the school year than during the summer, and during the school year they sleep less on school nights than on weekends (Crowley et al. 2007; Hansen et al. 2005; Stewart 2014). Moreover, surveys have found that students of all ages who start school earlier in the day obtained less total sleep on school nights (Carskadon et al. 1998; Knutson and Lauderdale 2009; Stewart 2014; Wolfson and Carskadon 1998; Wolfson et al. 2007).[3] When a large school district delayed its start time for high school by 60 minutes, average hours of sleep on school nights increased and "catch-up" sleep on weekends decreased (Danner and Phillips 2008). In addition, prior research suggests that wake-up times rather than bedtimes change in response to changes in school start times (e.g., Knutson and Lauderdale 2009; Stewart 2014). Epstein et al. (1998) found that early start times increased

[3] The range of estimates in the literature for a 60-minute delay in start time is additional sleep of 20 minutes to 60 minutes.

sleepiness in fifth graders regardless of the amount of sleep the children got. Thus, disrupting natural sleep cycles could also negatively affect academic achievement.

In addition to the evidence that later start times are associated with more sleep, studies have related sleep and achievement. Evidence from laboratory studies indicates that sleep deprivation impairs cognitive performance (Pilcher and Hufcutt 1996). Many studies document that students who obtain more sleep perform better in school and on standardized tests, although these correlations do not establish a causal relationship (Eide and Showalter 2012; Wolfson and Carskadon 2003).

Beyond sleep, there are several other potential mechanisms that may mediate the link between school starting times and academic achievement. Starting times may affect the amount of time that students spend in part-time work, sports, and other extracurricular activities. Starting times may also affect parental employment and the amount of time that students spend with their parents. Each of these things has its own influence on academic achievement and labor-market outcomes.[4]

Given the existing literature on starting times, sleep, and student achievement, it seems likely that other mechanisms are relevant. Specifically, the partial effect of a later starting time on achievement that operates through sleep is likely positive because a later start time should increase sleep and more sleep should improve achievement. If the total effect of a later starting time on achievement is smaller than the partial effect, other mechanisms would appear to be responsible. For instance, later start times may reduce participation in extracurricular activities, thereby reducing the achievement gains associated with increased sleep.

III. Data

A. Data Sets Used

Our data come primarily from the Child Development Supplement to the Panel Study of Income Dynamics (PSID-CDS) and its follow-up, the Transition to Adulthood (TA) survey. The PSID-CDS began in 1997 (referred to henceforth as CDS-I) with children aged 0-12 and is nationally representative. Up to two children in a family were interviewed. These children were then reinterviewed in 2002-03 (CDS-II) and again in 2007-08 (CDS-III). After a child reached

[4] For example, Light (2001) reviewed the positive benefits of student employment; Lipscomb (2007) found that participation in sports and other extracurricular activities increased students' math and science scores; and Stevenson (2010) found that increases in state-level female sports participation following Title IX resulted in increases in female college-attendance rates.

the age of 18 and was no longer attending high school, his/her participation in the CDS ended, but he/she was eligible for a follow-up TA survey. The TA surveys began in 2005 and have continued every two years. We use data from the TA surveys from 2005 through 2011.

For our study, the CDS-I provides background information on the child's race, and the main PSID interviews provide information on the respondent's family structure and mother's education.[5] A unique aspect of the PSID-CDS is the collection of two 24-hour time diaries – one for a randomly-assigned weekday and another for a randomly-assigned weekend day. Each diary contains start and stop times of students' primary and secondary activities occurring from midnight to midnight on the diary day as well as where each activity took place and who was with them in the room (or who accompanied them on an activity, if they were not at home). The TA provides a wealth of information on high school achievement, college attendance, and employment.

We control for high school-level variables by matching our sample to the NCES Common Core of Data (CCD) using school identifiers from the restricted-use version of the PSID-CDS (2014). We measure four-year college attendance and selective college attendance by matching our sample to the NCES Integrated Post-secondary Education Data System (IPEDS) and NCES-Barron's Admissions Competitiveness Index using TA IPEDS identifiers from the restricted-use version of the PSID-CDS (2013).

We obtain school start and end times from several sources, including current (2014-15) school websites and older school websites archived in the Internet Archive's Wayback Machine; School Start Later, Inc. (2015); the 2007 and 2011 restricted-use versions of the NCES Schools and Staffing Survey (SASS); and data provided by Mary Carskadon and Peter Hinrichs. In most cases, schools do not change their start times from year to year. Usually when we have two sources of bell times for a school in the same year, the sources concurred. As shown in Appendix Table A1, our primary source of bell times is school websites.

Our main independent variable is the school start time. School start time is measured in hours since midnight. It is reported in decimal form and thus indicates a fraction of an hour. In our PSID sample, start times ranged from 7:00 A.M. to 9:15 A.M., with a majority of students (79.5 percent) starting school between 7:30 A.M. and 8:29 A.M. and an average start time of

[5] We use the main PSID interview in 2003 for CDS-II high school respondents and the main PSID interview in 2007 for CDS-III high school respondents.

7:51 A.M.[6] In our regressions, we control for the length of the school day so that our estimates are the effects of starting the school day later without changing its length (as in Hinrichs 2010). The length of the school day is created by taking the difference between the school end time and start time. The length of the school day ranged from 5.5 to 8.33 hours per day, with an average day length of 7 hours per day.

B. Sample Construction

We examine a subsample of CDS respondents who were enrolled in grades 9-12 in a full-time public high school in either CDS-II (2002-03) or CDS-III (2007-08). To be included in our sample, students must have reported a weekday school-year diary and attended a high school class on that diary day. In addition, the respondent must have complete information on our main academic outcomes from the TA surveys. We examine only respondents who lived with a single parent, two biological parents, or a biological parent and stepparent. We exclude diaries where the student reported being sick more than two hours on the diary day, which could significantly affect time allocation on the school-day diary. In addition, we drop a few students from the sample because they were missing information on race, free or reduced-price lunch recipient status, usual night sleep, and sadness in past two weeks. We also drop 50 students for whom we were not able to determine school start time.[7] Appendix Table A2 details our sample construction. Our main analysis sample includes 670 respondents – 340 females and 330 males – who attended 510 unique high schools. We conduct separate analyses by gender because of the huge differences in schooling achievement and time use between males and females (Goldin et al. 2006; Jacob 2002; Kalenkoski and Pabilonia 2013).

C. Academic Outcomes

Our main dependent variables include both short-run and long-run academic outcomes: taking a college-entrance exam, scores on college-entrance exams, broad-reading and applied-problem standardized test scores on the Woodcock Johnson Revised Tests of Basic Achievement (WJ-R) that were administered at the time of the high school CDS child interview, college attendance by age 20, four-year college attendance, and selective college attendance. Table 1

[6] Specifically, 14.0 percent started before 7:30 A.M., 40.8 percent started between 7:30 A.M. and 7:59 A.M., 38.7 percent started between 8:00 A.M. and 8:29 A.M., and 6.3 percent started at 8:30 A.M. or later.
[7] Observation counts are rounded to the nearest ten in accordance with NCES disclosure requirements.

includes overall sample means for the academic outcomes as well as their means in four categories defined by school start times.

TA respondents were asked about college attendance and college-entrance exams only if they had graduated from high school or earned a GED. We use an indicator for taking a college-entrance exam as a measure of a student's intention to pursue postsecondary education. This variable is equal to 1 if the student reported taking the SAT or ACT, and 0 otherwise. We measure scores on college-entrance exams using the combined (math + reading) SAT score; for students who took the ACT but not the SAT, we use their ACT composite score and concordance tables (Dorans et al. 1997; College Board 2009) to create a predicted (combined) SAT score. Average college-entrance exam scores reported in Table 1 are only for those who took a test.

College attendance by age 20 is equal to 1 if the TA respondent reported in the TA that he/she attended a college before turning age 20; it is equal to 0 otherwise.[8] This is a good indicator of long-term achievement because students who enroll in college directly after high school are more likely to attend four-year colleges and have higher college-graduation rates (Bozick and DeLuca 2005). In addition, we define four-year college attendance equal to 1 if the TA respondent reported that the first college he/she attended before turning age 20 was a four-year college and 0 otherwise. We determine selective college attendance based primarily upon the 2008 Barron's rankings of college competitiveness. Selective college attendance is equal to 1 if the first college that the TA respondent attended before turning age 20 was a four-year college ranked between "highly competitive" and "competitive," and 0 otherwise.[9]

Given long-run trends in schooling (Goldin et al. 2006), it is not surprising that we find that female students were more likely than male students to have attended any college by age 20 (85 percent versus 80 percent), more likely to have attended a four-year college (49 percent versus 39 percent), and more likely to have attended a selective four-year college (39 percent versus 32 percent). Female students were also more likely to report taking a college-entrance

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[8] In each TA, the student recorded the first enrollment date in the current/last college attended and then the first enrollment date for one college attended prior to the current college. We use this information to create a history of college enrollment with the available TAs and compare the first recorded enrollment date with the date the student would have turned age 20. It is possible that the student did not respond to a TA in each year and that when he/she did respond, he/she had attended more than two colleges prior, resulting in measurement error in this dependent variable.

[9] If the 2008 ranking was not available, we used the 2004 ranking. The results are robust to including "less competitive" colleges as selective. The Barron's selectivity categories have been used in other research measuring college selectivity (e.g., Long 2008).

exam (82 percent versus 77 percent), perhaps indicative of gender differences in the types of colleges attended. Male students scored slightly higher than female students on the SAT. Male students also scored higher than female students on the WJ-R applied-problems test, a result consistent with the literature on the gender gap in math test scores (Niederle and Vesterlund 2010).

When we examine the means of the academic outcomes across four start-time categories, we find two striking relationships. For female students, we find that those who started between 7:00 A.M. and 7:59 A.M. were more likely to attend college than were those who started at 8:00 A.M. or later. For both sexes, we find that those who started between 7:00 A.M. and 7:29 A.M were much more likely to attend a four-year college (especially a selective four-year college) than were those who started at 7:30 A.M. or later. In our econometric analyses, we examine the relationship between academic outcomes and school start time with a rich set of controls for individual, family, school, and community characteristics.

D. Intermediate Outcomes

Sleep

In addition to the academic outcomes, we examine numerous intermediate outcomes, each of which could be affected by start times. Some of these are created from the time diaries, while others are from general survey questions. All measures of time spent on an activity are reported in hours per day. We calculate weekday measures and all-day measures. The latter is calculated by taking a weighted average of the weekday and weekend-day activity times. We argue that measures of time spent on an activity that are aggregated from time-use diaries are preferable to measures of "usual" time spent because they are less subject to both aggregation bias and social desirability bias (Juster, Ono, and Stafford 2003). We consider the effects of school start time on students' activities across the day as well as on annual sports participation, daily time spent with parents, employment, weight, and mood. See Appendix Table A3 for the 15 categories that we use to classify students' time allocation across the day.

We first examine three measures of sleep on weekdays – all diary sleep, night diary sleep, and usual sleep – in order to observe whether we see tradeoffs between sleep and start times as observed by previous researchers. The two diary-sleep measures are intended to measure sleep on school nights. We use weekday diaries but exclude Fridays because Friday bedtime corresponds to a weekend schedule. Usual sleep is obtained from the child-interview portion of the PSID-CDS rather than the time diary. We assume that the usual night sleep reported by students is for a weeknight, because the questionnaire asked "What time do you usually go to bed on weeknights?" just prior to asking about a usual night's sleep. We also consider sleep on all days to determine whether students who go to school earlier are able to "catch-up" on sleep on weekend days.

As shown in Table 2, there is little difference in the sample means between all diary sleep and night diary sleep (a difference of 0.17 and 0.23 of an hour for females and males, respectively).[10] In most cases, night sleep includes parts of two sleep episodes: the first episode is the latter part of the sleep cycle begun the day prior to the diary, and the second episode is the first part of the sleep cycle begun on the day of the diary. Female high school students sleep on average 7.91 hours per night on weekdays but report sleeping only 7.26 hours on a "usual" night. Male students sleep slightly more – on average 8.04 hours per night on their diary day and 7.56 hours on a "usual" night.

In addition to examining the effect of start times on sleep time, we consider how start times affect students' wake-up times and bedtimes. Wake-up time is defined as the end time of last night-sleep episode occurring before 1:00 P.M. on Monday through Thursday diary days.[11] Consistent with prior research (Crowley et al. 2007), female students wake up earlier than male students on school mornings (three minutes earlier on average). Bedtime is defined as either the start time of the last recorded night-sleep episode (if beginning after noon on the diary day) or the start time of the first night episode that begins at or after midnight but before noon (if the former episode does not exist) on Monday through Thursday diary days.[12] Female students go to bed three minutes later on average. In Table 3, we report the average hours per day spent on

[10] One criticism of the diary measure that should not affect our estimates of the effect of school start times is that night sleep can include sleeplessness (Eide and Showalter 2012). In Appendix Table A5, we present separate estimates of diary night sleep and sleeplessness on school nights from the American Time Use Survey (ATUS) for a sample of high school students aged 15-18. In the ATUS, we find little reporting on sleeplessness, and teens' night sleep is actually slightly longer than that reported in the PSID-CDS. Even though the ATUS diary runs from 4 A.M. on one day to 4 A.M. on the next day, the duration of the last activity (usually sleep) is obtained. Therefore, the ATUS measures a complete night-sleep episode.

[11] Some students report starting several night-sleep episodes in the early-morning hours, with other short spells of another activity in between periods of sleep. Although Friday diary days could also be used to examine wake-up times, we do not include them so that our estimated effects on night sleep, bedtime, and wake-up time are for the same sample.

[12] Bedtime is measured in hours. For bedtimes after midnight, we add 24 hours so that they occur after bedtimes before midnight.

activities on both all weekdays and all days. Over all days, female students sleep 8.77 hours per day on average while male students sleep 8.70 hours per day on average.

Other intermediate outcomes

It is often argued by opponents of later start times that moving the high school day later would mean that sports teams cannot practice or would have to shorten their practices due to less daylight after school (National Sleep Foundation 2005a). Opponents also argue that students' afterschool employment would be negatively affected (National Sleep Foundation 2005b). We examine two measures of sports participation. One, from the child-interview portion of the CDS, is whether the student participates in an athletic or sports team at school during that academic year. The other is the number of hours the student participates in sports on the diary day. On average, male students are more likely to participate in a sports team than female students (41 percent versus 29 percent). We examine two measures of employment. One is whether the student is currently employed. The second is the number of hours worked on the diary day.

Proponents of later start times argue that students would be less tired if they started school later and thus be more efficient at doing their homework; however, they may also be more rested and thus able to do more homework, resulting in better grades. Indeed, Edwards (2012) found that middle school students spent more time doing homework when schools started later. We examine only homework time that was recorded as a primary activity.[13]

School start times may also affect the amount of time that students spend with their parents on weekdays, due to the degree of synchronization between school schedules and parents' work schedules. We measure time with parents as the sum of all hours on activities where the student reported being in the same room with a parent while at home or accompanying a parent while away from the home. We measure a student's being overweight using an indicator for whether the student's age and gender-specific BMI percentile was equal to 85 or greater (i.e., being considered overweight or obese according to the CDC). Male students are more likely than female students to be considered overweight (37 percent versus 25 percent). Proponents of later start times argue that the lack of sleep resulting from early start times contributes to students' mood problems (Wahlstrom 2002). We measure students' mood with an indicator for whether the student was "many times" or "always" sad in the last two weeks. Consistent with other surveys (e.g., Youth Behavior Risk Survey [Department of Health and

[13] Students often report doing homework as a secondary activity (Kalenkoski and Pabilonia 2013; Pabilonia 2015).

Human Services 2008]), female students are more likely than male students to report being sad (27 percent versus 11 percent).

E. Control Variables

In our analysis, we include a rich set of controls for individual, family, high school, school-district, county, and state characteristics.[14] Our individual controls include indicators for black race and Hispanic ethnicity, Census region in high school, and cohort (based on the year in which the student would typically take a college-entrance exam). The cohort control (implemented with a set of dummy variables) accounts for the age/grade in which students were interviewed, broad trends in education, and changes in test scoring or composition.[15] To proxy for ability, we include age-adjusted broad-reading and applied-problems standardized-test scores from the Woodcock-Johnson Revised Tests of Basic Achievement (WJ-R) that were given during the CDS child interview occurring about five years prior to the CDS high school observation.[16] Tests taken at that time are more likely to measure inherent ability (as opposed to achievement) than tests taken during high school. We also control for whether the student was ever classified by a school as needing special education for learning disabilities or language problems.

In the test-score and college-by-20 regressions, we control for whether students were living in a state that mandated that all high school students take the ACT or SAT (Goodman 2013). We also control for whether the state had a compulsory-schooling law requiring attendance until age 17 or 18. In our time-use regressions, we also include controls for season of interview because some activities (such as sports) are seasonal. We control for several family characteristics, including whether the student lives with two parents, the number of biological siblings in the family unit, whether the mother has a college degree, and whether the student received a free or reduced-price lunch at school.

We control for several high school-level characteristics: the student-teacher ratio, the fraction white, the fraction eligible for free- or reduced-price lunch, the log of the number of

[14] See Appendix Table A4 for means of these control variables.

[15] In 2005, the SAT added a writing section, changed the content of the math and reading sections, and increased the time and cost of the test (Jacobsen 2013). In the same year, the ACT added a writing section and increased the time of the test (ACT Inc. 2009). Because of these changes, we use a different concordance table (for creating a predicted SAT score from an ACT score) for 2002-04 and 2005-10.

[16] Approximately 21 percent of the sample is missing these scores. We include an indicator for missing scores and impute a score for these students using the average score.

students, urbanicity indicators (suburban, town, and rural), and whether the school made adequate yearly progress (AYP) in 2002-03 under the *No Child Left Behind Act* (NCLB).[17] We control for the log of the median household income in the school district and the log of the population density in the county where the high school is located. Our intent is to control for school or community factors that might be correlated with both achievement and start times. For example, districts located in the suburbs of major cities tend to have above-average schools and traffic congestion (as proxied by population density); congestion is one factor in districts choosing multiple-tiered busing schedules, which typically involve early start times for high schools.

To motivate our choice of school, school-district, and county controls, we estimate a series of regressions using the school-level data in the 2007-08 SASS. The dependent variable in the regressions is school start time (coded in hours since midnight), and each regression has a different set of controls. The school controls are Census region, urbanicity, the log of the number of students, an indicator for making AYP in 2002-03 under NCLB, student-teacher ratio, percent white, and percent eligible for free- or reduced-price lunch. The district variable is the log of median household income (for 1999, based on data from the 2000 Census). The county variable is the log of population density (for 2010, based on data from the 2010 Census). The results, shown in Appendix Table A6, indicate that the most important determinants of start times are Census region (schools in the Northeast start earlier), urbanicity (suburban schools start earlier), and school size (larger schools start earlier).[18] The variation by urbanicity and school size is consistent with the notion that large suburban districts are more likely to have earlier start times in order to reduce transportation costs.

IV. Econometric Analyses

For the discrete outcomes (e.g., college by age 20), we estimate simple probit models of the following form:

[17] This variable is from Reback et al. (2011). Whether a school meets AYP is based on student performance on state standardized tests.

[18] In these regressions, the effect of school size is reflected in both the coefficient on log (students) and the coefficient on the student-teacher ratio. When log (students) is included but the student-teacher ratio is not included (specification 3), the coefficient on log (students) is negative and significant. When the student-teacher ratio is added (specification 4), the coefficient on log (students) remains negative but lessens in magnitude and the coefficient on the student-teacher ratio is negative and significant. In the full specification (specification 6), the coefficients on both variables are negative; the coefficient on the student-teacher ratio is significant but the coefficient on log (students) is not significant.

$$Pr(Y=1) = F(a_0 + a_1S + a_2D + a_3X) \qquad (1)$$

where the dependent variable, Y, is the academic outcome or intermediate outcome; S denotes school start time; D denotes the length of the school day; X is the vector of control variables; a_0, a_1, a_2 and a_3 are the coefficients to be estimated; and F(.) is the CDF of the standard normal distribution. The subscripts indicating observation and outcome are suppressed. Our estimated effect of start time on Y is the average marginal effect of S.

For continuous outcomes (e.g., college-entrance exam scores), we estimate linear models using Ordinary Least Squares (OLS):

$$Z = b_0 + b_1S + b_2D + b_3X + u \qquad (2)$$

where Z represents the continuous outcome; b_0, b_1, b_2 and b_3 are the coefficients to be estimated; and u~N(0,1). Length of school day (D) is included as a control in (1) and (2) because we are interested in the effect of changing the school start time without changing the length of the school day. All regressions are weighted using the CDS child weights, and standard errors are adjusted for clustering by school.[19]

In estimating these equations, we are interested in the causal effect of start time on achievement. Although bell times are exogenous to the student, it is possible that our estimated coefficient on start time (b_1 in the linear models; or the average marginal effect of S in the probit models) does not represent that causal effect. In particular, it is possible that our estimates suffer from an omitted variables bias due to student sorting into schools with different starting times. Although our models include controls for a number of school characteristics, it could be that schools with earlier start times are better or worse than schools with later start times in ways that we do not capture in our controls.

Tables 4 and 5 present the average marginal effects from probit estimates of effects on taking a college-entrance exam, college attendance, and type of college.[20] The results indicate that delaying the school start time by one hour while holding school day length constant decreases the probability that male students attend a four-year college by 16.7 percentage points and a selective four-year college by 14.0 percentage points. There are no effects of school start times on these outcomes for female students.

[19] The CDS-II and CDS-III child weights account for attrition since the CDS-I. We do not account for further attrition in the TA.

[20] We estimate the college-entrance exam probits using the subsample of students who did not live in a state mandating an exam.

School day length has a negative effect on four-year college attendance for female students but a positive effect on college by age 20 for male students. Consistent with other research suggesting that math ability is related to academic and labor-market outcomes (Joensen 2007; Aughinbaugh 2012), the effect of the W-J applied-problem score on the probability of each of the academic outcomes is positive for females and males. The effect of living either with two parents or with a mother who has a college degree on academic outcomes is positive and in many instances statistically significant.[21] Among female students, we find that being black or Hispanic increases the probability of attending a four-year college by age 20. Being a free- or reduced-price lunch recipient reduces the probability of college attendance by age 20 by 7.7 percentage points for female students and 10.6 percentage points for male students. For female students, being a free- or reduced-price lunch eligible student reduces the probability of taking a college-entrance exam by 8.5 percentage points. For female students, the probability of taking a college-entrance exam increases with the number of siblings. For male students, the probability of graduating from high school or attending college by age 20 increases with the number of siblings. Living in a state that mandates a college-entrance exam increases the probability of college attendance by age 20 by 12.7 percentage points for female students and 20.8 percentage points for male students.

With respect to test scores, we find that delaying the school start time by one hour has a large positive effect on the SAT score for female students (an effect that is 9.1 percent of the mean score); however, we find no effect on the other test scores examined (Table 6). For male students, we do not find any statistically-significant effects of start times on test scores. For female students, we find that the school day length has a positive effect on the SAT score. For all students, the prior WJ-R applied-problem score has a positive effect on all test scores. The prior WJ-R broad-reading score has a small positive effect on female students' high school WJ-R broad-reading scores and male students' high school WJ-R broad-reading score and SAT score. Living with a mother with a college degree has a positive effect on the SAT score for female students and a positive effect on the W-J broad-reading score for both sexes.

[21] The latter effect is consistent with prior research suggesting the intergenerational transmission of human capital (Currie and Moretti 2003).

In Table 7, we show the effects of school start times and school day length on both the timing and duration of sleep on school days (using the Monday through Thursday diaries).[22] For female students, we find that in response to a delay in start time of one hour, they sleep 0.549 hours more per night. In response to a delay in start time by one hour, male students adjust their night sleep by 0.379 hours (not statistically significant at conventional levels). Thus, the diary measures indicate that in response to a delay in start time of one hour, students get almost a half an hour of extra sleep each night. In addition, we find that students sleep longer at night if they attend a longer school day. If we use the "usual sleep" measure, the effect of school start time on night sleep for both female and male students is smaller and statistically significant.

Similar to previous research (Knutson and Lauderdale 2009; Wolfson et al. 2007), we find that for both female and male students the extra sleep from starting school later is a result of waking up three-quarters (0.750) of an hour and 0.632 of an hour later in the day, respectively, with no statistically-significant effect on bedtimes. Broadly speaking, these effects on weekday sleep are consistent with the notion that early school schedules are not in sync with adolescents' circadian rhythms.

In Table 8, we show the effects of school start times on a full set of time-use activities and some other intermediate outcomes, including sports participation, time with parents, employment, and health outcomes. For female students, we find no difference in weekday and all-day estimates for sleep duration, suggesting that those who must wake early during the week for an early school start do not sleep extra on the weekends to "catch-up" on sleep. We find that start time has a positive effect on extracurricular activities but negative effects on personal care and leisure activities. These results do not suggest that female students' other activities (i.e., activities other than sleep) can explain the positive relationship between school start times and SAT scores. For male high school students, we again find no difference in weekday and all day sleep estimates. We find that they spend less time playing computer games when school starts later. Thus, for both sexes, start times have a negative effect on students' leisure activities but do not affect participation on sports teams, which is counter to the argument made by opponents of later school start times. It is possible that the lack of a relationship between school start times and SAT scores for males is due to either the lack of a large increase in sleep as a result of later

[22] Estimates for the other control variables are not presented here for the sake of brevity but are available from the authors upon request.

start times and/or differences between the math skills of regular computer gamers and those who play less frequently (Algan and Fortin 2015; Hofferth and Moon 2012).

In addition, with later start times, students are not any more or less likely to hold a job or spend time at work, which is counter to the argument made by opponents of later school start times. Nor do we find significant effects of start time on time spent on homework.

V. Summary and Concluding Remarks

Using the nationally representative PSID-CDS, we find that when school starts 60 minutes later, female students sleep 32 minutes more on school nights on average while male students sleep 22 minutes more on school nights on average. However, we do not find evidence that this increase in sleep translates into improved college attendance, although SAT scores do improve among female students. To the contrary, results suggest that later school start times have large negative effects on the probability of attending a four-year college for male students. We also investigated a number of other mechanisms (besides sleep) through which later school start times could affect academic achievement. Only the negative effects on computer gaming for males could possibly explain the relationships between school start times and academic achievement.

There are several other potential explanations for later start times having no effect or a negative effect on achievement. One reason is statistical: Although we controlled for several school-level characteristics, our estimated effects of school start time may still be biased by a failure to adequately control for particular school-level characteristics that are correlated with achievement and school start times.

Taking our results at face value, it is possible that later start times have no effect (or even a negative effect) on achievement even though later start times are associated with more sleep (Hinrichs 2010). When schools start later, students get more sleep and as a result may learn more per unit of time; however, because they are awake for less time, they may learn less outside of school. Although students with early start times get less sleep on school nights, they may be able to make other lifestyle changes so that their achievement is not affected. For instance, they could use caffeine to promote alertness for their morning classes or they could receive extra support from their parents (or tutors) with their homework.

Another set of reasons for why we may observe a negative effect on achievement relates to how school-related inputs to education production are affected by start times. Although students may prefer later start times, teachers may prefer earlier start times; as a result, teachers may be less productive with later start times. With later starting times, schools face potential conflicts with after-school sports and other extracurricular activities. They may shift these activities to the morning (counteracting any effect of later start times for student athletes) or dismiss students early on particular days, which would reduce instructional time.

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Table 1. Means of Academic Outcomes by School Start Time

Variables	All	7:00 – 7:29 AM	7:30 – 7:59 AM	8:00 – 8:29 AM	8:30 – 9:15 AM
Females					
Take SAT or ACT exam*	0.82	0.86	0.80	0.82	0.91
SAT (math + reading)†	1087.87	1112.54	1059.54	1102.90	1081.68
WJ-R broad-reading score	105.02	104.44	106.62	103.93	104.26
WJ-R applied-problems score	104.04	105.65	105.72	102.25	101.78
College attendance by age 20*	0.85	0.89	0.89	0.81	0.81
Four-year college by age 20*	0.49	0.66	0.45	0.47	0.35
Selective four-year college by age 20*	0.39	0.52	0.39	0.36	0.29
Observations	340	50	120	140	30
Males					
Take SAT or ACT exam*	0.77	0.85	0.76	0.75	0.80
SAT (math + reading)†	1131.16	1132.08	1103.89	1177.30	1098.73
WJ-R broad-reading score	104.00	101.81	103.51	103.87	110.92
WJ-R applied-problems score	109.34	109.65	107.41	110.40	110.77
College attendance by age 20*	0.80	0.83	0.79	0.81	0.77
Four-year college by age 20*	0.39	0.63	0.34	0.37	0.44
Selective four-year college by age 20*	0.32	0.54	0.27	0.27	0.39
Observations	330	50	140	110	40

Notes: CDS child weights used. Observation counts are rounded to the nearest ten in accordance with NCES disclosure requirements.

* Only asked for high school graduates and GED recipients. We assume zero for the outcome for those not asked.

† The sample includes those who reported either an SAT or ACT score. For those with only an ACT score, we use the ACT score and concordance tables to create a predicted SAT score.

Table 2. Means of Other Variables

Variables	Female	Male
Independent Variables of Interest		
School start time (hours since midnight) [clock time]	7.86 [7:51 A.M.]	7.86 [7:51 A.M.]
School day length (hours)	6.99	7.00
Intermediate Outcomes		
Sleep on weekday diary (hours, M-TH)	8.08	8.27
Night sleep on weekday diary (hours, M-TH)	7.91	8.04
Usual night sleep (hours, presumed weeknight)	7.26	7.56
Wake-up time (hours since midnight) [clock time]	6.37 [6:22 A.M.]	6.41 [6:25 A.M.]
Bedtime (hours since midnight) [clock time]	22.41 [10:25 P.M.]	22.37 [10:22 P.M.]
Participate in a sports team that year	0.29	0.41
Currently employed	0.23	0.21
Time spent with parent on weekday (hours/day)	3.59	3.63
Time spent with parent on all days (hours/day)	4.43	4.43
Overweight	0.25	0.37
Sad in last two weeks	0.26	0.11

Notes: CDS child weights used. Means of control variables are in Appendix Table A4.

Table 3. Means of Time-use Variables (Hours per Day)

	Female		Male	
	Weekdays	All days	Weekdays	All days
Sleep	7.99	8.77	8.15	8.70
Market work	0.41	0.50	0.33	0.47
Nonmarket work	0.42	0.68	0.28	0.50
Care activities	0.14	0.19	0.09	0.16
School	7.31	5.22	7.45	5.31
Other schooling	0.24	0.20	0.19	0.15
Homework as a primary activity	1.25	1.12	0.75	0.69
Extracurricular activities	0.27	0.42	0.32	0.46
Sports	0.54	0.53	0.84	0.92
TV	1.48	1.78	1.53	1.86
Computer games	0.09	0.11	0.69	0.87
Other computer use	0.44	0.49	0.44	0.47
Personal care	1.17	1.17	0.84	0.84
Leisure	2.18	2.73	2.04	2.51
Missing activities	0.09	0.10	0.07	0.07
Observations	340	340	330	320

Note: Means may not sum to 24 hours due to rounding.

Table 4. Effects of School Start Times on Academic Outcomes (Females)

Variables	Take college-entrance exam	College by 20	Four-year college	Selective four-year college
School start time	0.038	-0.074	-0.009	0.018
	(0.055)	(0.047)	(0.076)	(0.072)
Day length	0.066	0.009	-0.161**	-0.110
	(0.047)	(0.038)	(0.077)	(0.077)
Black or Hispanic	-0.036	0.081	0.197*	0.121
	(0.061)	(0.060)	(0.101)	(0.096)
Broad-reading score	0.001	0.000	0.002	-0.001
	(0.001)	(0.001)	(0.002)	(0.002)
Applied-problem score	0.005***	0.003**	0.007***	0.008***
	(0.002)	(0.002)	(0.002)	(0.002)
Live with two parents	0.056	0.105**	0.073	0.034
	(0.035)	(0.046)	(0.064)	(0.063)
Number of siblings	0.030*	0.023	0.024	0.029
	(0.017)	(0.015)	(0.029)	(0.028)
Mother college degree	0.082	0.056	0.121	0.151**
	(0.052)	(0.043)	(0.074)	(0.067)
Free/reduced-price lunch recipient	-0.085*	-0.077*	0.031	-0.006
	(0.051)	(0.046)	(0.071)	(0.072)
State-mandated college-entrance exam	-	0.127**	0.117	0.136
		(0.056)	(0.106)	(0.103)
Observations	310	340	340	340
Pseudo R-squared	0.401	0.400	0.268	0.302

Notes: CDS child weights used. Standard errors clustered by high school are in parentheses. All regressions also include indicators for Census region, cohort effects, special education, missing WJ-R score, missing mother's education, school-level characteristics, log of median household income in the school district, log of population density in the county, state compulsory education, and a constant. From the college-entrance-exam probits, we excluded respondents who lived in states that mandated an exam in the year they would typically have taken the exam.
Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Table 5. Effects of School Start Times on Academic Outcomes (Males)

Variables	Take college-entrance exam	College by 20	Four-year college	Selective four-year college
School start time	-0.049	-0.009	-0.167**	-0.140**
	(0.062)	(0.053)	(0.071)	(0.065)
Day length	-0.063	0.124**	-0.041	-0.074
	(0.073)	(0.062)	(0.077)	(0.072)
Black or Hispanic	0.124	0.069	-0.038	-0.110
	(0.087)	(0.068)	(0.086)	(0.080)
Broad-reading score	0.001	0.002	0.004*	0.002
	(0.003)	(0.002)	(0.002)	(0.002)
Applied-problem score	0.004	0.005*	0.005*	0.007***
	(0.003)	(0.002)	(0.003)	(0.002)
Live with two parents	0.104*	0.032	0.051	0.033
	(0.054)	(0.047)	(0.064)	(0.058)
Number of siblings	0.024	0.043**	-0.030	-0.001
	(0.025)	(0.022)	(0.029)	(0.028)
Mother college degree	0.193**	0.176***	0.169***	0.188***
	(0.085)	(0.066)	(0.065)	(0.053)
Free/reduced-price lunch recipient	-0.119	-0.106**	-0.067	0.011
	(0.075)	(0.053)	(0.082)	(0.074)
State-mandated college-entrance exam	-	0.208**	-0.116	-0.146
		(0.088)	(0.102)	(0.095)
Observations	310	330	330	330
Pseudo R-squared	0.255	0.342	0.253	0.335

Notes: CDS child weights used. Standard errors clustered by high school are in parentheses. All regressions also include indicators for Census region, cohort effects, special education, missing WJ-R score, missing mother's education, school-level characteristics, log of median household income in the school district, log of population density in the county, state compulsory education, and a constant. From the college-entrance-exam probits, we excluded respondents who lived in states that mandated an exam in the year they would typically have taken the exam.
Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Table 6. Effects of School Start Times on Test Scores

	Females			Males		
Variables	Broad-reading score	Applied-problem score	SAT (reading + math)	Broad-reading score	Applied-problem score	SAT (reading + math)
School start time	1.644	-0.919	99.489***	-1.413	0.120	-17.989
	(1.918)	(1.876)	(33.391)	(2.207)	(2.335)	(39.607)
Day length	2.484	1.284	55.867*	-1.766	-1.956	-67.891
	(1.819)	(1.722)	(30.101)	(1.946)	(2.289)	(42.512)
Black or Hispanic	-4.813*	-1.051	-110.185**	-1.776	-4.524	-112.596**
	(2.825)	(2.853)	(50.373)	(2.523)	(3.064)	(53.170)
Broad-reading score	0.338***	0.061	-0.551	0.608***	0.016	4.129***
	(0.084)	(0.049)	(0.810)	(0.083)	(0.063)	(1.229)
Applied-problem score	0.257***	0.410***	6.410***	0.135*	0.484***	3.857***
	(0.084)	(0.072)	(1.147)	(0.072)	(0.081)	(1.341)
Live with two parents	3.120**	0.467	-19.178	-1.163	1.431	-33.908
	(1.463)	(2.041)	(35.485)	(2.092)	(2.009)	(33.917)
Number of siblings	1.271*	0.175	21.461*	-0.088	-0.575	3.754
	(0.769)	(0.667)	(11.395)	(0.746)	(0.785)	(16.584)
Mother college degree	4.359**	1.154	75.590**	5.714**	1.604	31.855
	(2.020)	(1.672)	(30.872)	(2.420)	(2.372)	(31.854)
Free/reduced-price lunch recipient	-0.017	-1.967	28.723	3.235*	-2.159	37.530
	(1.984)	(1.913)	(33.297)	(1.728)	(2.443)	(53.607)
State-mandated college exam	3.354	2.083	44.600	-0.885	-3.244	-7.182
	(2.908)	(2.399)	(48.251)	(2.117)	(3.162)	(49.919)
Observations	340	340	220	330	330	200
R-squared	0.603	0.523	0.498	0.622	0.523	0.466

Notes: CDS child weights used. Standard errors clustered by high school are in parentheses. All regressions also include indicators for Census region, cohort effects, special education, missing WJ-R score, missing mother's education, school-level characteristics, log of median household income in the school district, log of population density in the county, state compulsory education, and a constant.
Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Table 7. Effects of School Start Times on Sleep

Variables	All diary sleep (M-TH)	Diary night sleep (M-TH)	Usual night sleep	Wake-up time (M-TH)	Bedtime (M-TH)
Panel 1. Females					
School start time	0.681***	0.549**	0.368*	0.750***	0.134
	(0.223)	(0.232)	(0.199)	(0.127)	(0.185)
Day length	0.321	0.391*	0.062	0.171	-0.134
	(0.213)	(0.217)	(0.202)	(0.165)	(0.195)
Observations	280	280	340	280	282
R-squared	0.190	0.209	0.249	0.295	0.134
Panel 2. Males					
School start time	0.263	0.379	0.356*	0.632***	0.237
	(0.306)	(0.252)	(0.200)	(0.104)	(0.215)
Day length	0.713**	0.849***	0.014	0.204	-0.659***
	(0.324)	(0.290)	(0.272)	(0.134)	(0.228)
Observations	280	280	330	280	280
R-squared	0.259	0.292	0.282	0.372	0.305

Notes: CDS child weights used. Standard errors clustered by high school are in parentheses. All regressions include WJ-R reading and applied-problems scores, the number of biological siblings in family unit and indicators for WJ-R score missing, race, region, family structure, mother college degree, mother college degree missing, free/reduced-price lunch recipient, cohort, special education, school-level characteristics, log of median household income in the school district, log of population density in the county, state compulsory schooling, and a constant.

Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Table 8. Effects of School Start Times on Time-use Activities, Weight, and Sadness

	Females		Males	
Dependent Variable	Weekdays	All days	Weekdays	All days
Sleep	0.756*** (0.198)	0.757*** (0.198)	0.384 (0.281)	0.387 (0.283)
Market work	0.203 (0.283)	0.049 (0.259)	0.130 (0.299)	0.014 (0.315)
Nonmarket work	0.066 (0.126)	0.054 (0.129)	-0.069 (0.104)	-0.058 (0.108)
Care activities	0.088 (0.062)	0.047 (0.059)	-0.023 (0.051)	0.038 (0.054)
School	-0.208 (0.235)	-0.149 (0.168)	0.236 (0.167)	0.169 (0.120)
Other schooling	-0.048 (0.089)	-0.074 (0.079)	-0.057 (0.079)	-0.039 (0.060)
Homework	-0.132 (0.243)	-0.111 (0.211)	0.186 (0.169)	0.119 (0.155)
Extracurricular activities	0.300** (0.128)	0.432*** (0.124)	-0.062 (0.159)	-0.005 (0.180)
Sports	-0.061 (0.210)	0.032 (0.201)	-0.006 (0.230)	-0.039 (0.196)
TV	-0.031 (0.281)	0.082 (0.301)	-0.246 (0.360)	-0.294 (0.313)
Computer games	-0.082 (0.054)	-0.100 (0.062)	-0.678*** (0.216)	-0.586*** (0.208)
Other computer	-0.219 (0.175)	-0.134 (0.184)	-0.111 (0.133)	0.003 (0.128)
Personal care	-0.201* (0.105)	-0.120 (0.089)	-0.007 (0.047)	-0.044 (0.268)
Leisure	-0.488* (0.274)	-0.664** (0.261)	0.224 (0.273)	0.232 (0.268)
Missing activities	0.057 (0.074)	0.039 (0.054)	0.100 (0.083)	0.079 (0.060)
Time with parents	0.209 (0.424)	0.391 (0.475)	-0.593 (0.430)	-0.492 (0.428)
Employed	-0.050 (0.057)	-	0.003 (0.068)	-
Sports team	0.125 (0.076)	-	-0.051 (0.080)	-
Overweight	-0.000 (0.061)	-	-0.019 (0.085)	-
Sad in last two weeks	-0.006 (0.070)	-	-0.058 (0.038)	-
Observations	340	340	330	320

Notes: For the continuous time-use variables, coefficients from OLS models are presented. For the dichotomous outcomes (employed, sports team, overweight, and sadness), average marginal effects from probit models are presented. CDS child weights used. Standard errors clustered by high school are in parentheses. All regressions include WJ-R reading and applied-problems scores, the number of biological siblings in family unit and indicators for WJ-R score missing, race, region, season, family structure, mother college degree, mother college degree missing, free/reduced-price lunch recipient, special education, cohort, school-level characteristics, log of median household income in the school district, log of population density in the county, state compulsory schooling, and a constant. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Appendix Table A1. Sources of School Start and End Times (N = 670)

Source	Percent
School or district website (current or archived)	76.16
Schools and Staffing Survey (SASS 2007-08 or 2011-12)	17.69
Wolfson and Carskadon (2001-2002)	3.45
Hinrichs (2000-2007)	2.25
School Start Later, Inc.	0.45

Note: Archived websites accessed via the Internet Archive's Wayback Machine.

Appendix Table A2. Sample Selection

	Number of Observations
Attend high school in CDS-II or CDS-III (27 dropouts prior to interview)	1,650
Drop those without a weekday school-year diary	1,440
Drop those interviewed during Christmas vacation and other major holidays and not attending school on their diary day	1,370
Drop those missing HS start time because not attending school on diary day (e.g., school holiday, sick, teacher workday)	1,230
Drop those missing child interview in 2007	1,220
Drop if teen does not live with biological parents, a biological parent/step-parent, or with biological single parent (e.g., lives with grandparents, other relatives, foster parents)	990
Drop if missing race	990
Drop if missing follow-up TA information on education (including college attendance, college selectivity, and college exams by age 20)	830
Drop students in private high schools	770
Drop if sick more than two hours on their diary day	770
Drop those who do not report free or reduced-price lunch recipient	760
Drop those who do not report usual night sleep	740
Drop if don't report sadness	730
Drop those for whom we were not able to determine a school start time or who did not attend a regular high school	670
Drop if missing more than 180 minutes on diary day	670
Total Sample Size:	
All	**670**
Females	**340**
Males	**330**

Note: Observation counts are rounded to the nearest ten in accordance with NCES disclosure requirements.

Appendix Table A3. Time-use Classifications

Classification	Examples of activities included
Sleep	Sleeping; naps
Market work	Part-time jobs; using computer at home for pay; coffee breaks while at workplace; job search
Nonmarket work	Food preparation; washing dishes; laundry; ironing; watering plants; gardening; car care; groceries; shopping for other goods
Care activities	Child care not for pay; reading to a child; helping adult household members or friends
School	Attending class; field trips; travel to school
Other schooling	Nonacademic classes; SAT prep; military training
Homework as a primary activity	Homework; using the computer for homework; being tutored; studying; reviewing homework with parent
Extracurricular activities	Volunteer work; attending church; youth group; fraternal organizations; community organizations; music lessons; playing an instrument; attending before- or after-school activities (not sports-related)
Sports	Playing sports; lessons in sports or dance; team sports; organized meets or games; exercise
TV	Watching television
Computer games	Playing computer games; playing games on a cell phone; electronic video games (Nintendo, Sony, Game Boy, Sega)
Other computer use	"Surfing the net"; downloading pictures, music; e-mail; reading media; Skype; Facebook; photo processing; learning how to use computer; financial services
Personal care	Bathing; dressing; medical care (sick or visiting doctor)
Leisure	Attending sporting events; going to the movies; museums; zoo; visiting with others; wedding; party; reading; radio; listening to music; conversations; relaxing; hobbies; arts and crafts; playing non-electronic games; eating meals; snacking; caring for pets
Missing activities	Time gap of greater than 10 minutes

Note: Travel time associated with each activity is included in the total time spent on the activity.

Appendix Table A4. Means of Control Variables

Variables	Female	Male
White	0.70	0.69
Black or Hispanic	0.30	0.31
WJ-R broad-reading score (before HS)	109.10	107.57
Lived in East region in HS	0.18	0.19
Lived in North Central region in HS	0.23	0.21
Lived in South region in HS	0.34	0.30
Lived in West region in HS	0.25	0.30
College test 2002/2003	0.24	0.27
College test 2004	0.15	0.13
College test 2005	0.14	0.11
College test 2007/2008	0.29	0.28
College test 2009/2010	0.18	0.21
WJ-R applied-problem score (before HS)	108.37	114.06
Missing a WJ-R score (before HS)	0.19	0.19
Ever in special education	0.07	0.12
Fall interview	0.31	0.34
Winter interview	0.58	0.56
Spring interview	0.11	0.10
State-mandated college-entrance exam	0.08	0.10
State compulsory schooling until age 17-18	0.64	0.64
Family Variables		
Lives with both biological parents or a parent and step parent	0.71	0.71
Number of biological siblings in family unit	1.33	1.31
Mother college degree (non-missing)	0.29	0.24
Mother education missing	0.06	0.06
Free or reduced-price lunch recipient	0.26	0.23
School-level Variables		
Student-teacher ratio	17.84	17.86
Fraction white	0.60	0.62
Fraction eligible for free or reduced-price lunch	0.30	0.32
Urban school	0.32	0.27
Suburban school	0.30	0.31
Town school	0.14	0.17
Rural school	0.24	0.25
Log (number of students in high school)	7.20	7.04
Made adequate yearly progress	0.45	0.45
District-level Variable		
Log (median household income in school district)	10.70	10.68
County-level Variable		
Log(population density in county)	6.03	5.87
Missing school-level, county, or district variable	0.12	0.10
Number of observations	340	330

Note: CDS child weights used.

Appendix Table A5. Sleep on School Nights, ATUS and PSID-CDS (Mean Hours per Day)

	ATUS (2003-2008)		PSID-CDS (2002-03/2007-08)	
Variables	Female	Male	Female	Male
Sleeplessness	0.03	0.04	-	-
Night sleep	8.45	8.40	7.91	8.04
N	1,550	1,560	280	280

Notes: All estimates are weighted. ATUS includes private schools but PSID-CDS does not. ATUS includes high school students aged 15-18 whereas the PSID-CDS includes high school students aged 13-18. School nights are Sunday-Thursday in the ATUS (and include all sleep after 7 P.M.) but Monday-Thursday in the PSID-CDS.

Appendix Table A6. Determinants of School Start Times

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Northeast	-0.199***	-0.159***	-0.200***	-0.237***	-0.241***	-0.218***
	(0.037)	(0.038)	(0.029)	(0.034)	(0.035)	(0.035)
Midwest	0.018	0.018	-0.011	0.012	0.019	0.019
	(0.030)	(0.030)	(0.026)	(0.029)	(0.030)	(0.030)
West	-0.045	-0.037	-0.035	0.029	0.038	0.003
	(0.034)	(0.035)	(0.031)	(0.033)	(0.035)	(0.037)
Suburb		-0.207***	-0.153***	-0.143***	-0.132***	-0.140***
		(0.046)	(0.040)	(0.041)	(0.043)	(0.043)
Town		-0.028	-0.005	0.005	0.015	-0.030
		(0.039)	(0.041)	(0.041)	(0.040)	(0.045)
Rural		-0.029	-0.037	-0.040	-0.026	-0.066
		(0.038)	(0.046)	(0.044)	(0.044)	(0.048)
School made AYP			-0.006	-0.016	-0.011	-0.015
			(0.024)	(0.023)	(0.023)	(0.023)
Log (students)			-0.082***	-0.040**	-0.033	-0.023
			(0.021)	(0.020)	(0.021)	(0.022)
Student-teacher ratio				-0.017***	-0.018***	-0.016***
				(0.004)	(0.004)	(0.004)
Percent white				0.001	0.001	0.000
				(0.001)	(0.001)	(0.001)
Percent free lunch				-0.000	0.000	0.000
				(0.001)	(0.001)	(0.001)
Log (h'hold income)					-0.002	0.061
					(0.070)	(0.074)
Log (pop'n density)						-0.028**
						(0.012)
Observations	2,230	2,220	2,020	2,000	1,990	1,990
R-squared	0.037	0.075	0.128	0.140	0.144	0.150

Source: Authors' calculations using data from SASS (2007-08), Common Core of Data, School District Demographics System, U.S. Census Bureau, and Reback et al. (2011).
Notes: Each column reports the results of a separate regression with school start time as the dependent variable. Log of median household income is defined at the school-district level. Log of population density is defined at the county level. The remaining variables are defined at the school level.
Significance levels: *** p<0.01, ** p<0.05, * p<0.1.