Early to Rise: The Effect of Daily Start Times on Academic Performance

Finley Edwards*

University of Illinois at Urbana-Champaign

March 9, 2011

Abstract

Local school districts often stagger daily start times for their schools in order to reduce busing costs. This paper uses data on all middle school students in Wake County, NC from 1999-2006 to identify the causal effect of daily start times on academic performance. Using variation in start times within schools over time, I find that a one hour later start time leads to a two percentile point gain in math test scores and a one and a half percentile point gain in reading test scores. The effect is stronger for students in the lower end of the distribution of test scores, and is roughly similar to raising parent's education by one year. I find evidence supporting increased sleep, less time spent watching television and more time spent on homework as mechanisms through which start times affect test scores.

*Address: 214 David Kinley Hall, 1407 W. Gregory, Urbana, Illinois 61801. e-mail: *fedward2@illinois.edu*. I am grateful to Darren Lubotsky for advice and suggestions, and to Ron Laschever, Daniel McMillen, Elizabeth Powers, and seminar participants at the University of Illinois for helpful comments. I owe a special thanks to Kara Bonneau and Clara Muschkin at the North Carolina Education Research Data Center (NCERDC) for facilitating use of their confidential data and to Ina Stringfellow at the Wake County Public School System Transportation Department for providing me with start time data. I am responsible for any errors.

1 Introduction

What time should the school day begin? There is considerable variation in daily start times both across the nation and within individual communities, with schools beginning as early as 7:30 a.m. or as late as 9:00 a.m.[1] The issue of timing is by no means trivial. Districts stagger the start times of different schools in order to reduce the number of buses used and thus reduce transportation costs. However, if beginning the school day early in the morning has a negative impact on academic performance, staggering start times may not be justified on a cost-benefit basis.

In recent years, school start times have received considerable attention in the popular press (see, for example, (Kalish, 2008) and (Trudeau, 2007)). Proponents of later start times argue that student in early starting schools do not receive enough sleep and that performance can be increased by beginning the school day at a later time. Several school districts have responded by delaying the start of their school day and a 2005 congressional resolution (H. Con. Res. 200) was introduced by Rep. Zoe Lofgren, recommending that all secondary schools start at 9:00 or later nationwide. Despite this attention, the relationship between start times and academic performance is not well understood.

This paper uses data on all middle school students in Wake County, North Carolina from 1999-2006 to examines how start times affect the performance of middle school students (grades 6-8) on standardized tests. Wake County is uniquely suited for this purpose because it has considerable variation in start times across schools within a single large school district, as well as variation in start times within schools over time. The differences in start time across schools are a result of bus scheduling concerns, while the differences within schools are driven by population growth. Using both sources of variation in start times, I find that a one hour delay in start time increases standardized test scores on both math and reading test by three percentile points. Since start times may be correlated with other characteristics that determine of test scores, I also estimate the effect

[1] Throughout this paper, all times are a.m., unless otherwise indicated.

using only variation in start times within the same schools over time and find a two percentile point improvement in math and a one percentile point improvement in reading. The effect of start times on academic performance is robust to different specifications and sources of variation, and is stronger for the lower end of the distribution of start times. The magnitude of the effect is similar to the difference in test scores for one additional year of parental education. The impact of later start times on test scores is persistent. Conditional on a high school fixed effect, a one hour later start time in grade eight is associated with an increase in test scores in grade ten similar in magnitude to the increase in grade eight.

The unique data used in this paper allow me to examine several possible mechanisms through which later start times might raise student performance. The rationale typically given for start times affecting academic performance is primarily biological. Earlier start times may result in fewer hours of sleep, since students may not fully compensate for earlier rising times with earlier bed times. In particular, adolescents have difficulty adjusting to early bed times due to the timing of the release of the hormone melatonin (Dahl and Lewin, 2002). A reduced amount of sleep has been demonstrated to reduce student's cognitive ability (Meijer et al., 2000). This in turn could reduce learning, resulting in lower test scores. I find evidence supporting this explanation: among middle school students, the impact of start times is greater for older students. However, I also find evidence of other potential mechanisms as well. Students who begin school later have fewer absences and spend more time on homework each week. These factors may also explain why later-starting students have higher test scores.

2 Why Might Start Times be Important?

One reason that schools begin the school day at different times is the use of tiered busing systems. Many school districts stagger the times their schools begin the school day so that the same bus and driver can serve multiple schools. For example, a school district might start a high school at 7:30, a middle school at 8:15 and an elementary school at 9:00. This has the potential to drastically reduce transportation costs compared to an alternative schedule where all three schools start at 8:15.

Only one nationally representative dataset records school start times: The 2001 Before- and After-School Programs and Activities section of the National Household Education Survey (ASPA-NHES), conducted by the National Center for Educational Statistics. This dataset does not contain any information on academic achievement, so it cannot be used to measure the impact of start times on student performance. However, it is useful in establishing the variation of start times across the nation and for comparing the data used in this paper to national norms. Table 1 lists summary statistics for middle school start times for the national sample in 2001. Nationally, the median middle school student begins school at 8:00. Over one fourth of students begin school at 8:30 or later, while more than 20 percent begin at 7:45 or earlier.

In addition to the national sample, Table 1 also lists statistics for middle school start times in Wake County from 1999-2006. As would be expected when comparing a specific district to the national distribution, start times in Wake County are more concentrated than they are nationwide. In Wake County, 53.1 percent of middle school students start school at 7:30, and another 22.4 percent begin at 8:15. In comparison, only 26.7 percent of students start at the national modal time of 8:00. More importantly, start times are consistently earlier in Wake County than nationwide: the median Wake County student begins school earlier than over 90 percent of students nationwide. Since the marginal impact of start times on academic performance may decrease (or increase) for later start times, care should be taken in imputing the conclusions reached in this paper to schools that have a later start time. Put another way, the gain from later start times found here derive largely from changes from 7:30 to 8:15. The same gains may not occur from changing start times from 8:30 to 9:15, for example.

[Table 1 about here.]

Another source of information on nationwide start times is a survey of high school start times by Wolfson and Carskadon (2005). They randomly selected 4,116 schools and asked them to report start times retrospectively since 1965. While the survey deals with high schools instead of middle school and has response problems (fewer than ten percent of schools selected are included in their final sample), it does provide useful information about the types of schools that begin early or late. They find that large schools (>1000 students) begin on average 15 minutes earlier than small (<1000 students) schools, and that rural schools begin 15 minutes later than urban or suburban schools. Schools that are not part of a tiered busing system begin on average 15 minutes later than schools with a two tiered system and 20 minutes later than schools using a three tiered system. Their findings are consistent with the WCPSS being a urban/suburban school district with a three tiered busing system and having somewhat earlier start times than the national sample.

There is credible evidence (Danner and Phillips, 2008; Baroni et al., 2004) that students who begin the school day earlier sleep less. To obtain the same amount of sleep as students who have a later start time, early-starting students would need to go to sleep earlier. Activities such as sports, work, family and social schedules may make it difficult for students to adjust the time they go to bed. In addition, the onset of puberty brings two factors that can make this adjustment particularly difficult for adolescents: an increase in the needed amount of sleep and a change in the natural timing of the sleep cycle. Hormonal changes, in particular the secretion of melatonin, shift the natural circadian rhythm of adolescents, making it increasingly difficult to fall asleep early in the evening. It is well established in the physiological literature that less sleep is associated with a decrease in cognitive performance, both in a laboratory settings and through self-reported sleep habits (Pilcher and Huffcutt, 1996).[2] Specific to academic achievement, numerous studies have reported a negative correlation between self reported hours of sleep and grades among both middle and high school students.[3]

[2] Laboratory studies tend to focus on large amounts of sleep loss. The amount of sleep lost from starting school earlier would be much less. Laboratory results should be viewed as establishing a credible relationship between sleep and cognitive performance.

[3] See Wolfson and Carskadon (2003) for a survey of these studies.

Since students who start school earlier typically sleep less, and less sleep is associated with decreased academic performance, one would expect that students in early-starting schools would perform worse on standardized tests. However, there is little empirical evidence directly linking school start times and academic performance. Allen (1992) and Wolfson et al. (2007) examine a small number of schools and find a positive correlation between later start times and student grades. This approach is inherently limited; any increase in performance could reflect other unobserved factors rather than the impact of a later start time.

The study most widely cited in the popular press (Wahlstrom, 2000) examined two Minnesota school districts (Minneapolis Public Schools and Edina) which changed the start times in their secondary schools to start over an hour later.[4] Walstrom is concerned with the impact of start times on a wide range factors, including attendance, sleep behavior, school discipline and extra-curricular activities, in addition to academic performance. The impact of a delayed start time is measured by comparing the mean grade obtained by high school students during the three years prior to the start time change and mean grades from three years after the change. Wahlstrom finds a positive but statistically insignificant increase in mean grades, but does not report the actual results.

Two working papers by Hinrichs (2010) and Carrol et al. (2010) avoid many of the issues of extant studies. Hinrichs uses individual ACT data on students in the Minneapolis metro area for the same policy change as Wahlstrom. However, he includes additional school districts, allowing him to control for secular time trends. Hinrichs also uses school-level data on Kansas assessment tests in the 10th and 11th grades. Using a variety of specifications, he finds no effect of later start times in any of his specifications. Carrol et al. (2010) examine how the time of the first class of the day affects college freshman. They use data from the United States Air Force Academy, where freshman are randomly assigned to class periods.[5] They find that a one hour delay in the first class of the day increases grades by 0.15 standard deviations.

[4] Edina school district changed their start times from 7:25 to 8:30 and Minneapolis changed from 7:15 to 8:40.

[5] Some students have a first period class and others do not, but all students must attend mandatory breakfast prior to the first class period.

This paper complements existing studies in several ways. First, I am better able to control for unobservable factors by using use multiple sources of variation in start times, both across schools and within schools over time. Second, I examine students in middle school (6th - 8th grades), while existing studies tend to examine high school students, often in a single grade. If adolescent hormones determine how start times affect academic performance, middle school students may respond differently than high school students. Third, I use standardized test scores instead of letter grades or grade point average. Fourth, I examine changes in start times that occurred in different years for different schools, and are not intended to increase student achievement. This makes Hawthorne effects[6] unlikely and will allow me to separate out year effects. Lastly, my unique data set allows me to examine several specific mechanisms through which start times may affect academic performance, in particular whether the "adolescent hormone" hypothesis explains the effect of start times on academic performance.

3 Data and Institutional Background

The data set used in this paper is combined from two sources. The first source is administrative data for every student in North Carolina between 1999 and 2006.[7] The data contain detailed demographic variables for each student as well as end of grade test scores in both reading and math.[8] The raw test scores vary considerably by year, so I use the statewide data to construct

[6] A Hawthorne effect occurs when subjects modify their behavior because they are being studied, and not because of a change in an explanatory variable.

[7] The administrative data were provided by the North Carolina Education Research Center.

[8] The data also contain information on teachers, potentially allowing me to control for teacher and classroom characteristics. However, I am unable to link students to the teacher data set for roughly 28% of my sample. In addition, the teacher that is linked is the teacher who suppervised the exam, which may not be the teacher the student had for the school year. I construct a "class size" index which is the number of students coded with the same teacher, class period, and year. For 15% of students matched to teachers, the "class size" was over 50. This suggests for many students the teacher linked to their record was not their true teacher, but rather a supervisor of a test for multiple classes. As a result, I do not include teacher or class characteristics in the results shown. Results are generally similar when teacher characteristics are included.

percentile scores for each student within their grade and the current year.[9] The second source of data is the start time for each school in the Wake County Public School System (WCPSS), by year.[10] Start times were matched to the school code for each student in the administrative data.

There are several factors that make these data well suited for examining the effect of start times on academic performance. Examining a single school district avoids problems resulting from correlation of start times with unobserved characteristics at the district level. Since start times are generally determined at the district level, it may be that well-run districts tend to have earlier (or later) start times, or they may be more (or less) likely to change the start times of their schools. The WCPSS is also large enough to measure effects precisely. It has considerable variation in start times both across schools and within schools over time. By focusing on middle school students, I am able to test the "adolescent hormones" hypothesis of why later start times affect test scores.

The WCPSS is the eighteenth largest public school district in the United States with 120,504 students (kindergarten through twelfth grade) in the 2005-06 school year. It encompasses all public schools in Wake County, a mostly urban and suburban county that includes the cities of Raleigh and Wake Forest. Start times for schools in the district are proposed by the transportation department (which also determines bus schedules) and are approved by the school board. While the school board could in theory make changes to the bell schedule, they did not do so during the sample period of 1999-2006. The practice of combining school start times and bus scheduling is supported by the Operations Research literature concerning the "school bus problem," where it is well established that costs can be reduced up to 30% if start times and bus routes are simultaneously chosen (Keller and Muller, 1979; Fugenschuh, 2009).

Since 1995, WCPSS has operated under a three-tiered system. While there is some variation

[9] Specifically I pool the raw test scores for all students in North Carolina in a given year and grade. I then assign each student in Wake County a percentile rank based on where their raw test score falls in the statewide distribution. Percentile scores were constructed seperately for math and reading. An alternate normalization would be to construct Z-scores by subtracting the statewide mean and deviding by the statewide standard deviation. Results using Z-scores are presented in table 7 and are very similar to those for percentile ranks.

[10] The start time data was provided by the WCPSS transportation department.

in the exact start times, most Tier I schools begin at 7:30, Tier II schools at 8:15 and Tier III at 9:15. Tiers I and II are composed primarily of middle and high schools, and Tier III is composed entirely of elementary schools. Figure 1 is a histogram of the distribution of start times of middle schools for the pooled sample.[11] Just over half of middle schools begin at 7:30, with substantial numbers of schools beginning at 8:00 and 8:15 as well.

[Figure 1 about here.]

Wake county is divided into 1,134 student assignment nodes. Each node is associated with a elementary, middle and high school that is the "base" school for all students living within the node. Nodes are matched to schools based on facility utilization, distance and diversity. Each year, as the population changes and new schools are built, a limited number of nodes are reassigned to new schools. Nodes remain with a given school for a minimum of three years between reassignments. A majority (72.5 % in 2006) of students attend their base school. Alternatively, students may choose to apply to attend a magnet school.[12] Magnet schools use a specialized curricula and typically have smaller enrollments. Magnet school admittance is determined by lottery.[13] Bus transportation is provided to students whether they attend the base school or a magnet school.

Since buses serving magnet school must cover a larger geographic area, ride times tend to be longer for magnet school students. As a result, almost all magnet schools begin at the earliest start time. For example in 2004, nine out of ten magnet schools began at 7:45 or earlier compared with nine out of sixteen base schools. Students at magnet schools tend to have higher test scores, which may cause a spurious negative relationship between start times and test scores. Furthermore, since students can choose to apply to magnet schools, it is possible that they chose a magnet school partially based on start time. For these reasons, I exclude magnet schools from my sample. Five

[11] Most schools are represented seven times (once for each year) although sometimes with different start times.

[12] A small number ($< 5\%$) of students transfer to a base school other than the one they are assigned. Such transfers are only allowed for exceptional circumstances and for grandfathered students who live in a reassigned node. Bus transportation is not provided for transfer students. I do not have information on which students have transfered to a differant base school than the one to which they are assigned.

[13] Preference within the lottery is given to some students based on sibling enrollment, distance and diversity.

schools began a magnet program during the sample period. These schools are included in the sample prior to becoming a magnet school and excluded after. Results including magnet schools are presented in table 7.

Over the seven years examined in this paper, WCPSS grew from 20,530 students enrolled in twenty-two middle schools during the 1999-2000 school year to 27,686 students enrolled in twenty-eight middle schools in 2005-2006. In addition to population growth, the WCPSS increased the number of magnet schools from five to thirteen by opening three new magnets schools and converting five existing non-magnet schools into magnet schools. Three new non-magnet schools were also opened.

As a result of population growth, the transportation department changed start times to accommodate new schools and increased enrollment at existing schools. Existing non-magnet schools had their start times change fourteen times in the sample, with some schools starting earlier and others later. In the portion of my analysis that uses school or student fixed effects, it is these changes that identify the effect of later start times. Table 2 tabulates the changes in start times. Each cell contains the number of schools that switched from the corresponding old start time to the corresponding new start time. Four schools changed their start time twice. Those schools appear twice in the table. Eleven schools did not change their start time in the sample period. Those schools appear in the diagonal cells and have the same old and new start time. There were a total of fourteen changes in start times by nine schools. Seven of those changes were of thirty minutes or more.

[Table 2 about here.]

Table 3 lists means of selected demographic variables by start time for 2000 and for 2006. Panel A includes student characteristics, while Panel B includes (unweighted) school characteristics.[14] For the purposes of tabulation, I separate start times into two groups: Tier I (7:30-7:45) and Tier

[14] Tabulations for other years in the sample are similar to 2000 and 2006, but are not presented.

II (8:00-8:45). Buses that serve Tier I schools would have time to serve two additional schools, but buses that serve Tier II schools would only have time for one more school. For almost all of the student demographics, there are differences between earlier and later starting schools in 2000. The differences are generally small in magnitude, but precisely measured. For example, 24% of students in Tier I schools are black, compared to 21% of Tier II students. Students in earlier starting schools are more likely to be female, belong to an ethnic minority, be eligible for free lunches and have less educated parents. In 2006, the demographic characteristics of the two tiers are generally closer together, but several differences still remain. Since the characteristics more prevalent amoung Tier I students are generally believed to be associated with lower test scores, the simple correlation between test scores is unlikely to represent a causal effect. Moreover, if students in early-starting schools have other characteristics that are correlated with test scores, contolling for the observed characterstics may not be sufficient to give an unbiased estimate of the effect of start times.

The school characteristics in each tier are much more similar to each other.[15] In particular, schools in both tiers have similar enrollments and pupil to teacher ratios. For none of the variables are the differences between the two tiers statistically significant at conventional levels. Even for variables that are statistically different in panel A, the corresponding percentages in Panel B are not statistically different.

[Table 3 about here.]

4 The Relationship Between Start Time and Performance

The simple relationship in test scores for start times for math and reading scores can be seen in figures 2 and 3. These figures present the empirical cumulative distribution function of test scores

[15]The differences in the percentage characteristics in panel B and the corresponding variables in panel A is mainly a result of Panel B being unweighted.

in schools with earlier (Tier 1) and later (Tier 2) start times. For both the reading and math test, the cumulative distribution for late-starting schools first-order stochastically dominates the distribution for early-starting schools; for every percentile a greater proportion of students score at or below that percentile in the early-starting schools than in later starting schools.[16] For example, 45% of students in early-starting schools have math test scores at or below the 50th percentile, while only 36% of students at late-starting schools score at or below the 50th percentile.

[Figure 2 about here.]

[Figure 3 about here.]

These figures suggest that later start times positively impact student performance. Since there are other differences between early- and late-starting schools, the simple relationship between test scores and start times should not be viewed as representing the impact of later start times. I estimate several regression models to account for observed characteristics and unobserved effects. Without any fixed-effects, the specifications have the basic form:

$$y_{ijt} = \beta START_{jt} + X'_{ijt}\gamma + Z'_{jt}\delta + \epsilon_{ijt} \tag{1}$$

Here y_{ijt} is the test score of student i who attends school j in year t. $START_{jt}$ is the start time of school j in year t, measured in hours after midnight. X_{ijt} is a vector of individual characteristics (not all of which vary over time) including gender, race, age, economic status, grade and parental education. Z_{jt} is a vector of school characteristics including pupil-to-teacher ratio, racial and economic composition, magnet status, and ϵ_{ijt} is the error term.

In order to isolate different sources of variation, I use different fixed effects in some specifications. Most specifications include a year specific effect. Some specifications use a school fixed effect, using only variation in start times within the same school, over time. A student fixed effect

[16] In an alternate specification (not shown), I restricted the estimates to schools that started at either 7:30 or 8:15 (roughly 75% of the sample). Results were highly similar to those in figures 2 and 3.

identifies the impact of start times using only those students who had different start times in different year. This could occur in two ways: the student could switch to a new school which begins at a different time, or the student's school could change time. Finally a student-school fixed effect uses only changes in start times for students who stay in the same school.

Tables 4 and 5 present results of nested models of math and reading test scores respectively. These specifications use both variation in start times across and within schools. Each column adds additional explanatory variables to the previous specification. Column 1 gives a simple regression of test scores on start times, without any additional covariates. For both math and reading, the coefficient on start time is quite large, 9.5 percentile points per hour for both tests.[17] The effect drops substantially as I add additional covariates. Column 2 adds individual characteristics (the X_{ijt}). The coefficient on start time drops to 4.5 for math and 4.8 for reading. This is not surprising since students at early-starting schools are more likely to belong to an ethnic minority, be eligible for free lunches and have less educated parents. The large effect found in column 1 reflects in part these trends. When school characteristics are added to the specification in column 3, the effect changes slightly to 4.8 for both tests. Column 4 adds year and grade effects and obtains a result of 2.9 percentile points for math and 3.2 percentile points for reading. The start time coefficient decreases slightly as I add school characteristics, year and grade effects, but the drop is much less than from column 1 to column 2. In all cases the effect is statistically different from zero at the 1% level of significance.

[Table 4 about here.]

[Table 5 about here.]

As noted above, there are differences in observed demographic characteristics of students in early and late starting schools. If there are also unobserved differences that are correlated with

[17]Throughout the paper, I measure differences in start times in hours to ease interpretation. The difference between early and late starting schools in the data is typically 45 minutes.

start times, the results found in tables 4 and 5 may be a biased estimate of the true effect of start times on academic performance. To account for this, I also estimate specifications that use school and student-school fixed effects. The results are presented in table 6. The advantage of these specifications is that any unobserved characteristics that do not change over time will be captured by the relevant fixed effect. By disregarding the variation in start times across schools and identifying the effect of later start times using only the variation in start time within a given school, my estimates are less precise. In addition, only 28% of students in the sample experienced a change in start times. Since the estimate of the impact of start times on test scores will be identified soley by those schools or students who changed start times, I estimated the specification in column 4 of tables 4 and 5 with the sample restricted to schools or students who experienced a change in start times. Results (not shown) were similiar to those found in tables 4 and 5.

Columns 1 and 2 in table 6 estimate specifications using school fixed effects for the math and reading test respectively. In this case the effect of a later start time is identified using only the variation in start times within schools over time. The effect of a one-hour later start time is a 2.1 percentile point increase in math test scores and a 1.5 percentile point increase in reading test scores. The school fixed effect controls for all time invariant school level characteristics. However, a remaining concern is that the characteristics of schools may change over time. To address this issue, columns 3 and 4 use student-school fixed effects, identifying the impact of later start times using only from students whom experience a change in start time while remaining in the same school The effect of a one-hour later start time is 1.8 and 0.8 percentile points for math and reading respectively. The results found using variation within students are generally lower than those found using both variation within and across schools, but are still significantly different from zero. The results for the reading test are lower than those from the math test. A possible explanation for this is that math skills are more dependent on the school environment than reading skills.

[Table 6 about here.]

To investigate how the effect of later start times varies across the distribution of test scores, I estimate the model given in equation 1 by quantile regression for each decile of the distribution. I include a full set of explanatory variables, as well as year and grade dummy variables.[18] Figures 4 and 5 presents the conditional quantile effect of a one-hour later start time for the math and readings tests graphically. The shaded area represents a 90% confidence interval for the point estimate.[19] The solid horizontal line is the corresponding OLS coefficient (columns 1 and 3 of tables 6 and the dotted horizontal lines the OLS 90% confidence interval. For both tests, the effect of later start times is much greater in the bottom half of the distribution, and is monotonicaly decreasing after the third decile. This indicates that start times have a greater impact on the bottom half of students. This is one possible explaination as to why my results differ from those found in Hinrichs (2010). Hinrichs uses ACT test scores for students in the Minneapolis-St. Paul, MN metro area. For his sample years, between 55 and 66 percent of high school students in Minnesota took the ACT. As a result his sample does not include the students (the bottom portion of the grade distribution) where I find the largest impact of start times. The larger impact on the lower end of the grade distribution suggests that delaying school start times may be an especially relevant policy change for school districts trying to meet minimum competency requirements (such as those mandated in the No Child Left Behind Act).

[Figure 4 about here.]

[Figure 5 about here.]

Table 7 gives estimation results for an alternative sample and test score normalization. Each entry is the coefficient on start time. Columns one and two show results for the math test, while

[18]This model does not include any fixed effects. Since the conditional quantile function is not a linear operator, the interpretation and estimation of fixed effects is different in quantile regression than in OLS regression. In results available on request, I estimate a quantile regression model including school fixed effects, using the two step estimator proposed in Canay (2010), which models fixed effects as pure location shifts. The point estimates of conditional quantile effects in this model have the same shape (decreasing after the third decile) as the results shown.

[19]Standard errors are estimated using the Huber sandwich procedure described in Koenker (2005).

columns three and four show results for the reading test. Columns one and three use both variation within and across schools, while columns two and four use only variation within schools for given students (a student-school fixed effect). The first row reproduces results found in tables 4, 5, and 6 for comparison purposes. The second row expands the sample to include magnet schools. Results are similar, but slightly smaller than those found excluding magnet schools. Since students at magnet schools tend to have higher test scores, the quantile regression results found above may explain these differences. The third row uses an alternate normalization of test scores. Instead of constructing percentiles, I normalize test scores by subtracting the statewide mean and dividing by the statewide standard deviation for a given grade and year. Results are very similar to those using percentiles.[20]

[Table 7 about here.]

[Table 8 about here.]

5 Why Do Start Times Matter?

The typical explanation as to why later start times might increase academic achievement is that by starting school later, students will get more sleep. As students enter adolescence, hormonal changes make it difficult for them to compensate for early school start times by going to bed earlier. Since students enter adolescence during their middle school years, examining the effect of start times as students age provides a test of the “adolescent hormone” explanation. To do this, I separated students in my sample by quarter years of age and estimated the effect of start time on test scores separately for each group (including a full set of covariates and a student-school fixed effect). Figures 6 and 7 present these results. The shaded area is a 95% confidence interval. For both tests, the effect is relatively flat until age 13, when it begins to increase and continues to

[20] On average there are 30 percentiles to a standard deviation, so a 0.06 standard deviation effect is similar to a 1.8 percentile effect.

increase through the rest of the observed age range. This provides evidence that at least part of the effect of later start times is due to increased sleep.

[Figure 6 about here.]

[Figure 7 about here.]

To further investigate how the effect of later start times varies with age, I estimate the effect of start times on upper elementary (grades 3-5) students and high school students. If adolescent hormones are the mechanism through which start times affect academic performance, pre-adolescent elementary students should not be affected by early start times. Results for elementary students are shown in table 9. The first two columns present results using a student-school fixed effect. Start times had no effect on elementary students regardless of the specification used. However, elementary schools start much later than middle schools (over half of elementary schools begin at 9:15, and almost all of the rest begin at 8:15). As a result, it is not clear if there is no effect because start times do not impact the academic performance of prepubescent students, or because the schools start much later and only early start times effect performance. Columns 3 and 4 present results using the (future) start times in grade 6. These specifications serve as a falsification test. If students with higher test scores in Elementary school tend to be assigned to later starting schools, the coefficient on 6th Grade start time would be positive. That is not the case here, the effect of grade 6 start times is statistically insignificant and has a negative sign.

[Table 9 about here.]

High school students do not take a specific test at the end of each *grade*. Instead they are required to take an exam at the end of specific *courses*, such as geometry or physical science. There is no explicit requirement for the grade in which each course is to be taken, and the typical sequence often varies from school to school. For example, in some schools, students typically take Geometry before Algebra II, while in others they take Geometry after Algebra II. Furthermore some students take these end-of-course exams in eighth grade (particularly Algebra I). However, all students are required to take the "High School Comprehensive Exam" at the end of grade 10.[21] The comprehensive exam measures growth in reading and math since the end of grade eight and is in most respects similar to the end of grade tests taken in grades 3-8. An important distinction is that students taking the comprehensive exam may not be enrolled in a math class during their sophomore year. Table 6 presents estimation results for the high school comprehensive test. Columns 1 and 4 use the high school start time, columns 2 and 5 use the student's start time in 8th grade and columns 3 and 6 use both. Each specification uses a school fixed effect and so are comparable to the middle school results found in columns 1 and 3 of tables 6. The effect of a one-hour-later start time in grade ten is not slightly larger than the effect in middle school: 3.3 percentiles on the math test and 3.7 percentiles on the reading test. A one-hour later start time in eighth grade increases test scores on the high school comprehensive exam by 2.0 percentile points for math and 1.6 percentile points for reading. When both start times are included in the same specification, results are similar, although the results for high school are imprecise. In comparison, the effect was 2.1 percentile points for math and 1.5 percentiles for reading in grade eight. This indicates that the negative impact of early start times persists over time.

Increased sleep is not the only possible reason why later starting students have higher test scores. Students in early-starting schools could be more likely to skip breakfast. Since they also get out of school earlier, they could spend more (or less) time playing sports, watching television or doing homework. They could be more likely to be absent, tardy or have behavioral problems in school. Other explanations are possible as well. While my data do not allow me to explore all possible mechanisms, I present evidence in favor or against some explanations below.

A unique aspect of the NCERDC data set is that it includes self-reported amounts of television watched per day and time spent doing homework per week. Column 1 of table 6 shows the result of

[21] Due to changes in state policy, the High School Comprehensive Exam exam was not administered in the 2001-02, 2004-05 or 2005-06 school years.

a regression of minutes of television per day against start time and a full set of covariates. Students who start school one hour later watch 15 fewer minutes of television per day. In Column 2, I regress minutes of homework per week against start time. Students who start school 1 hour later spend 17 minutes more on homework per week.[22] These results could be a result of students who start school earlier spending more time at home alone. Students who start school earlier also come home from school earlier and likely go to bed earlier. As a result, early-starting students spend more time at home alone and less time at home with their parents, relative to late starting students. If students watch television when they are home alone and do their homework when their parents are home, this could explain why students who start school later have higher test scores. Another way of putting this, is that it is not early start times that matter, but early end times.

The existing start times literature tends to find that students in early-starting schools are both more likely to be tardy to school and to be absent.[23] The data set used in this paper only has data on absences for two years: the 2003-04 and 2004-05 school years. Since no schools had a change in start time between those two years (there was one new school), I can only consider variation in start times across schools. Column 3 of table 6 presents the results of a regression of days absent per year on start time and a full set of covariates. Students who start school one hour later have 1.3 fewer absences (the median student has 5 absences). Reduced absences may explain why later starting students have higher test scores. Students who have an early start time miss more school (this may or may not be a result of getting less sleep) and as a result perform worse on standardized tests.

[Table 10 about here.]

[22]For both television and homework, the results are similar if I use a school fixed effect, identifying the differences based only on the variation in start times within schools.

[23] See for example (Wahlstrom, 2000).

6 Conclusion

Later school start times have been often cited in the popular press as a way to increase student performance. However, there has not been much empirical evidence supporting this claim, or calculating how large of an effect later start times might have. Using variation in start times both within and across schools, I find that an increase in start times by one hour would lead to a 3 percentile point gain in both math and reading test scores for the average student. Using only variation within schools the effect is 2 percentile points for math and 1 percentile point fro reading. The impact of middle school start times on test scores persists into the tenth grade. The effect is larger for the lower end of the distribution of test grades. I find evidence that reduced sleep, combined with the adolescent hormonal cycle is a mechanism through which start times may affect test scores. I also find evidence supporting time at home with parents as a mechanism.

These results suggest that delaying start times may be a cost-effective method of increasing student performance. Since the effect of later start times is stronger for the lower end of the distribution of test scores, later start times may be particularly effective in meeting accountability standards that require a minimum level of competency. If elementary students are not affected by later start times (which can not be definitively determined from my data), it may be possible to increase test scores for middle school students at zero cost by having elementary schools start first. Alternatively, the entire schedule could be shifted later into the day. However, these changes may be politically unfeasible due to childcare constraints for younger students and jobs and after school activities for older students. A third option would be to eliminate tiered busing schedules and have all schools begin at the same time. A plausible estimate of the cost of moving start times later is the additional cost of running a single tier bus system. The WCPSS Transportation Department estimates that over a ten year period from 1993-2003, using a three tiered bus system saved roughly $100 million in transportation costs (Wake County Public School System Department of Transportation, 2004). With approximately 100,000 students per year divided into three tiers, it would cost roughly $150 per student each year to move each student in two earliest start time tiers to the latest start time. In comparison, Krueger (1999) finds the reducing class size by one third increases test scores by 4 percentile ranks in the first year at a cost of $2151 per student per year. While very rough, these calculations suggest that increased spending on bus transportation, in order to delay the beginning of the school day, may be substantially cheaper than reducing class size to gain the same improvement in test scores.

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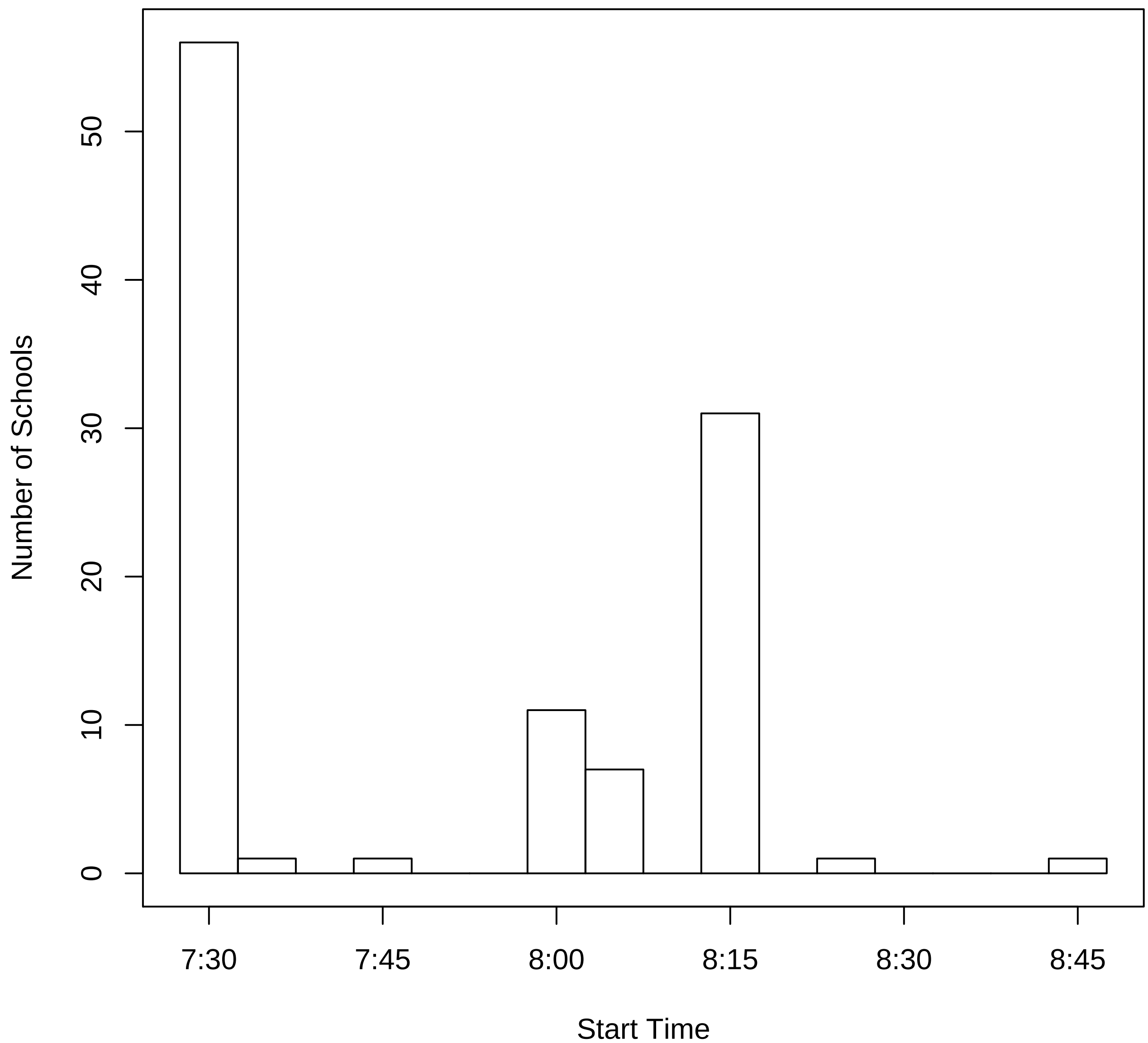
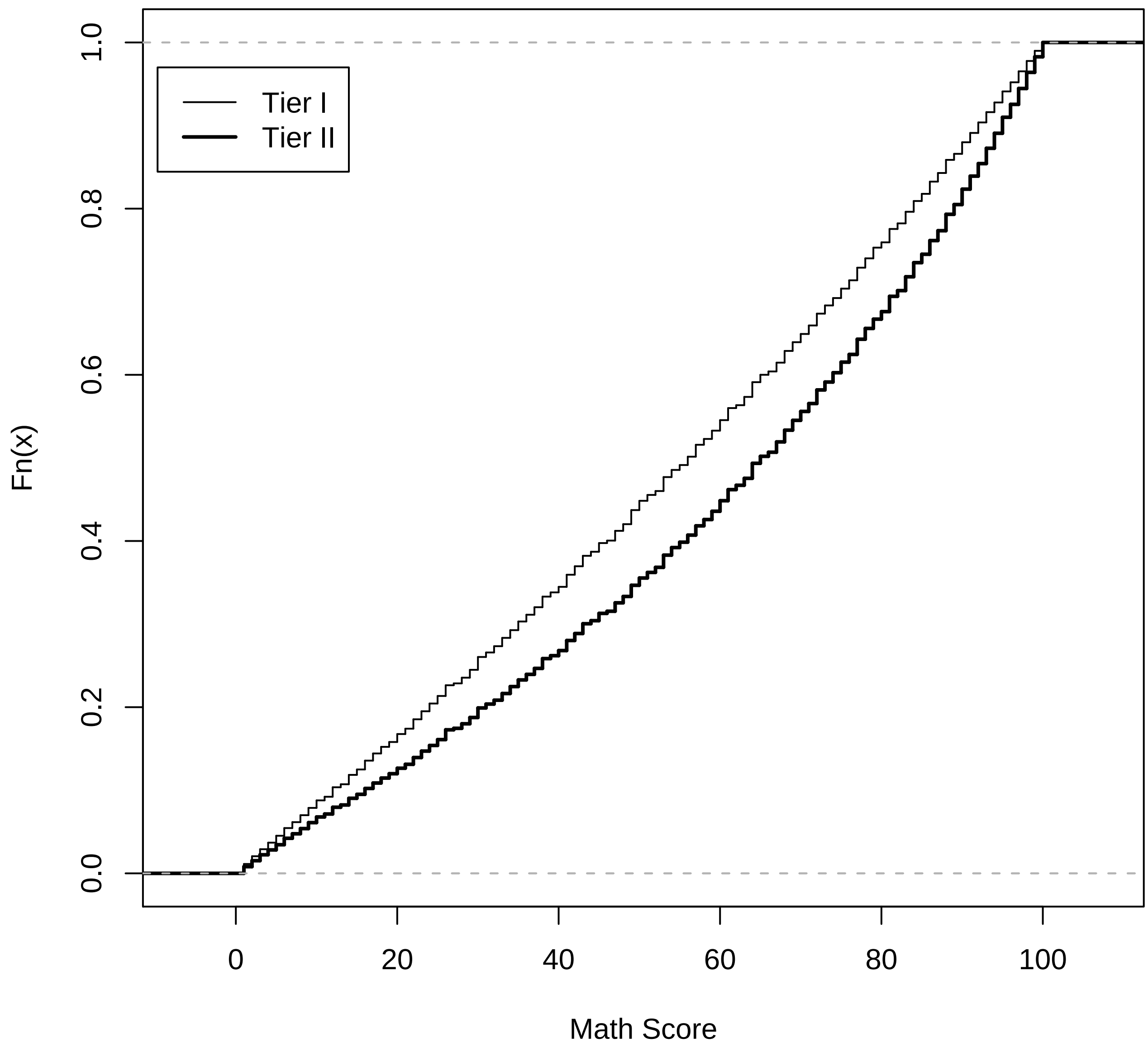
List of Figures

Figure 1: Histogram of Middle School Start Times



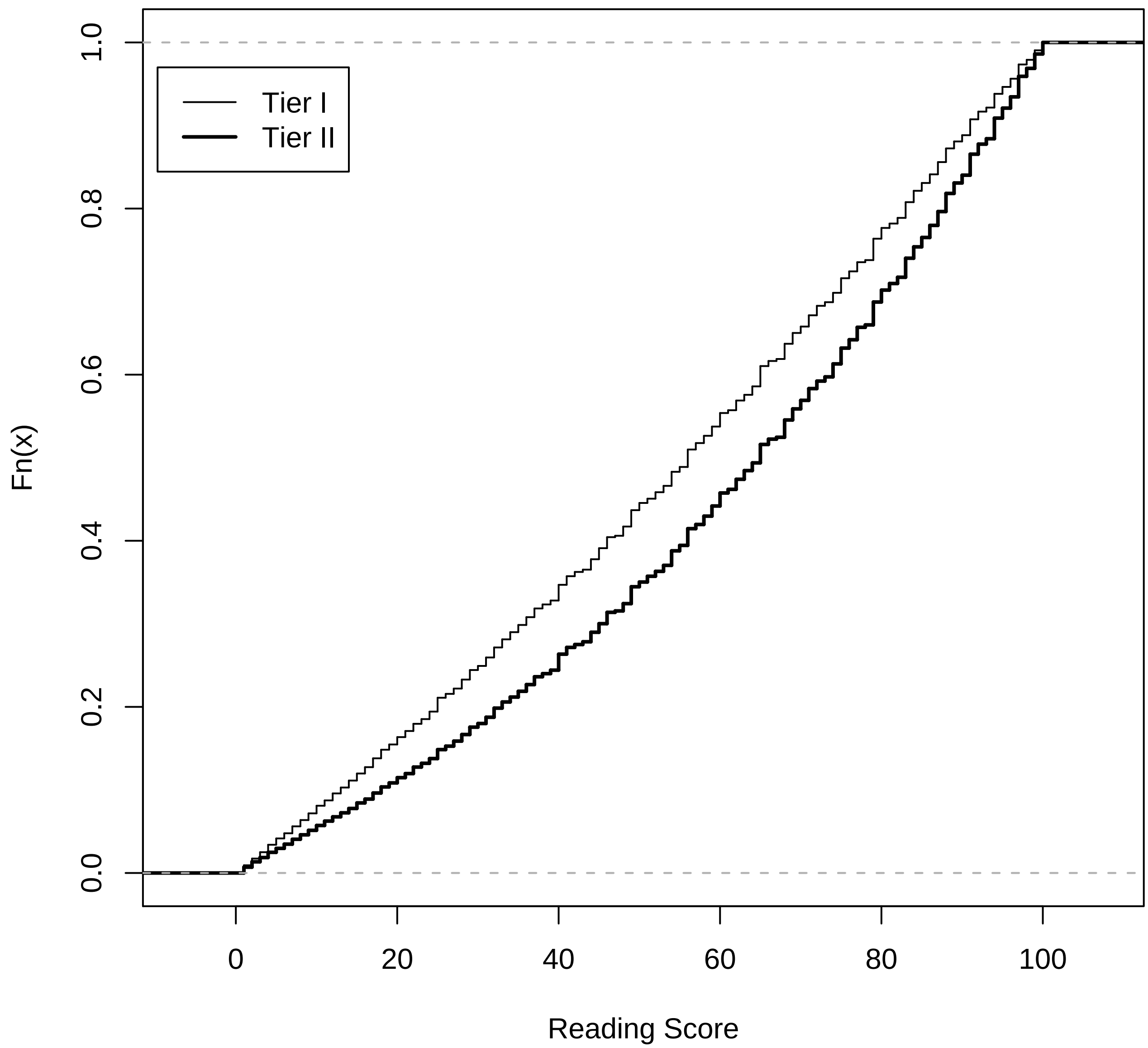
Source: Author's calculations from data provided by the WCPSS transportation department. Figure includes all non-magnet middle schools in Wake County, NC from 1999-2006. Each school appears once per school year.

Figure 2: Empirical Cumulative Distribution of Math Test Scores by Start Time Tier



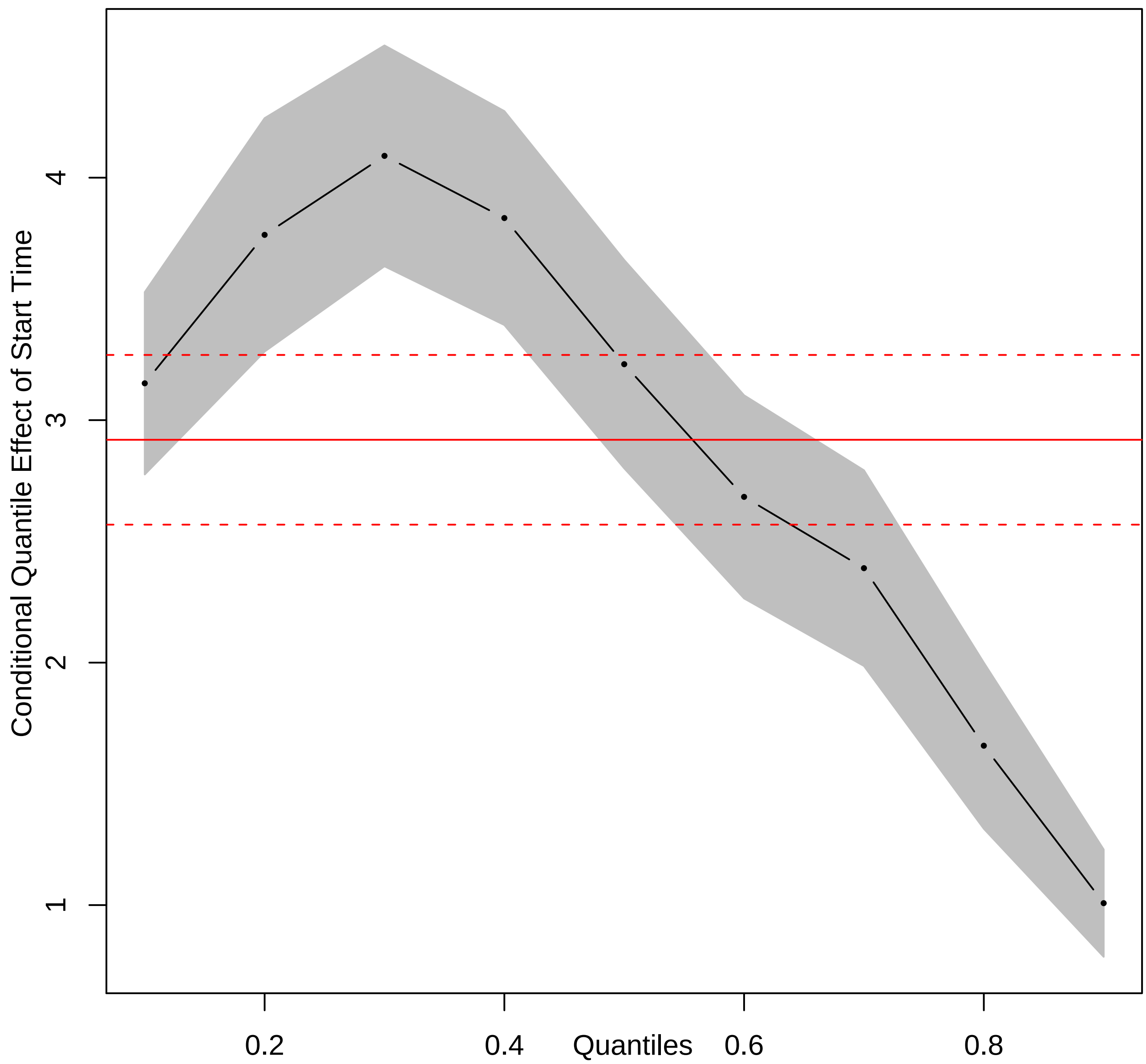
Note: Data includes all middle school students in non-magnet schools in the Wake County Public School System from 1999-2006. Test score is the percentile rank on the end of grade math test administered to all students in North Carolina.

Figure 3: Empirical Cumulative Distribution of Reading Test Scores by Start Time Tier



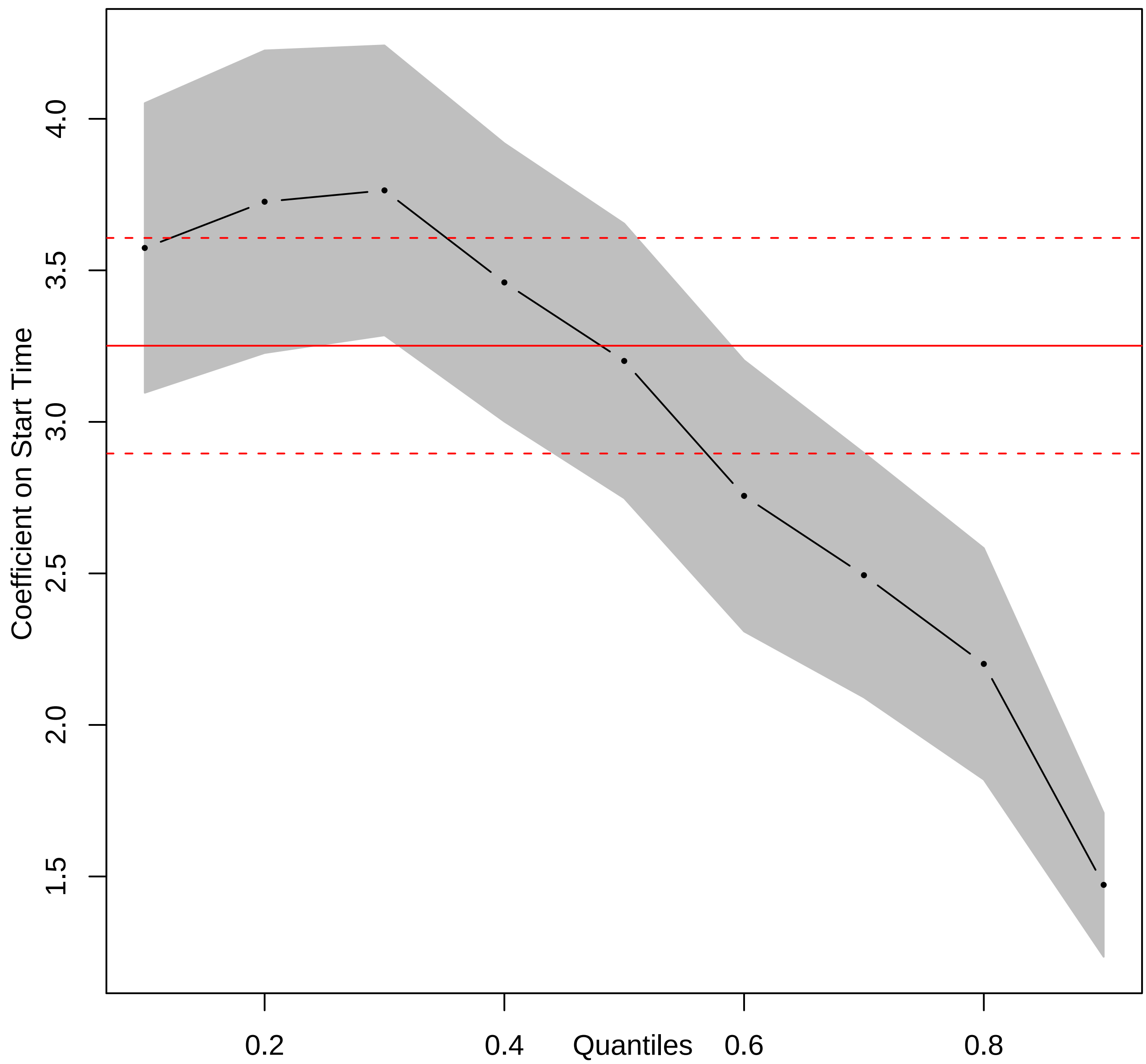
Note: Data includes all middle school students in non-magnet schools in the Wake County Public School System from 1999-2006. Test score is the percentile rank on the end of grade reading test administered to all students in North Carolina.

Figure 4: Quantile Regression of Math Test Score on Start Time



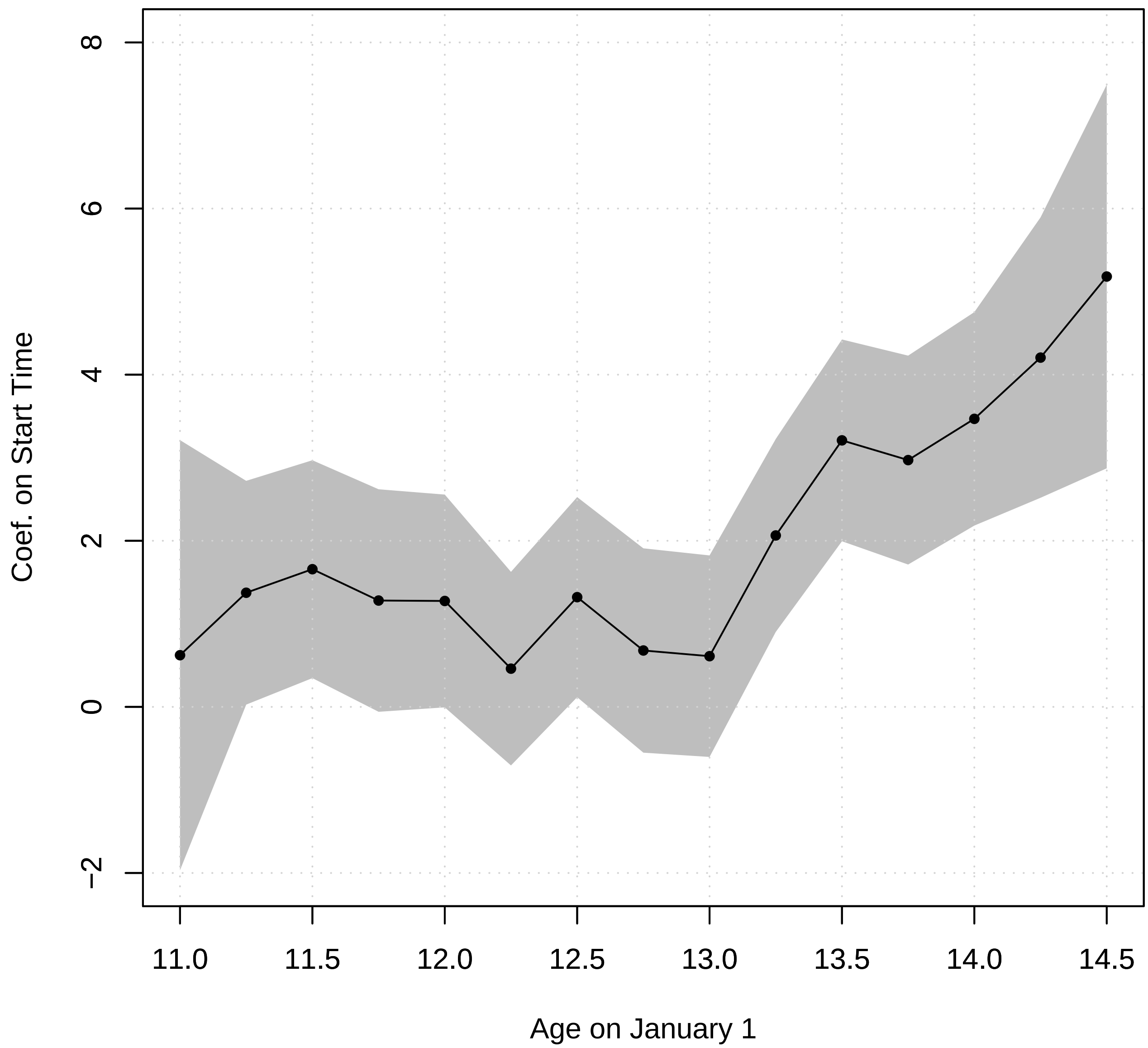
Note: Each point represents the conditional quantile effect of a one hour later start time on the percentile rank on the end of grade math exam. The shaded area is a 90% confidence interval. The solid horizontal line is the corresponding OLS estimate, and the dotted horizontal lines bound a a 90% confidence interval of the OLS estimate. See text for additional details.

Figure 5: Quantile Regression of Reading Test Score on Start Time



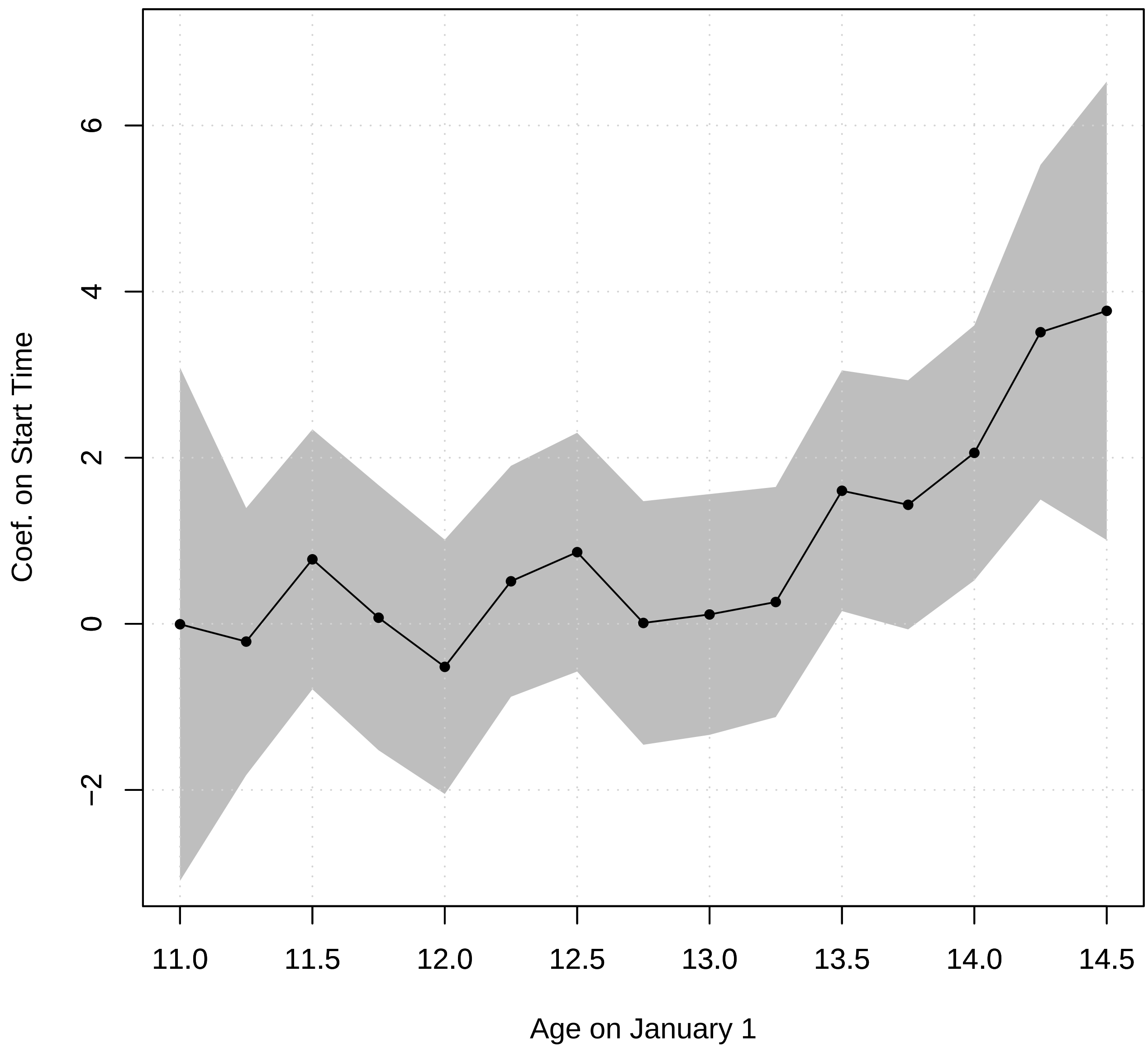
Note: Each point represents the conditional quantile effect of a one hour later start time on the percentile rank on the end of grade reading exam. The shaded area is a 90% confidence interval. The solid horizontal line is the corresponding OLS estimate, and the dotted horizontal lines bound a a 90% confidence interval of the OLS estimate. See text for additional details.

Figure 6: Effect of Start Time on Math Test Score by Age



Note: Each point represents the effect of a one-hour later start time on the percentile rank on the end of grade math exam. The shaded area is a 95% confidence interval. Age is measured in quarter years as of January 1. See text for additional details.

Figure 7: Effect of Start Time on Reading Test Score by Age



Note: Each point represents the effect of a one-hour later start time on the percentile rank on the end of grade reading exam. The shaded area is a 95% confidence interval. Age is measured in quarter years as of January 1. See text for additional details.

List of Tables

Table 1: Nationwide and Wake County Student Start Time Statistics

	Percentiles				
	10%	25%	50%	75%	90%
Nationwide	7:35	7:55	8:00	8:30	8:45
Wake County, NC	7:30	7:30	7:30	8:15	8:15

	S. Dev (Minutes)	Mode	Percentage at Mode	Sample Size
Nationwide	27.7	8:00	26.7%	4,568
Wake County, NC	20.4	7:30	53.1%	173,791

Students are in grade 6-8. Nationwide data comes from the ASPA-NHES (2001). Wake County data is pooled data from 1999-2006.

Table 2: Changes in Start Times

		New Start Time							
		7:30	7:35	7:45	8:00	8:05	8:15	8:25	8:45
	7:30	8	-	-	1	-	2	-	-
	7:35	-	-	-	-	-	1	-	-
Old	7:45	-	-	1	-	-	-	-	-
Start	8:00	1	-	-	1	-	4	1	-
Time	8:05	-	-	-	-	1	-	-	-
	8:15	2	-	-	-	-	-	-	-
	8:25	-	-	-	1	-	-	-	-
	8.45	-	-	-	-	-	1	-	-

Source: Author's tabulation. Each cell contains the number of schools that changed their start time from the given old start time to the new start time. Schools on the diagonal had no change in start time.

Table 3: Means by Start Time for 2000 & 2006

Panel A: Student Characteristics

	2000		2006	
	Tier I	Tier II	Tier I	Tier II
Female	0.495	0.481	0.494	0.490
	(0.005)	(0.006)	(0.006)	(0.006)
Age	13.545	13.544	13.630	13.620
	(0.009)	(0.012)	(0.013)	(0.013)
Black	0.240	0.207	0.247	0.249
	(0.004)	(0.005)	(0.005)	(0.005)
Hispanic	0.0516	0.0253	0.102	0.0721
	(0.002)	(0.003)	(0.003)	(0.003)
Free Lunch Eligible	0.237	0.140	0.284	0.243
	(0.004)	(0.005)	(0.005)	(0.005)
Parent's Education	14.86	15.00	14.45	14.81
	(0.02)	(0.03)	(0.03)	(0.04)
Math Score	55.92	59.63	56.29	61.41
	(0.285)	(0.37)	(0.347)	(0.336)
Reading Score	56.5	59.49	54.65	60.1
	(0.278)	(0.362)	(0.336)	(0.325)
Number of Students	10544	6082	7191	7675

Panel B: School Characteristics

	2000		2006	
	Tier I	Tier II	Tier I	Tier II
% Black	0.256	0.237	0.292	0.289
	(0.034)	(0.046)	(0.050)	(0.054)
% Hispanic	0.0443	0.0261	0.103	0.0714
	(0.006)	(0.009)	(0.016)	(0.017)
% Free Lunch Eligibile	0.239	0.156	0.294	0.250
	(0.060)	(0.080)	(0.051)	(0.055)
Avg. Parent Education	14.90	14.89	14.61	14.68
	(0.238)	(0.322)	(0.364)	(0.420)
Pupil/Teacher Ratio	15.65	14.80	14.91	15.66
	(0.47)	(0.63)	(0.38)	(0.40)
Enrollment	958.5	1013.7	898.9	1096.4
	(87.6)	(118.5)	(49.0)	(52.4)
Avg. math score	56.14	58.48	55.88	61.03
	(2.59)	(3.51)	(4.22)	(4.51)
Avg. Reading Score	56.78	58.23	54.22	59.71
	(2.45)	(3.31)	(3.01)	(3.22)
Start Time	7:32	8:01	7:30	8:14
	(0:01)	(0:02)	(0:01)	(0:01)
Schools	11	6	8	7

Tier I: 7:30-7:45. Tier II: 8:00-8:45. Standard errors in parentheses. Panel B is unweighted.

Table 4: Specifications Using Variation Within and Across Schools: Math

	(1)	(2)	(3)	(4)
Start Time	9.478***	4.486***	4.838***	2.919***
	(2.425)	(1.667)	(1.660)	(1.104)
Female		-0.736***	-0.858***	-1.671***
		(0.233)	(0.228)	(0.193)
Age		-1.729***	-1.699***	-4.756***
		(0.170)	(0.168)	(0.367)
Black		-17.07***	-16.24***	-15.95***
		(0.445)	(0.369)	(0.353)
Hispanic		-4.891***	-5.239***	-5.586***
		(0.558)	(0.530)	(0.501)
AG		23.30***	23.02***	23.17***
		(0.438)	(0.415)	(0.388)
Learning Disability		-6.492***	-7.594***	-12.63***
		(1.998)	(1.842)	(1.193)
Limited English		-11.47***	-12.68***	-12.45***
		(0.972)	(0.977)	(1.096)
Parent Education		3.004***	2.793***	2.666***
		(0.164)	(0.127)	(0.107)
Free Lunch		-6.796***	-6.406***	-5.241***
		(0.444)	(0.357)	(0.333)
Enrollment			-0.00586	-0.00527*
			(0.00363)	(0.00316)
Pupil/Teacher Ratio			0.0122	-0.0257
			(0.0687)	(0.0542)
% Black			-16.38***	-18.54***
			(5.725)	(4.775)
% Hispanic			52.98***	8.127
			(15.42)	(13.96)
% Free Lunch			-3381.4	-398.9
			(2473.4)	(2049.2)
Year Effect	No	No	No	Yes
Grade Effect	No	No	No	Yes
Observations	102521	102521	102521	102521
Adjusted R^2	0.013	0.452	0.464	0.490

Data is from WCPSS grades 6-8 during the 1999-2006 school years. Dependent variable is score on end of grade math test. All specifications include a constant term. Additional ethnicity controls not reported. Standard errors (robust to clustering at the school level) in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Specifications Using Variation Within and Across Schools: Reading

	(1)	(2)	(3)	(4)
Start Time	9.455***	4.810***	4.821***	3.236***
	(2.050)	(1.292)	(1.293)	(0.790)
Female		3.325***	3.233***	2.608***
		(0.203)	(0.199)	(0.180)
Age		-1.475***	-1.465***	-3.527***
		(0.136)	(0.131)	(0.280)
Black		-16.22***	-15.54***	-15.30***
		(0.321)	(0.307)	(0.305)
Hispanic		-5.358***	-5.606***	-5.863***
		(0.495)	(0.475)	(0.451)
Academically Gifted		19.99***	19.79***	19.93***
		(0.356)	(0.336)	(0.313)
Learning Disability		-7.028***	-7.884***	-12.13***
		(1.586)	(1.481)	(1.088)
Limited English		-19.11***	-19.96***	-19.74***
		(0.785)	(0.852)	(0.919)
Parent Education		2.774***	2.618***	2.543***
		(0.136)	(0.113)	(0.0955)
Free Lunch		-6.943***	-6.666***	-5.749***
		(0.408)	(0.357)	(0.355)
Enrollment			-0.00293	-0.00240
			(0.00276)	(0.00248)
Pupil/Teacher Ratio			0.0665	0.0314
			(0.0614)	(0.0436)
% Black			-13.35***	-15.39***
			(4.486)	(3.305)
% Hispanic			46.35***	10.42
			(12.89)	(10.24)
% Free Lunch			-3382.3*	-783.3
			(1849.9)	(1364.1)
Year Effect	No	No	No	Yes
Grade Effect	No	No	No	Yes
Observations	102265	102265	102265	102265
Adjusted R^2	0.014	0.421	0.428	0.446

Data is from WCPSS grades 6-8 during the 1999-2006 school years. Dependent variable is score on end of grade math test. All specifications include a constant term. Additional ethnicity controls not reported. Standard errors (robust to clustering at the school level) in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Specifications Using Variation Within Schools Over Time

	(1) Math	(2) Reading	(3) Math	(4) Reading
Start Time	2.137***	1.479***	1.803***	0.822**
	(0.419)	(0.427)	(0.290)	(0.346)
Female	-1.746***	2.523***		
	(0.131)	(0.134)		
Age	-4.704***	-3.519***	-0.104	0.121
	(0.119)	(0.122)	(0.266)	(0.325)
Black	-15.81***	-15.27***		
	(0.184)	(0.188)		
Hispanic	-5.479***	-5.841***		
	(0.333)	(0.341)		
Academically Gifted	23.23***	19.84***	1.095***	0.534
	(0.182)	(0.185)	(0.290)	(0.345)
Learning Disability	-13.45***	-12.73***	0.549**	0.0370
	(0.191)	(0.195)	(0.258)	(0.308)
Limited English	-12.45***	-19.91***	-1.354*	-1.070
	(0.468)	(0.492)	(0.812)	(0.971)
Parent Education	2.619***	2.470***	-0.0347	0.0830**
	(0.0418)	(0.0426)	(0.0351)	(0.0417)
Free Lunch	-5.518***	-5.995***	0.0792	0.105
	(0.193)	(0.197)	(0.228)	(0.273)
Pupil/Teacher Ratio	-0.114***	-0.0565**	-0.0366**	-0.0179
	(0.0233)	(0.0238)	(0.0152)	(0.0181)
Enrollment	-0.000840	0.00112	-0.000827	0.000233
	(0.000887)	(0.000904)	(0.000634)	(0.000754)
% Black	-2.698	-2.553	1.867	4.729**
	(2.826)	(2.885)	(1.816)	(2.163)
% Hispanic	-41.30***	-21.35***	5.029	3.842
	(4.647)	(4.745)	(4.058)	(4.831)
% Free Lunch	-19.96	-194.8	-697.9	-633.6
	(644.7)	(656.9)	(442.1)	(526.0)
Year Effect	Yes	Yes	Yes	Yes
Grade Effect	Yes	Yes	Yes	Yes
Fixed Effect	School	Student-School	School	Student-School
Observations	100680	100680	100427	100427
Adjusted R^2	0.37	0.89	0.33	0.83

Dependent variable is score on end of grade math or reading exam. All specifications include a constant term. Additional ethnic controls omitted. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Results for Alternate Specifications and By Subpopulation

Panel A: Alternate Specifications					
	Math	Math	Reading	Reading	Sample Size
Full Specification	2.702***	1.898***	3.204***	0.797**	100695
	(0.942)	(0.291)	(0.566)	(0.346)	
Magnet Included	2.011**	1.442***	2.684***	0.744**	166664
	(0.918)	(0.244)	(0.536)	(0.292)	
Z Scores	0.0928***	0.0599***	0.103***	0.0297**	100695
	(0.0328)	(0.0100)	(0.0208)	(0.0122)	

Columns 1 and 3 use both variation within and across schools (no fixed effect). Columns 2 and 4 use only variation within schools for specific students (student-school fixed effect). Sample size is for math test, sample size for reading test is typically slightly smaller. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: High School Comprehensive

	(1) Math	(2) Math	(3) Math	(4) Reading	(5) Reading	(6) Reading
Start Time	3.326**		4.355	3.711**		6.999
	(1.327)		(5.612)	(1.482)		(6.885)
Start Time (8th Grade)		2.033***	1.983***		1.603**	1.553**
		(0.671)	(0.673)		(0.760)	(0.760)
Female	-3.435***	-3.655***	-3.656***	2.640***	2.450***	2.449***
	(0.271)	(0.389)	(0.389)	(0.307)	(0.446)	(0.446)
Age	-4.296***	-2.682***	-2.673***	-3.961***	-3.202***	-3.187***
	(0.564)	(0.840)	(0.841)	(0.656)	(1.081)	(1.081)
Black	-12.23***	-10.58***	-10.58***	-13.07***	-11.17***	-11.17***
	(0.407)	(0.617)	(0.617)	(0.446)	(0.681)	(0.681)
Hispanic	-6.593***	-3.416***	-3.405***	-6.807***	-4.375***	-4.360***
	(0.832)	(1.163)	(1.163)	(0.907)	(1.316)	(1.316)
Asian	2.851***	1.624*	1.638*	-4.042***	-4.221***	-4.198***
	(0.619)	(0.875)	(0.875)	(0.674)	(0.954)	(0.955)
Other	-5.921***	-4.375***	-4.368***	-3.491***	-0.484	-0.474
	(0.961)	(1.610)	(1.610)	(1.089)	(1.877)	(1.880)
Academically Gifted	11.71***	12.30***	12.30***	13.07***	14.58***	14.58***
	(0.356)	(0.501)	(0.501)	(0.389)	(0.547)	(0.547)
Learning Disability	-10.14***	-10.69***	-10.67***	-11.38***	-11.78***	-11.77***
	(0.501)	(0.751)	(0.751)	(0.560)	(0.878)	(0.878)
Limited English	-4.279***	-7.943***	-7.947***	-15.27***	-13.46***	-13.51***
	(1.130)	(2.047)	(2.046)	(1.164)	(2.142)	(2.147)
Parent Education	1.024***	1.095***	1.100***	1.319***	1.174***	1.179***
	(0.0832)	(0.145)	(0.146)	(0.0906)	(0.154)	(0.154)
Free/RP Lunch	-2.669***	-3.416***	-3.410***	-3.394***	-4.243***	-4.244***
	(0.592)	(0.729)	(0.730)	(0.663)	(0.840)	(0.840)
Enrollment	-0.00307**	0.0164**	0.0158*	-0.00565***	0.0364***	0.0371***
	(0.00135)	(0.00822)	(0.00814)	(0.00152)	(0.0126)	(0.0127)
Pupil/Teacher Ratio	0.188	-0.217	-0.311	0.475**	-1.936	-2.272*
	(0.164)	(0.840)	(0.867)	(0.185)	(1.191)	(1.275)
% Black	17.36	-106.4***	-125.2***	20.02	-45.75	-80.87
	(12.13)	(33.93)	(44.51)	(13.33)	(38.69)	(53.44)
% Hispanic	-94.57***	-127.8**	-125.2**	-35.56	-91.87	-94.54
	(24.81)	(61.95)	(61.76)	(27.73)	(68.99)	(69.11)
% Free/RP Lunch	-3.459	129.8***	135.8***	-12.45	40.78	53.67
	(6.552)	(34.47)	(36.49)	(7.626)	(38.11)	(40.96)
Observations	18491	8512	8512	18221	8338	8338

Dependent variable is score on high school comprehensive math or reading exam. All specifications include year, course and high school effects. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Results for Elementary Schools

	(1) Math	(2) Reading	(3) Math	(4) Reading
Start Time	-0.217	0.118		
	(0.196)	(0.214)		
Start Time (Grade 6)			-0.404	-0.471
			(0.289)	(0.280)
Female	1.130	-0.359	-1.645***	2.587***
	(1.745)	(2.106)	(0.192)	(0.186)
Age	0.0292	0.00233	-0.124	-0.574***
	(0.287)	(0.248)	(0.186)	(0.189)
Black	1.263	-0.926	-22.05***	-19.04***
	(1.608)	(1.716)	(0.275)	(0.268)
Hispanic	3.270	2.133	-13.11***	-13.28***
	(1.995)	(2.129)	(0.535)	(0.512)
Academically Gifted	0.0248	-0.0314	10.31***	10.73***
	(0.149)	(0.173)	(0.147)	(0.158)
Learning Disability	1.430***	0.965***	-7.909***	-9.964***
	(0.217)	(0.229)	(0.256)	(0.259)
Limited English	-0.0829	-1.240**	-5.998***	-8.774***
	(0.516)	(0.552)	(0.544)	(0.547)
[.75em] Parent Education	-0.0956***	-0.0924**	1.288***	1.536***
	(0.0362)	(0.0398)	(0.0385)	(0.0410)
Free Lunch	-0.425*	-0.238	-6.079***	-6.668***
	(0.242)	(0.264)	(0.224)	(0.231)
P/T Ratio	0.00166	0.0145	-0.0726***	0.00822
	(0.0264)	(0.0290)	(0.0267)	(0.0282)
Enrollment	-0.00235***	-0.000797	-0.00171***	-0.00190***
	(0.000714)	(0.000782)	(0.000604)	(0.000626)
% Black	-2.863***	0.836	-12.85***	-7.421***
	(0.981)	(1.076)	(0.792)	(0.813)
% Hispanic	4.404**	3.708*	-5.443***	-3.078*
	(1.860)	(2.030)	(1.684)	(1.732)
% Free Lunch	437.9	-55.85	905.9**	-467.0
	(409.9)	(442.9)	(404.5)	(424.1)
Observations	168474	167552	99413	99037

Dependent variable is score on end of course math or reading exam. Additional controls omitted. All columns include grade and year effects. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10: Mechanisms

	(1) TV	(2) Homework	(3) Absences
Start Time	-15.25***	16.94***	-1.309***
	(1.763)	(4.293)	(0.335)
Female	-7.914***	23.87***	-0.301**
	(0.802)	(1.100)	(0.117)
Age	1.905***	-5.890***	2.258***
	(0.639)	(0.890)	(0.154)
Black	62.13***	-20.43***	-1.095***
	(1.023)	(1.385)	(0.212)
Hispanic	6.490***	1.330	-2.122***
	(1.548)	(2.177)	(0.262)
Asian	-8.299***	24.62***	-3.089***
	(1.606)	(2.477)	(0.234)
Other	19.74***	-8.364***	0.261
	(2.061)	(2.888)	(0.248)
Parent Education	-4.759***	7.200***	-0.502***
	(0.224)	(0.431)	(0.0402)
Free Lunch	7.487***	-6.763***	2.510***
	(1.187)	(1.534)	(0.149)
Enrollment	0.00245	-0.0000605	0.00364***
	(0.00587)	(0.0156)	(0.000993)
Pupil/Teacher Ratio	0.0824	-0.610*	-0.0277
	(0.108)	(0.314)	(0.0374)
% Black	65.43***	-60.59***	4.551*
	(5.667)	(13.75)	(2.637)
% Hispanic	-50.43**	-66.54	-5.826
	(23.31)	(46.75)	(4.842)
% Free Lunch	4322.1	-10963.8	261.3
	(4090.5)	(10870.0)	(2832.9)
Constant	276.5***	69.87**	-11.61***
	(17.11)	(31.29)	(3.240)
Observations	101645	101692	30896
Adjusted R^2	0.158	0.058	0.104

TV is measured in minutes per day, Homework in minutes per week, and Absences in days per year. Standard errors (robust to clustering at the school level) in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ See text for additional details.