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A Multi-State, Student-Level Analysis of the Effects of the Four-Day School Week on Student Achievement and Growth

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Abstract

Four-day school weeks are becoming increasingly common in the United States, but their effect on students' achievement is not well-understood. The small body of existing research suggests the four-day schedule has relatively small, negative average effects (~-0.02 to -0.09 SD) on annual, standardized state test scores in math and reading, but these studies include only a single state or are limited by using district-level data. We conduct the first multi-state, student-level analysis that estimates the effect of four-day school weeks on student achievement and a more proximal measure of within-year growth using NWEA MAP Growth assessment data. We conduct difference-in-differences analyses to estimate the effect of attending a four-day week school relative to attending a five-day week school. We estimate significant negative effects of the schedule on spring reading achievement (-0.07 SD) and fall-to-spring achievement gains in math and reading (-0.06 SD in both). The negative effects of the schedule are disproportionately larger in non-rural schools than rural schools and for female students, and they may grow over time. Policymakers and practitioners will need to weigh the policy's demonstrated negative average effects on achievement in their decisions regarding how and if to implement a four-day week.

Four-day school weeks are a growing phenomenon in the United States, but their effect on students' achievement is not well-understood. The four-day week schedule was implemented in over 650 public school districts in 24 states as of the spring of 2019 (Thompson et al., 2021a). In the 2020-21 school year, many districts adopted alternative school schedules, including four-day school weeks, in response to challenges related to COVID-19 (Altavena, 2020). Though some of those schedule changes were temporary, anecdotal evidence across several states further suggests increasing numbers of districts adopted the four-day school week for 2021-22 school year or are adopting it for the 2022-23 school year (Mazur, 2022; Nickerson, 2022; Russell, 2022; Vidmar, 2022).

With this rapid growth in four-day school week use, research around the academic implications of these school schedules has also been on the rise. The majority of the existing research (Kilburn et al., 2021; Morton, 2021; Morton, 2022; Thompson, 2021b; Thompson & Ward, 2022; Thompson et al., 2021b) on the academic effects of the schedule suggests relatively small, negative average effects (~-0.02 to -0.09 standard deviations (SD)) of the policy on student achievement in math and reading. Despite providing evidence that improves upon the information district leaders and communities have historically used in making these four-day school week decisions, this body of research is limited in several ways. First, much of the research to date presents only average effects of the policy that may mask important heterogeneity in the effects across and within districts. Moreover, all of the existing work leverages only annual spring testing data as the academic outcome of interest, which conflates school-year effects with year-over-year effects that include the summer. Finally, most of the studies also use district-level data and/or use data from only one state. District-level data, as opposed to student-level data, can result in small sample sizes and analyses that may be statistically underpowered to detect an effect of the four-day school week schedule. Effects estimated using data only from a single state may not generalize to other states.

To address these limitations, we conduct a multi-state, student-level analysis that provides a more precise estimate of the effect of four-day school weeks on student achievement and within-year growth. More specifically, we use the quasi-experimental difference-in-differences approach to estimate the effect of attending a four-day week school relative to attending a five-day week school. Consistent with the existing literature, we find negative effects of the schedule on year-over-year spring achievement, and we contribute new, more proximal estimates of the negative effects of the schedule on school-year achievement gains. We find that the negative effects are disproportionately greater in non-rural schools than rural schools and for female students. Finally, we also find suggestive evidence that the negative effects of the schedule grow in magnitude over time and that they appear to vary by student race.

A more precise understanding of the effects of four-day school weeks on academic outcomes and the conditions under which and for whom they are positive or negative is critical, as policies enabling four-day school weeks are currently being disputed by many state legislatures – most notably in Minnesota, New Mexico, and Oklahoma. Indeed, policy that thwarts four-day weeks because of the reported negative average effects that may mask heterogeneous effects could harm districts who have implemented the schedule under conditions (e.g., maintained or increased instructional time, rural areas) such that achievement was not negatively affected. Given the sustained recent growth of four-day school weeks, the relevant ongoing legislation, and their increased use in response to and following COVID-19, research on the implementation and effects of this policy is unprecedentedly salient and consequential.

Background on Four-Day School Weeks

Districts implementing four-day school weeks, which are a primarily small, rural districts,[1] typically increase the length of the four days they have school and have either Fridays or Mondays off (Thompson et al., 2021a). These adjustments typically result in fewer annual days and hours at school for four-day week students relative to five-day week students. However, schools may reorganize daily schedules such that the resulting typical differences in subject-specific instructional time on a four-day week schedule are unknown (Kilburn et al., 2021). Some school districts may also offer "fifth day" remedial and/or experiential learning opportunities.[2]

Four-day school weeks are made possible by state policies that require districts to meet a minimum number of instructional hours without mandating a minimum number of instructional days. The number of schools operating on a four-day school week has increased sharply, by over 600%, over the past two decades, from 257 schools across 108 districts in 1999 to 1,607 schools across 662 school districts in 24 states[3] in 2019 (Thompson et al., 2021a). This estimate is also likely conservative, as four-day school week implementation is systematically tracked in only six states (Heyward, 2018). A recent survey (Thompson et al., 2021a) suggests that, historically, school districts have turned to the four-day school week for financial savings, attendance-related

[1] There are a few districts that are exceptions to this pattern; for example, an urban district in Colorado that serves 18,000 students adopted a four-day week at the start of the 2018-2019 school year and two urban districts in Arizona that each serve over 12,000 students adopted a four-day week for the 2020-2021 school year in response to COVID-19 (Altavena, 2020).

[2] There is only limited information on what happens in districts on the "fifth day" that students are not in school. A study that conducted interviews and surveys in the winter of 2019 of 18 rural and town school districts (located across three states) operating on four-day school weeks found that district-run services or programming for students on the fifth day were rare (Kilburn et al., 2021). Indeed, students of all ages reported being primarily at home on the fifth day, spending their time on the fifth day primarily on free time, chores, playing sports, and working for their family or at a job. The study also found that parents and students were highly satisfied with the four-day week and overwhelmingly reported (85% of parents and 95% of students) that they would choose a four-day week over a five-day week. However, whether fifth day programming, students' experiences, and families' perceptions of four-day school weeks are similar in other districts and states is unknown.

[3] States with at least one school operating on a four-day school week schedule during the 2018-2019 school year were: Alaska, Arizona, California, Colorado, Georgia, Idaho, Iowa, Kansas, Louisiana, Michigan, Minnesota, Missouri, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Utah, Texas, Washington, and Wyoming. The states where the four-day week is particularly popular include Colorado, Idaho, Missouri, Montana, Oklahoma, Oregon, New Mexico, and South Dakota (Kilburn et al., 2021). Colorado is leading the trend, with over 60% of its districts using a four-day week as of the spring of 2021.

issues (e.g., low attendance rates, missing school for appointments or athletics), and issues related to being in a rural area (e.g., long bus rides, time to work on family farms and ranches, student/teacher retention), yet these financial and attendance motivations do not appear to come to fruition in many instances.[4]

COVID-19 led to additional adoption of the policy across a variety of states, as a broader range of districts turned to four-day weeks in response to the economic and logistical challenges of COVID-19 (Altavena, 2020; Haas, 2020). These adoptions generally were not typical in their implementation, as many schools offered entirely or partially remote instruction during the year and/or altered their typical school day schedules. Nevertheless, as the pandemic-specific challenges waned during the 2021-22 school year, some districts persisted on the schedule and new districts continue to report adopting the schedule for the 2022-23 school year (Mazur, 2022; Nickerson, 2022; Russell, 2022; Vidmar, 2022). Anecdotally, these districts adopting four-day weeks for the 2022-23 school year are more similar to the small, rural districts who have historically adopted the schedule, and the schedules they are planning to implement are more consistent with the four-day week schedules used by schools before the pandemic (e.g., school is in-person, the off day is Friday or Monday, the other school days are extended).

Previous Literature on Effects of Four-Day School Weeks on Achievement and Growth

Average effects

[4] Previous research indicates that district expenditures decrease by only 1-2% on average as a result of the schedule change, and student attendance is not significantly affected (Anderson & Walker, 2015; Kilburn et al., 2021; Morton, 2021; Morton, 2022; Thompson, 2021a; Thompson, 2021b; Thompson et al., 2021b). Some survey data suggest that the schedule does provide students with additional time at home with family and does reduce the weekly time students spend commuting to school by about 30 minutes relative to similar districts operating on a five-day week schedule (Kilburn et al., 2021). Whether improved student and teacher retention or any other intended consequences of four-day school weeks have been realized by the districts who have adopted them remain empirically unfounded.

Despite the growing adoption of four-day school weeks since the late 1990s, the first empirical analysis of the academic effects of four-day school weeks was not conducted until 2015 (Anderson & Walker, 2015). Prior research consisted of anecdotal evidence from interviews and opinion surveys that generally touted various benefits of the schedule for students. Since 2015, seven studies (Anderson & Walker, 2015; Kilburn et al., 2021; Morton, 2021; Morton, 2022; Thompson, 2021b; Thompson & Ward, 2022; Thompson et al., 2021b) have leveraged panel data and difference-in-differences research designs to study the causal effects of attending a school with a four-day week as opposed to school with a five-day week. The majority of this research, as summarized in Appendix Table A1, uses standardized test score outcomes and estimates small, mostly negative average effects of the schedule on students in grades 3-11, ranging from +0.02 SD to -0.09 SD on math and -0.02 SD to -0.04 SD on English Language Arts (ELA) or reading (Kilburn et al., 2021; Morton, 2021; Thompson, 2021b; Thompson & Ward, 2022; Thompson et al., 2021b; Morton, 2022). One notable exception, Anderson and Walker's (2015) study of the four-day school week's effect in Colorado finds a significant, positive effect of the schedule on achievement: they report a 7.4 percentage point ($p<0.05$) increase in the percent of fifth grade students scoring proficient or advanced in math and a 3.8 percentage point ($p<0.1$) increase in the percent of fourth grade students scoring proficient or advanced in reading.[5]

The size of these effects ranges from no effect to small, trivial effects, to non-trivial, meaningful effects (Kraft, 2020). For context, in fifth grade, student achievement is estimated to improve about 0.40 SD over the course of the academic year (Bloom et al., 2008), and schools

[5] One limitation of Anderson and Walker's (2015) study relative to more recent research on four-day school week achievement effects is their chosen outcome measure, the percent of students scoring proficient or advanced. While this may be an important metric from a school accountability perspective; however, it is limited for the purpose of understanding the effect of the policy on student achievement, as it is impossible to know whether the schedule improved achievement on average or just around the state test proficiency threshold (Ho, 2016). Nevertheless, Anderson and Walker's (2015) study is the only previous study of the four-day school week that includes achievement data from Colorado, one of the states with the greatest prevalence of the schedule.

only account for around 40% of these achievement gains (Chingos, Whitehurst, & Gallaher, 2015; Konstantopolus & Hedges, 2008; Luyten et al., 2017). Therefore, Thompson's (2021b) estimated 0.06 SD drop in math achievement across grades 3-8 due to the four-day school week is substantial, as it could be approximated to nearly one-sixth of a student's expected achievement gains, or about five to six weeks of schooling in the fifth grade.

Of note, the estimates from the studies that leverage district-level data are generally not statistically significant, whereas most of the estimates from studies using student-level data are statistically significant. This difference may be attributed to the relatively smaller sample sizes and lack of statistical power to detect small effects when using district-level data as opposed to student-level data. However, it is also possible that the significant negative effects estimated in the two studies using student-level data can be attributed to the specific implementation of four-day weeks in the state of Oregon, as both student-level studies used only data from Oregon (Thompson, 2021b; Thompson et al., 2021b). Therefore, the differences in the estimated effects in the existing research may be artifacts of the studies' level of data and/or represent meaningful state-based differences in the implementation and consequences of the four-day school week for student achievement.

Heterogeneous Effects

These studies provide important preliminary evidence regarding the effects of the schedule on academic achievement, but generally present only average effects of the policy that may mask important heterogeneity in the effects across and within districts. A few studies have examined heterogeneous effects of the schedule based on student- and district-level demographic characteristics as well as other relevant factors, such as weekly hours of school (Thompson, 2021b; Thompson & Ward, 2022; Thompson et al., 2021b). This small body of research suggests that different implementations of the schedule and different compositions of schools adopting the schedule could drive, at least in part, different effects of the schedule across states. These studies are often limited, however, in their statistical power to detect a heterogeneous effect, or they estimate effects in only one state that may not hold true in other states due to state-based differences in implementation of the policy.

There are several factors that the existing literature has identified as factors associated with heterogeneous average effects of the four-day school week on student achievement. The factors that have been examined to date include the following school-level factors: rurality, weekly time in school, and the following student-level factors: race, grade, gender, federal free or reduced-price lunch (FRPL) eligibility, English language learner (ELL) status, special education status, and gifted/talented designation (Thompson, 2021b; Thompson et al., 2021b; Thompson & Ward, 2022). As presented in Appendix Table A1, each of these heterogeneous factors has been examined in only a single study and may have limited generalizability to four-day school weeks implemented in other contexts. Nevertheless, the identified differences (and lack of differences) in the effects of the schedule across schools and students are valuable context for understanding how the effects of the schedule may be linked to its implementation.

Indeed, weekly time in school, school rurality, student grade level, special education status, and ELL designation have all been shown to matter for the effect of the four-day week on achievement. More specifically, Thompson and Ward (2022) find that their estimated negative average effects of the four-day week on district-level achievement across 12 states are driven by larger negative effects of the schedule (-0.04 to -0.06 SD) for districts in the bottom third of the distribution for weekly hours of school. At districts in the middle and top third of the distribution, average effects ranged from -0.01 to +0.02 SD, but none of the estimated effects were significantly different from zero. This finding suggests that the four-day week's effect on student achievement may depend on the extent to which the schedule decreases students' total time at school.[6] Furthermore, this type of information is very valuable for policymakers and practitioners, as they respectively decide on policy constraints for school schedules and consider implementing or revising a four-day school week schedule in their district.

Thompson et al. (2021b) also find that the negative effects of adopting a four-day week on achievement are concentrated in non-rural schools. More specifically, among 11th grade students in Oregon, average negative achievement effects of four-day school weeks (math effect=-0.09 SD, $p<.01$; reading effect=-0.03 SD, *n.s.*) were explained entirely by the effects of the schedule among students in non-rural schools (math effect=-0.13 SD, $p<.01$; reading effect=-.04 SD, *n.s.*). The average effect of the four-day week on achievement among 11th grade students attending rural four-day week schools was positive, though not statistically significant (math effect=0.08 SD, *n.s.*; reading effect=0.01 SD, *n.s.*). This finding suggests that there may be key differences in the implementation of and students' experiences on a four-day week in rural and non-rural districts producing heterogeneous effects of the schedule. However, whether this association holds in states other than Oregon and the implementation factors that explain the differences in the effects for rural and non-rural districts is unknown.

Finally, there is little evidence of differences in the effect of the schedule on achievement based on student characteristics. Thompson (2021b), using a sample of students in grades 3-8 in Oregon, finds no significant differences in the effect by student race, gender, FRPL eligibility, or gifted/talented designation. He finds evidence of 8th grade students being significantly more

[6] Much of the previous four-day school week measures time in school as the difference between the school day start time and school day end time. This is a different measure than instructional time (i.e., time in front of a teacher), due to various breaks in the school day for things such as passing time between classes, lunch, recess, etc.

negatively affected by the schedule relative to 3rd grade students in math (-0.09 SD, *p*<.01) and reading (-0.06 SD, *p*<.01), special education students being more positively affected by the schedule in only math (+0.03 SD, *p*<.05), and ELL students being more negatively affected by the schedule in only reading (-0.04 SD, *p*<.01). Although this information is crucial for understanding the consequences of the policy for all students, whether these subgroup differences generalize to four-day school weeks implemented in states other than Oregon is also unknown. If these results are replicated in additional states, exploring and identifying the mechanisms causing the schedule to impact certain student groups more negatively (and how to prevent those impacts or provide additional support to those students) should be a key priority for future research.

Within-Year Academic Growth

Much of the existing research on academic effects of the four-day week, described above, examines effects on standardized annual spring test scores (i.e., achievement status), which conflates effects of the policy during the school year with effects during the summer. Thus, a major contribution of the present study is its examination of the effects of the four-day school week on within-year fall-to-spring (school year) student test score gains, or growth, in addition to spring achievement. Despite the facts that the policy is implemented only during the school year (i.e., fall-to-spring), all relevant research to date has examined only spring-to-spring standardized achievement on state assessments as an outcome. Estimating the effects of the four-day week only on spring achievement problematically conflates the effects of the schedule on students' academic progress during the school year and students' academic progress (or losses) over the summer. Because we would expect summer learning to be unrelated to the weekly school schedule during the school year, including summertime in the outcome measure theoretically includes unnecessary statistical noise in the outcome. This included additional noise would cause the standard errors of the estimate to be inflated, such that one would be less likely to detect a significant effect of a school-year policy on spring achievement as opposed to school year gains.

Within-student school-year gains are not only a more proximal and valid outcome measure for the policy, but they also are less strongly associated with students' entering achievement levels and other socioeconomic inequalities (Atteberry & McEachin, 2020). Indeed, research shows that students' academic gains over time are a more effective and potentially less biased measure of school quality than students' performance on a test at one point in time (Chingos & West, 2015). Relatedly, growth is likely a better and more sensitive measure of the effect of the four-day school week compared to achievement because schools and districts have been shown to have more influence on growth than students' achievement level at any one point in time (Atteberry & McEachin, 2020; Reardon, 2019; Stiefel, Schwartz, & Rotenberg, 2011). Therefore, to better understand how four-day weeks affect students, it is important to parse the effects of the schedule on fall-to-spring gains. We compare these effects to the estimated effect on spring achievement in the same sample, as well as to the existing evidence on the effect of the schedule on spring achievement.

Methods

Data

This study employs 12 years (2008-09 to 2019-20) of school-level data from a national database of school-level four-day school week adoption history (Thompson et al., 2021a), school- and district-level demographic data from the National Center on Education Statistics (NCES) Common Core of Data (CCD), and seasonal student test event data from NWEA's anonymized longitudinal student achievement database.

The national four-day school week adoption dataset includes the year that each school adopted a four-day school week and whether they had a four-day school week each year from 2007-08 to 2018-19.[7] School- and district-level demographic data from the CCD include school enrollment, the percent of students in a school eligible for FRPL, the school student-teacher ratio, the percent of students in a district classified as ELL, the percent of students in a district with an Individualized Education Program (IEP), a district's total current expenditures per pupil, and the urbanicity of the district.

NWEA MAP Growth Assessment Data

School districts use NWEA's Measures of Academic Progress (MAP) Growth assessments to monitor elementary and secondary students' reading and mathematics growth throughout the school year, with assessments typically administered in the fall, winter, and spring. We use the fall and spring test scores, standardized by grade and term, to calculate fall-to-spring (school year) achievement gains. Districts choose the week(s) that they administer the assessment each term; for this reason, we control for test date or time between tests in each of our empirical analyses. For each student, we record fall-to-spring gains in the relevant spring term and drop the fall term data from the dataset. The NWEA data also include demographic information, including student race/ethnicity and gender, though student-level socioeconomic status is not available.

Sample

[7] These data were originally collected via direct correspondence with school districts and examination of historical lists of four-day school weeks from state departments of education. Based on the yearly lists of four-day school weeks and from responses of school districts an indicator for four-day school week use was generated for the years of this study. See Thompson, et al. (2021a) for more details on the original data collection process.

The sample includes over 6 million total fall and spring test scores (in math and in reading) of approximately 1 million kindergarten- to eighth-grade students in over 1,700 schools across 619 districts. Of this sample, 35 schools and 20 districts ever have a four-day school week, and just over 12,000 students attend a school that ever adopts a four-day week. Two of the 35 schools that adopt a four-day week during the study time period switch back to the five-day school week, or have a "transitory" four-day school week. The schools in the analytic sample are from the six states, Colorado, Iowa, Kansas, Montana, North Dakota, and Wyoming, that have any schools in the NWEA sample that administer MAP Growth and adopt four-day school weeks. Across these states, the NWEA sample includes student test event observations from an average of 40% of the districts that have schools that adopt a four-day school week during the study period in each state. The control group includes all students who attend schools in these states and were tested on MAP Growth during the study period. Consistent with previous research on this topic (Morton, 2022; Thompson, 2021b), districts located in cities are excluded from the sample, as no districts that adopt four-day weeks are located in cities (as defined by NCES), such that city districts would not provide a useful comparison for treated districts. Counts of test score events, students, schools, and districts in the sample are displayed by subject, grades, and treatment group in Table 1. The representativeness of the schools in our analytic sample of all schools in the same states are presented in Appendix Table A2. Although we observe some small differences, the five-day and four-day week schools in the analytic sample are broadly representative of the respective groups across the six states.

Descriptive statistics of the analytic sample are presented in Table 2. Students in the sample who attend schools that ever adopt a four-day week are less likely to be white, are more likely to be Native American, and have lower standardized scores on MAP Growth in math and reading than students who attend schools that never adopt a four-day week. As expected, the schools and districts that ever adopt four-day school weeks have smaller enrollments, have higher percentages of students eligible for FRPL, and are more rural and less suburban than five-day week schools and districts. Differences in the characteristics of the students, schools, and districts in the pre- and post-four-day week adoption samples are generally small and not statistically significant. These descriptive differences are useful context for understanding the composition of the control and treatment samples, but they do not provide any insight into the causal effects of four-day school weeks.

Empirical Strategy

Difference-in-Differences

Average Effects. To examine the causal impacts of the four-day week schedule on students' MAP Growth test scores, we use a quasi-experimental research design. More specifically, we leverage panel data and a quasi-experimental two-way fixed effects (TWFE) difference-in-differences (DID) research design to estimate the impact of four-day school weeks by comparing the changes over time in outcomes of students at schools with four-day school weeks to the contemporaneous changes in students at schools that never or did not yet have four-day school weeks. We first estimate variations of the following specification:

$$Y_{isdgt} = \pi_i + \delta_s + \theta_{gt} + \beta Fourday_{sdt} + \gamma TestDate_{isdgt} + \epsilon_{isdgt} \quad (1)$$

where Y_{isdgt} is the dependent variable of interest (i.e., grade-term standardized spring reading and math test scores or grade-term standardized fall-to-spring (school year) reading and math test score gains) for student *i* in term *t*, school *s*, district *d*, grade g. π_i are student fixed effects, δ_s are school fixed effects, and θ_{gt} are grade-term fixed effects for each spring term in the sample. $Fourday_{st}$ is an indicator variable that is equal to one each term that a student's school *s* has a four-day week schedule. $TestDate_{isdgt}$ represents the relevant date of a student's test (i.e., spring test date) or time between a student's two test dates (i.e., days between the fall and spring test in a school year) that corresponds to the specified dependent variable of interest. ϵ_{isdgt} is an idiosyncratic error term that accommodates for clustering at the district level (Bertrand, Duflo, & Mullainathan, 2004).

We further examine the dynamic effects of the four-day school week to see if the effect of the schedule changes over time based on the number of years a school has had the schedule. We use the Granger causality test ("event study") to estimate the effect of the four-day school week on the specified outcome variables for the spring terms before and after a school adopts the schedule:

$$Y_{isdgt} = \pi_i + \delta_s + \theta_{gt} + \sum_{k=2}^{3} \beta_{-k} Fourday_{sd,t-k} + \sum_{k=0}^{3} \beta_{+k} Fourday_{sd,t+k} + \gamma TestDate_{isdgt} + \epsilon_{isdgt} \quad (2)$$

where β_{-k} and β_{+k} respectively represent the "effect" of being k spring terms prior to or post adoption (k =0 for the first spring term the four-day week is adopted) relative to never adopting four-day weeks or being one spring term pre-adoption. Joint F-tests are employed to test the null hypothesis of a constant post-treatment "effect", H_0: $\beta_0 = \beta_1 = \beta_2 = \beta_3$. We present our results of this event study analysis conducted as an intent-to-treat (ITT) analysis that includes all schools that ever adopt a five-day week in the treatment group. The ITT analysis provides more conservative estimates of the effects of the schedule than a treatment-on-the-treated (TOT) analysis that excludes the two transitory four-day week schools from the analysis; nevertheless, in this case, the two approaches yield substantively similar results.[8]

Heterogeneous Effects. We further examine whether impacts of the four-day school week vary by school rurality and student characteristics. To test whether four-day school weeks vary by

[8] Estimates from the TOT analysis can be provided upon request.

rurality, we delineate four-day school week adoption into two separate treatments: (1) rural four-day school weeks and (2) non-rural four-day school weeks. We then separately estimate Equation (1) for each of these definitions of *Fourday*. To examine differences in the effects of the four-day week by grade, we estimate Equation (1) separately by grade level. Finally, to examine heterogeneous effects of the four-day week based on student characteristics, we interact binary student-level demographic variables with the *Fourday* indicator in Equation (1) and report the interaction effect. The interaction effects can be interpreted as the extent to which four-day school weeks have more (or less) of an effect for the specified student subgroup relative to the specified omitted subgroup. We estimate interaction effects of the four-day school week with student gender and race.

Alternative Control Groups. Moreover, we conduct an additional robustness check that tests the sensitivity of our preferred DID estimates to the chosen control group (i.e, all students who took MAP Growth tests in a five-day week school in a state that had at least one school that administered MAP Growth and was operating on a four-day week). We estimate Equation (1) using an alternative control group restricted to students attending five-day week schools in rural locations. Though reduced in size and statistical power to detect an effect of the schedule, this control group provides a valuable comparison because treated schools are mostly (71%) located in rural areas; therefore, it is reasonable that rural five-day week districts could be a better counterfactual for districts that adopt four-day weeks than all non-city five-day week districts.

Validity of Empirical Design

Parallel Trends. Several important assumptions are embedded in the DID approach that can be tested using various robustness checks. First, DID models assume that there would be "parallel trends" in the outcomes of the control units and treated units over time if the treated units had never received treatment. It is of course impossible to test this assumption in the post-treatment period, as we cannot observe any untreated treated students, but we can test this assumption during the pre-treatment period. The assumption would be violated in this study if, for example, students who ever attend a school with a four-day school week during the study period had decreasing spring test scores before their school adopted the four-day week relative to students at schools that never adopted the four-day week. In that case, one would not be able to determine whether any observed declines in four-day week students' test scores should be attributed to the four-day week as opposed to the pre-existing negative trend for those students. Therefore, we use the event study equation specified in Equation (2) to test the parallel trends assumption during the pre-treatment period. To uphold the parallel trends assumption during the pre-treatment period, the estimated "effect" of attending a four-day school week school in the future (i.e., β_{-k}) should not be significantly different from zero. Joint F-tests are employed to test the null hypothesis of a constant pre-treatment "effect" equal to zero, $H_0: \beta_{-3} = \beta_{-2} = 0$.

The pre-treatment period point estimates in the event studies are presented in Table 5 and Appendix Tables A3 and A4, and depicted in Figures 1 and 2. These estimates are used to evaluate whether, conditional on student and grade-term fixed effects, outcomes of students attending schools that eventually adopt a four-day school week but had not yet adopted it ("3 years before," "2 years before," etc.) were trending differently in the pre-treatment period relative to the outcomes of students at schools that never adopt a four-day week. The results fail to reject the null hypothesis that the students in the treatment and control groups are trending similarly during the pre-treatment period. The joint F-tests presented in Table 5 also fail to reject the null hypothesis that the combined pre-treatment "effects" of attending a school that would adopt a four-day week were constant and equal to zero, providing further support for the parallel trends assumption.

Selection Into and Out of Treatment. The validity of DID estimates also hinge on the assumption that selection into and out of treatment is random. The inclusion of fixed effects in the DID model addresses concerns about selection into treatment based on baseline differences in the treatment and control group. The fixed effects effectively enable comparisons of the changes *within* the treatment group over time to changes *within* the control group over time (i.e., the difference in the differences), so the average difference between the two groups is not a concern. The inclusion of student fixed effects in the DID model, therefore, enable us to evade most concerns about nonrandom school-level selection into treatment, as we examine changes in academic outcomes within students, and we do not observe any students who both switch schools and switch treatment status during the study period.[9] We likely do not observe any students who switch schools *and* switch treatment status in part because NWEA testing is a school or district decision, so students who leave their NWEA partner school for another school that does not use NWEA testing would not continue to be observed in our data.

Relatedly, another potential threat to the validity of the DID approach is if the composition of a school changes in response to adopting the four-day week such that students are systematically selecting into or out of four-day week schools. For example, if students were systematically disenrolling in a school following its adoption of the four-day week because they or their family disliked the four-day week, school enrollment would decrease in the year(s) following adoption. The composition of the students would also necessarily change such that a greater percentage of students and/or families would be in-favor of the four-day week. In such a case, it would again be impossible to know if any observed effects of the four-day week on students should be attributed

[9] We likely do not observe any students who switch schools *and* switch treatment status in part because NWEA testing is a school or district decision, so students who leave their NWEA partner school for another school that does not use NWEA testing would not continue to be observed in our data.

to the four-day week as opposed to the changes in the population at their school. However, substantial spikes in enrollment and/or disenrollment are generally unlikely at schools that adopt four-day school weeks due to the rurality of the communities in which they are located. Nevertheless, we test for evidence of changing school composition at the school-level in response to four-day week adoption using the following specification:

$$Z_{sdt} = \delta_s + \theta_t + \beta Fourday_{sdt} + \epsilon_{sdt} \quad (3)$$

where Z_{sdt} represents school, and district demographic characteristics related to school composition, including school enrollment, the percent of white students, the percent of Native American students, the percent of Hispanic students, the percent of students who are FRPL-eligible, the percent of students with an IEP, the percent of students classified as ELL, and the student-teacher ratio. All of the point estimates in Appendix Table A5 are substantively small and statistically insignificant, indicating that we fail to reject the null hypothesis that school composition is not changing during the post-treatment period as an effect of the four-day school week. Therefore, we find no strong evidence for selection into or out of treatment based on observables using this method.

Variation in Treatment Timing. A final robustness check is required to address an assumption embedded in TWFE DID specifications with variation in treatment timing, such as the specification used in this study. When there is variation in treatment timing and the effects of treatment vary over time, the TWFE DID estimator represents a weighted average of all two-group[10] by two-period (i.e., year) DID estimators (Goodman-Bacon, 2021). The weights on each 2x2 comparison are determined by the proportion of students in the treatment versus control group

[10] The analytic subsamples in this study include up to 11 "groups": never-treated districts, always-treated districts (only for the attendance analyses sample), and the nine cohorts of districts that adopted four-day weeks each year from 2011-2019.

and the variance of the treatment dummy in the full sample each year. Whereas the proportion of treated students will be highest in comparisons made toward the end of the study period, the variance of treatment status will be largest in comparisons made in the middle of the study period. Therefore, a school adopting the four-day week during the study period could cause the estimated effect of the schedule to be underrepresented or overrepresented in the overall TWFE DID estimator. A developing body of literature shows that these weighted average fixed effects estimators can poorly represent the average treatment effect, and they are more likely to poorly represent the average treatment effect if there are heterogeneous treatment effects by treatment timing (Goodman-Bacon, 2021; de Chaisemartin & D'Haultfoeuille, 2020; Callaway & Sant'Anna, 2021; Sun & Abraham, 2021). To address this issue, we compare our event study point estimates to reweighted estimates calculated using Sun's (2021) *eventstudyinteract* Stata package. This package uses an interaction weighted estimator to reweight the event study estimates in the following three steps: (1) estimating the interactions between relative time indicators (i.e., years pre- and post- four-day school week adoption) and cohort indicators (i.e., calendar year of four-day school week adoption), (2) estimating the cohort shares in each relative time group, and (3) estimating the weighted average of the estimated interactions with weights proportional to the estimated cohort shares.

Results

Difference-in-Differences

DID analyses, as specified in Equation (1), were conducted examining the effect of the four-day school week schedule on students' grade-term standardized math and reading MAP Growth test scores. More specifically, we examine effects of the schedule on two outcomes: (1) spring achievement and (2) fall-to-spring (school year) achievement gains. We first examine average effects using the full sample of schools that adopt four-day school weeks, and then we examine heterogeneity in the effects based on school rurality and student characteristics.

Average Effects

The DID point estimates of the average effect of the four-day school week on students' math and reading spring achievement and school year gains are presented in Table 3. We include the fully unrestricted models in columns (1) and (4) and the school fixed effects models in columns (2) and (5) for completeness, but we focus our substantive interpretation on the point estimates produced by the preferred student fixed effects models, presented in columns (3) and (6). The results from the preferred model suggest that four-day school weeks have a negative average effect on students' spring test score performance and their school year gains.

Specifically, as presented in Panel A, when examining standardized spring test score outcomes, we find the student fixed effects model estimates a negative but non-statistically significant effect of the schedule on math scores (β=-0.03, *n.s.*) and a significant negative effect on reading scores (β=-0.07, p<.05). Effects of the four-day week on students' fall-to-spring (school year) test score gains are presented in Panel B of Table 3. The student fixed effects model estimates a 0.06 SD decrease (p<.05) in school year gains in math and a 0.06 SD decrease (p<.05) in school year gains in reading.

Taken together, the more precisely estimated negative effects of the four-day week on fall-to-spring gains relative to year-over-year spring achievement suggest that the effects of the four-day school week are likely concentrated during the school year. Indeed, the negative effects of the schedule on students' fall-to-spring gains are likely driving declines in spring achievement observed in the present study and previous literature.

We further examine the dynamic effects of four-day school weeks over time based on the event study estimates presented in Table 5. The results show that the magnitudes of the negative effects of the four-day school week generally increase (or at least hold steady) over time, with larger negative effects of the schedule observed in each of the years following implementation than the first year for all specifications. However, the differences between the effects each year are not statistically significant, as the joint F-tests conducted for each specification failed to reject a constant treatment effect over time.

To interrogate possible bias in our TWFE DID point estimates due to heterogeneous effects of treatment based on treatment timing (i.e., treatment cohort), we also re-estimate the event study presented in Table 5 using Sun and Abraham's (2021) interaction weighted estimator. These results, displayed in Appendix Table A7, are consistent with the original event study results presented in Table 5, suggesting that variation in treatment timing is not strongly biasing the original estimates. Moreover, this finding aligns with that of other studies that have examined the influence of variation in treatment timing on DID analyses of four-day school weeks (Morton, 2022; Thompson & Ward, 2022).

Finally, we test the sensitivity of the student fixed effects estimates presented in Tables 3 and 4 by repeating the analyses with an alternative, more restrictive control group. We conduct the same student fixed effects DID specified in Equation (1) but include only students attending five-day week schools in rural areas in the control group. As presented in Appendix Table A6, we find that, compared to the original student fixed effects models estimated in Tables 3 and 4, the models including only students attending rural five-day week schools as a control group estimate similar average effects of all four-day weeks on spring achievement in math (β=-0.01, *n.s.*) and reading

(β=-0.04, *n.s.*), and similar but larger negative average effects of four-day weeks on fall-to-spring gains in math (β=-0.08, p<.01) and reading (β=-0.09, p<.01).

Heterogeneous Effects

Examining how the effects of the four-day school week vary (or do not vary) across schools and students is important for further investigating what factors could be responsible for driving the observed negative average effects. We examine whether the estimated average effects of the four-day school week vary by school rurality and student characteristics.

Rurality. First, as presented in Table 4, we estimate the student fixed effects DID model specified in Equation (1) separately for rural schools that adopt four-day weeks (columns (2) and (5)) and non-rural schools that adopt the four-day week (columns (3) and (6)). For spring achievement, we find no detectable effect of rural four-day weeks on math (β=0.02, *n.s.*) or reading (β=-0.04, *n.s.*), but we find a significant 0.08 SD decrease (p<.05) in math scores and 0.11 SD decrease (p<.01) in reading scores as effects of non-rural four-day school weeks. When examining fall-to-spring gains, we find the rural four-day week decreases reading gains with trend-level significance by 0.04 SD (p<.10) but has no detectable effect on math gains (β=-0.01, *n.s.*); however, the non-rural four-day week significantly decreases students' math and reading gains, by 0.08 SD (p<.01) and 0.09 SD (p<.01) respectively.

We also test the effects of rural and non-rural four-day school weeks using this alternate, rural-only control group. In alignment with the original results presented in Table 4, we find (see Appendix Table A6) the negative effects of the schedule on spring achievement and fall-to-spring gains are larger for students attending non-rural four-day week schools (spring math β=-0.07, p<.05; spring reading β=-0.07, p<.05; fall-to-spring math β=-0.12, p<.01; fall-to-spring reading β=-0.11, p<.01) than for students attending rural four-day week schools (spring math β=0.05, *n.s.*;

spring reading β=0.00, *n.s.*; fall-to-spring math β=-0.04, *n.s.*; fall-to-spring reading β=-0.06, p<.01).

Separate event study specifications for rural and non-rural four-day week schools were conducted to further examine the dynamic effects of the schedule in each setting. As displayed in Appendix Tables A3 and A4, the pattern of increasingly negative effects of the four-day school week over time we observed in the overall sample is also observed, respectively, in the rural and non-rural four-day week school samples. Therefore, despite the smaller and less negative average effects of four-day school weeks in rural schools, the growing negative effects over time suggest that the average effect estimated herein may underestimate the effect of the schedule examined over a longer time period.

Student Characteristics. We further examine heterogeneous impacts of the four-day school week by student grade level, gender, and race. Results of the student fixed effects DID specification in Equation (1) conducted separately for each grade level are presented in Appendix Table A8. Overall, we do not observe any discernable pattern in the results that suggest the effects vary meaningfully for students in earlier versus later grades.

Results of the student fixed effects DID specifications from Equation (1) that additionally interact four-day school week status with student gender and race are presented in Appendix Table A9. We do not find statistically significant differences in the effects of four-day school weeks on spring achievement by gender or race. However, when examining fall-to-spring gains, we find that the four-day school week has a greater negative effect on female students' math (β=-0.04, p<0.01) and reading (β=-0.04, p<.05) gains than male students' gains.

We also find some significant differences by race: the four-day school week has a less negative effect on Native students' math gains (β=0.12, p<.01) and a greater negative effect on

Hispanic students' math gains (β=-0.07, p<.01) relative to its effect on White students' math gains. For reading gains, our interaction effect estimates are also positive for Native students and negative for Hispanic students relative to White students, but the magnitudes of the interaction effects are smaller and not statistically significant.

Discussion

States, districts, and schools across the country are making policy decisions on the four-day school week with limited information about its effect on student achievement. The prior research fails to come to a consensus on the effect of the schedule, with the majority of rigorous studies estimating average effects on students' annual, spring state test scores that are not significantly different from zero. The present study addresses these limitations of the previous research by leveraging seasonal student test data from multiple states to provide a more granular estimate of the effect of four-day school weeks on student achievement and school-year growth. Specifically, this study uses panel student-level data for students in grades 3-8 across six states and a difference-in-differences research design to parse the effects of the four-day school week on annual spring student achievement and school-year growth and to examine differences in these outcomes by school and student characteristics.

Our findings on the average effect of the schedule on standardized spring test scores align with the existing research that estimates a +0.02 to -0.09 SD change in test scores from adopting the schedule. We find a non-significant 0.03 SD average decline in math test scores and a significant 0.07 SD decline in math. Like Thompson et al. (2021b), we find that these negative average effects are driven by the larger negative effects (-0.08 SD in math and -0.09 SD in reading) of four-day weeks implemented at non-rural schools (i.e., those located in a town or suburb), as opposed to those being implemented at rural schools. Putting the average effect sizes in perspective of other education interventions, the average effects of the four-day week may be considered "small" (<0.05 SD) for math achievement and "medium" (0.05 to <0.20 SD) for reading achievement (Kraft, 2020). However, the estimated effects on math and reading achievement in non-rural four-day week schools are "medium" and meaningful, approximately equal to a quarter of the estimated impact of a year of school on achievement in the fifth grade (Bloom et al., 2008). At rural four-day week schools, the average estimated effects are small and not significantly different from zero.

However, our results also find some suggestive evidence that the effects become increasingly negative over time in both non-rural and rural districts, reaching "medium" sized effects in the third year of implementation. If the negative effects observed in the later post-treatment years hold or continue to grow larger, the average effects of rural four-day school weeks estimated herein may underestimate the average effect of the schedule for students exposed to it beyond four years. Thus, our findings provide further support for the argument that four-day school weeks may be implemented and/or experienced differently in rural areas such that they are less harmful for student achievement than in non-rural areas, but the schedule may still have substantial negative consequences for students' achievement and growth in rural districts over time.

The average effects of the schedule also mask differences in the effects of the schedule by student characteristics. More specifically, we find differences in effects of the schedule on school year gains by gender, such that the schedule negatively impacts female students more than male students, and by race, such that the schedule negatively impacts Hispanic students more and Native students less than White students. The magnitudes of the differences in the effects between female and male students are small, whereas, for math gains, the magnitudes of the differences in the effects for Hispanic and Native students are relatively larger. Again, however, the observed differential effects of the schedule by race may be explained entirely or in part by differences in the implementation of the schedule across schools and/or states as opposed to differences in the effect of the same implementation on students of different races. Examining the implementation factors that may explain the disproportionate impact of the schedule on different subgroups of students is a promising direction for future research.

Estimating the effects of the policy on fall-to-spring gains in addition to spring achievement is a key contribution of this study, as the school year gains estimates provide a more proximal and valid measure of students' academic outcomes related to the four-day school week than spring achievement. As expected, when we estimate effects of the schedule on school year gains, the standard errors of the estimates are smaller, allowing us to estimate the impact of the schedule with more precision. We find that four-day school weeks significantly decrease students' reading and math gains by 0.06 SD, just barely a "medium" effect size (Kraft, 2020). The effect is again more negative and among non-rural schools, where students' fall-to-spring gains dropped 0.08 SD in math and 0.09 SD in reading as an effect of their school adopting the schedule. Alternatively, the effects of the schedule on fall-to-spring gains of students at rural four-day week schools are arguably trivial and less than half of those at non-rural four-day week schools: rural four-day week students' scores decline only by 0.01 SD in math (not statistically significant) and 0.04 SD in reading (significant at the statistical trend level).

Another surprising finding in this study is that we find larger declines in fall-to-spring gains and spring achievement in reading than in math due to the four-day school week. These findings contrast that of Thompson's (2021b) and Thompson et al.'s (2021b) studies using student-level data from Oregon. Additionally, a separate body of research indicates that school inputs have larger effects on math achievement than on reading (Jacob, 2005; Rivkin, Hanushek, & Kain, 2005;

Rockoff, 2004). Based on those findings, we would have expected the four-day week to have larger effects on math than reading. Various implementation factors could be related to the relative magnitudes of the effects on math and reading achievement and gains, such as the proportion of instructional time allocated to each subject when the schedule changed. Investigating the mechanisms and implementation factors underlying this finding, including how the four-day school week impacts subject-specific instructional time, is also an important direction for future research attempting to understand the effects of the schedule.

The present study faces several key limitations. First, we are limited in our ability to generalize our findings to students and schools that do not administer NWEA assessments, and those schools may be fundamentally different from schools that do administer the assessments. However, the four-day school week schools in the analytic sample do represent 40% of the schools that adopted four-day weeks in the included states during the study period. Our results also may not generalize to the states beyond those included in this study, though the similarity of our findings and those of Thompson and Ward (2022), whose sample of 12 states includes ten states that are not in our sample, suggests that these negative effects of the schedule persist for certain implementations of the schedule (i.e., low time in school, non-rural areas) across states. Unlike Thompson and Ward (2022), we are not able to test differences in effects by time in school because the time in school data are not publicly available for some of the schools in the sample, and there is limited variation in the time school data across the districts for which time data are available. Our test score data are also limited because they do not capture the effects of the four-day week on students who move to another district that does not administer NWEA tests, and we cannot distinguish between a student no longer being enrolled at a district versus still being enrolled but not taking the NWEA test. Because we find no evidence that four-day weeks were differentially impacting school enrollment relative to five-day weeks in our sample, this missingness should not bias our estimates of the effect of the four-day week within the analytic sample. However, this missingness means that our results are not generalizable to mobile students.

For policymakers and practitioners, this study addresses previous uncertainty about the effects of four-day school weeks on academic outcomes and provides evidence supporting concerns about four-day school week effects on student achievement and growth, particularly for those implemented in non-rural areas. The estimated effects on math and reading gains during the school year are, while not "large" by the developing standards used to interpret effect sizes of education interventions (Kraft, 2020; What Works Clearinghouse, n.d.), they are also not trivial. For the many districts and communities who have become very fond of the schedule, the evidence presented in this study suggests that how the four-day school week is implemented may be an important factor in its effects on students. As these schedules become increasingly popular across the country, understanding the key aspects of their implementation (e.g., annual subject-specific instructional time, daily start and end times, fifth-day opportunities) that enable the schedule to better support students' academic progress will be critical for informing future adoptions and continued use of the four-day school week.

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Table 1: Math and Reading Sample Counts

Sample	All non-city five-day schools		Four-day week schools pre-adoption		Four-day week schools post-adoption	
	Math	Reading	Math	Reading	Math	Reading
Test events (fall and spring)						
K	314,227	306,263	1,097	1,097	3,884	3,506
1	430,222	412,705	1,427	1,430	4,335	3,975
2	647,825	630,335	2,224	2,230	6,218	5,313
3	788,816	778,454	2,233	2,238	5,934	5,629
4	804,754	798,861	1,974	1,973	5,748	5,144
5	811,794	804,847	1,759	1,739	5,359	4,722
6	840,948	832,906	1,578	1,566	5,270	4,906
7	843,991	836,093	1,238	1,239	3,794	3,785
8	823,036	820,333	1,217	1,206	3,589	3,588
Students						
K	78,973	77,401	758	729	1,235	1,136
1	84,166	80,659	783	820	982	967
2	115,174	112,188	1,176	1,184	1,621	1,389
3	122,251	123,298	1,028	1,005	1,389	1,374
4	114,505	114,263	864	859	1,246	1,117
5	118,417	117,324	818	843	1,209	1,128
6	134,937	135,110	889	877	1,462	1,376
7	150,153	148,956	744	754	1,035	1,076
8	191,463	191,735	856	851	1,406	1,354
Schools	1,750	1,745	35	35	35	35
Districts	599	599	20	20	20	20

Table 2: Descriptive Statistics

	Analytic sample					
	Students attending non-city five-day schools		Students attending four-day schools pre-adoption		Students attending four-day schools post-adoption	
	Mean	SD	Mean	SD	Mean	SD
Standardized achievement and growth outcomes[a]						
Spring math score	-0.01	0.99	-0.15	0.95	-0.11	0.94
Spring reading score	0.03	1.00	-0.10	0.98	-0.06	0.99
Fall-to-spring math gains	0.00	0.60	0.04	0.61	0.03	0.61
Fall-to-spring reading gains	-0.01	0.64	0.03	0.68	0.05	0.67
Student characteristics						
% Black	2.7	16.3	0.6	7.5	1.0	10.1
% White	68.3	46.5	55.3	49.7	51.8	50.0
% Native	2.4	15.3	11.9	32.4	11.3	31.7
% Hispanic	12.2	32.8	14.5	35.2	17.2	37.8
% Asian	2.1	14.5	0.4	6.0	0.4	6.2
% Female	51.3	50.0	51.8	50.0	51.3	50.0
School characteristics						
Enrollment	470.7	237.5	253.8	105.1	247.2	100.3
% FRPL	35.8	20.9	54.1	21.4	54.0	21.6
Student-teacher ratio	15.3	3.2	12.9	3.1	13.1	3.1
District characteristics						
% ELL	5.9	8.1	7.5	7.6	7.1	6.7
% IEP	10.9	6.2	6.0	7.8	7.5	8.0
Total current expenditures per pupil ($ thousands)	10.3	2.7	11.7	4.9	11.7	5.0
% Rural	32.4	45.3	52.6	48.7	53.7	48.5
% Town	30.2	44.9	41.3	48.1	37.6	47.2
% Suburb	37.4	47.7	6.1	23.1	8.6	27.5

[a]Achievement and growth outcomes in math and reading are calculated based on the math and reading grade-term standardized MAP Growth test scores. Scores were standardized based on the mean and standard deviation of the population of students who tested using MAP Growth across all states included in the present study in each grade-term.

Notes. FRPL = Free- or reduced-price lunch. ELL = English Language Learner. IEP = Individualized Education Program.

Table 3: Effects of the Four-Day School Week on Student Achievement and Growth

	Dependent variables: Standardized NWEA MAP Growth test scores					
	Math			Reading		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Spring achievement						
Fourday	-0.153*	-0.010	-0.033	-0.122*	-0.025	-0.072**
	(0.085)	(0.043)	(0.037)	(0.073)	(0.020)	(0.034)
Observations	3085041	3085007	2817648	3032209	3032177	2765031
R-squared	0.000	0.132	0.861	0.000	0.108	0.832
Panel B: Fall-to-spring gains						
Fourday	0.013	-0.033*	-0.051*	0.020	-0.010	-0.062***
	(0.023)	(0.020)	(0.029)	(0.021)	(0.021)	(0.017)
Observations	2750658	2750632	2498362	2704725	2704704	2454045
R-squared	0.025	0.050	0.310	0.011	0.027	0.300
Grade-term FE		x	x		x	x
School FE		x	x		x	x
Student FE			x			x

Notes. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$

Table 4: Effects of the Four-Day School Week on Achievement and Growth by Rurality

	Dependent variables: Standardized NWEA MAP Growth test scores					
	Math			Reading		
	All four-day weeks	Rural four-day weeks	Non-rural four-day weeks	All four-day weeks	Rural four-day weeks	Non-rural four-day weeks
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Spring achievement						
Fourday	-0.033	0.022	-0.081**	-0.072**	-0.039	-0.106***
	(0.037)	(0.042)	(0.031)	(0.034)	(0.040)	(0.036)
Observations	2817648	2804046	2802537	2765031	2753186	2749950
R-squared	0.861	0.861	0.861	0.832	0.832	0.832
Panel B: Fall-to-spring gains						
Fourday	-0.051*	-0.012	-0.083***	-0.062***	-0.038*	-0.086***
	(0.029)	(0.026)	(0.032)	(0.017)	(0.019)	(0.024)
Observations	2498362	2486107	2485399	2454045	2443714	2441092
R-squared	0.310	0.310	0.310	0.300	0.300	0.300
Grade-term FE	x	x	x	x	x	x
School FE	x	x	x	x	x	x
Student FE	x	x	x	x	x	x

Notes. $*p < 0.10$, $**p < 0.05$, $***p < 0.01$

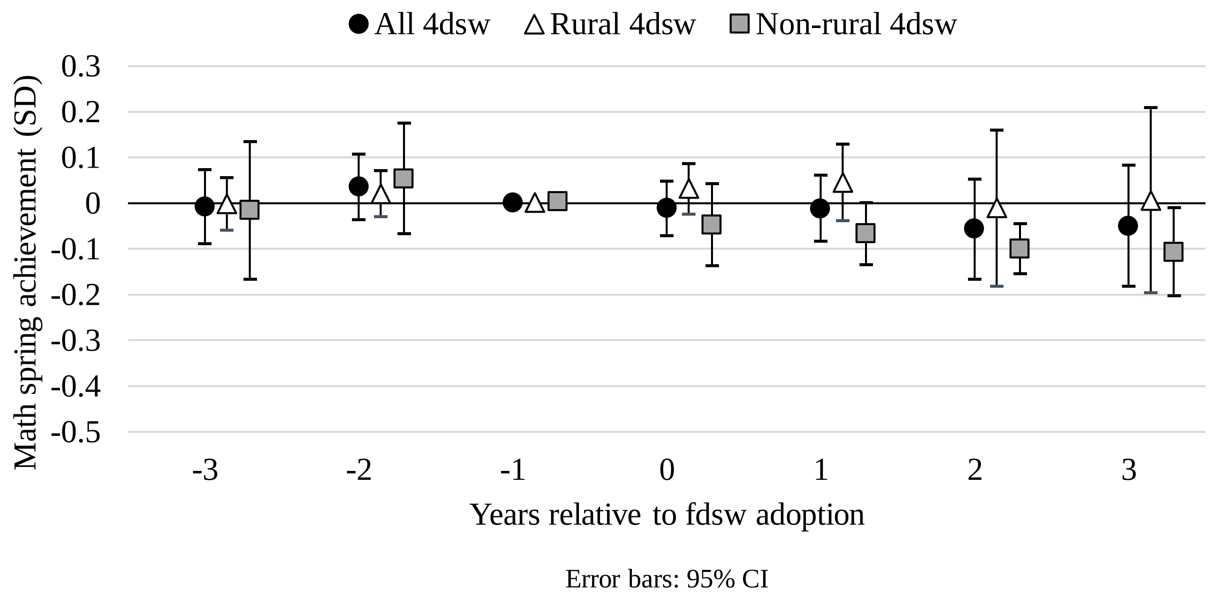
Table 5: Effects of the Four-Day School Week on Achievement and Growth (Event Study)

	Spring achievement		Fall-to-spring gains	
	Math	Reading	Math	Reading
	(1)	(2)	(3)	(4)
3 years before	-0.008	0.010	0.003	0.003
	(0.041)	(0.054)	(0.034)	(0.050)
2 years before	0.035	0.039	0.016	0.033
	(0.036)	(0.050)	(0.027)	(0.043)
Adoption year	-0.011	-0.031	-0.037	-0.032
	(0.030)	(0.021)	(0.030)	(0.033)
1 year after	-0.012	-0.076**	-0.052**	-0.065***
	(0.037)	(0.035)	(0.023)	(0.022)
2 years after	-0.057	-0.116*	-0.087**	-0.072
	(0.056)	(0.066)	(0.037)	(0.045)
3 years after	-0.050	-0.131**	-0.041	-0.077
	(0.068)	(0.063)	(0.052)	(0.049)
Observations	2817887	2765269	2498597	2454279
R-squared	0.861	0.832	0.310	0.300
p-value: $(H_0: \beta_{-3} = \beta_{-2} = 0)$	0.108	0.192	0.838	0.640
p-value: $(H_0: \beta_0 = \beta_1 = \beta_2 = \beta_3)$	0.195	0.483	0.100	0.346

Notes. All models include grade-term FE and student FE.
**p*< 0.10, ***p*< 0.05, ****p*< 0.01

Figure 1: Effects of the Four-Day School Week on Spring Achievement (Event Study)

(a) Math



(b) Reading

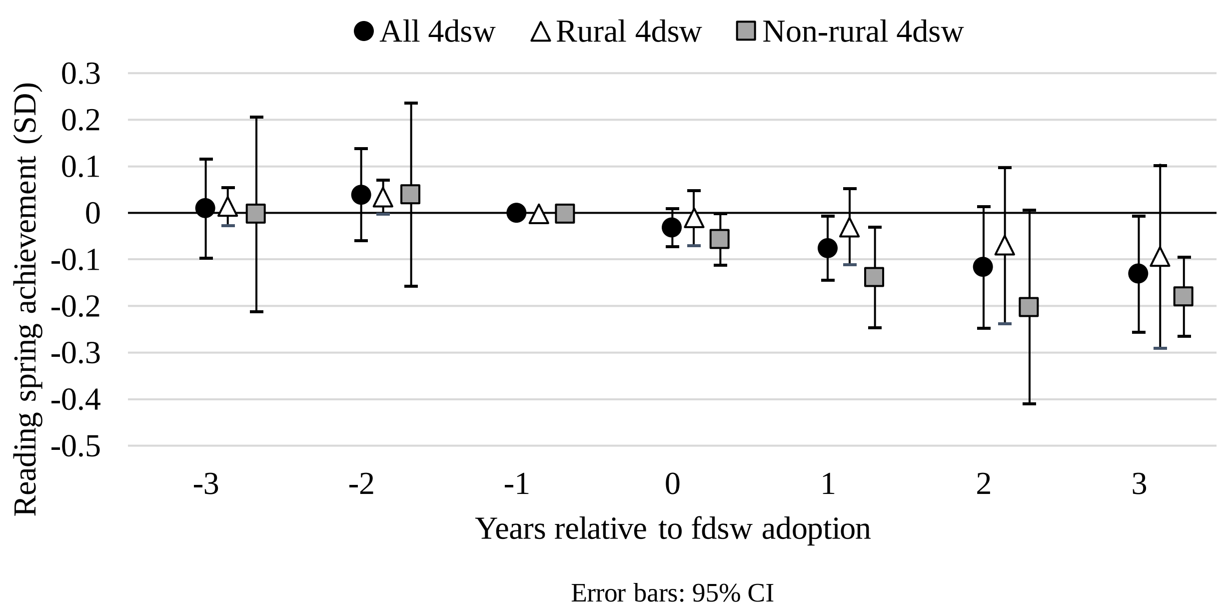
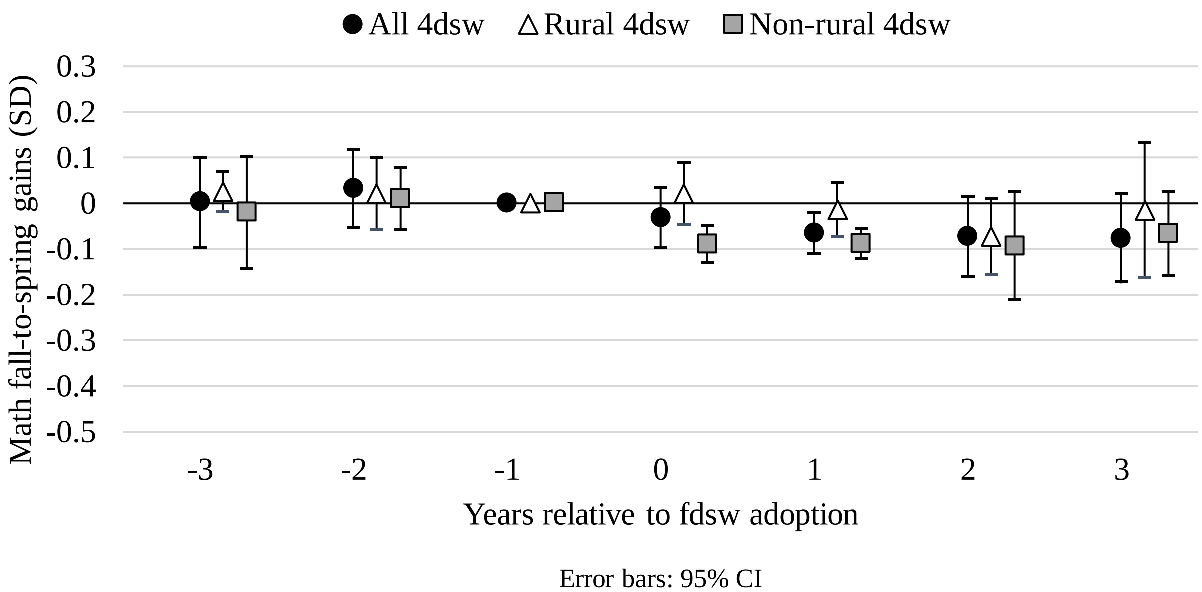
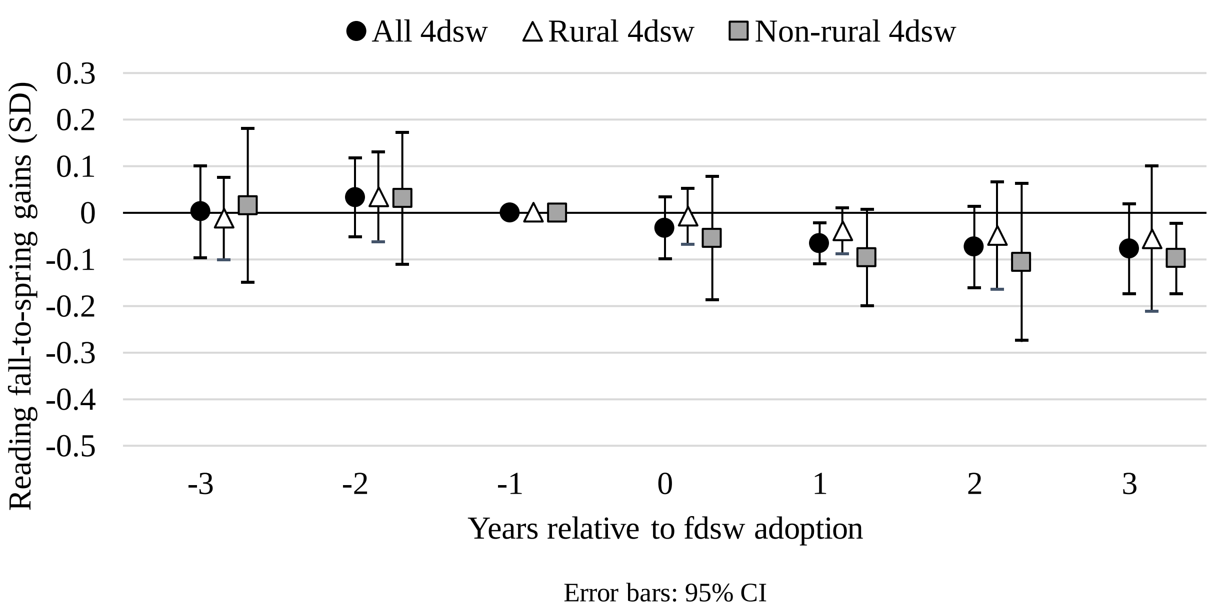


Figure 2: Effects of the Four-Day School Week on Fall-to-Spring Gains (Event Study)

(a) Math



(b) Reading



Appendix Table A1: Existing Literature on the Academic Effects of Four-Day School Weeks

Study	State(s)	Grades	Subject	Level	Effect size (SD)	Heterogeneous effects
Morton (2021)	OK	3-8	Math	District	-0.05	N/A
Morton (2021)	OK	3-8	ELA	District	-0.03	N/A
Thompson (2021b)	OR	3-8	Math	Student	-0.06**	Special education (+); 8th grade (-); No significant differences by race, gender, FRPL, ELL, or G/T designation
Thompson (2021b)	OR	3-8	Reading	Student	-0.04**	ELL (-); 8th grade (-); No significant differences by race, gender, FRPL, special education, or G/T designation
Kilburn et al. (2021)	ID, MO, NM, OK, SD	3-8	Math	District	-0.03	N/A
Kilburn et al. (2021)	ID, MO, NM, OK, SD	3-8	ELA	District	-0.04	N/A
Thompson & Ward (2022)	12 (AZ, GA, ID, KS, MN, MO, MT, NM, NV, OK, OR, SD)	3-8	Math	District	-0.03*	Time in school (+), significant only for lowest time in school group
Thompson & Ward (2022)	12 (AZ, GA, ID, KS, MN, MO, MT, NM, NV, OK, OR, SD)	3-8	ELA	District	-0.02	Time in school (+), significant only for lowest time in school group
Thompson et al. (2021b)	OR	11	Math	Student	-0.09***	Rural (+)
Thompson et al. (2021b)	OR	11	ELA	Student	-0.03	Rural (+)
Morton (2022)	OK	11	Math	District	+0.02	N/A
Morton (2022)	OK	11	ELA	District	-0.02	N/A

Notes. *p<.10, **p<.05, ***p<.01

Appendix Table A2: Representativeness of Schools in the Analytic Sample

	Always five-day				Ever four-day[a]			
	Schools in the analytic sample[b]		All public schools in states in analytic sample[b]		Schools in the analytic sample[b]		All public schools in states in analytic sample[b]	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Student characteristics								
% Black	1.9	2.7	0.6	0.4	4.4	8.4	0.9	2.0
% White	78.7	19.4	66.3	26.2	71.7	26.0	71.4	25.9
% Native	2.9	11.9	8.8	24.6	2.6	10.8	3.9	13.6
% Hispanic	12.3	15.4	21.4	19.2	16.4	20.7	21.2	23.9
% Asian	1.6	2.5	0.4	0.5	1.8	2.8	0.6	1.8
School characteristics								
Enrollment	342.4	211.4	196.6	112.5	325.3	242.3	167.5	176.6
% FRPL	38.2	20.5	54.5	19.8	44.1	23.9	48.1	22.4
Student-teacher ratio	14.4	3.3	12.0	3.3	15.8	14.5	12.0	4.5
District characteristics								
% ELL	4.8	7.6	7.5	7.3	7.1	10.1	4.7	6.9
% IEP	10.5	6.6	6.7	7.8	10.6	8.2	6.4	8.0
Total current expenditures per pupil ($ thousands)	11.0	3.1	13.4	5.4	10.9	3.8	13.3	5.8
% Rural	41.7	–	70.6	–	35.8	–	76.1	–
% Town	27.0	–	27.3	–	22.4	–	11.4	–
% Suburb	31.2	–	2.1	–	16.7	–	6.2	–
% City[c]	0.0	–	0.0	–	25.1	–	6.3	–

[a]The school ever implemented a four-day school week by the 2019-20 school year.
[b]School-level data from the Common Core of Data (CCD) were averaged for each school from the period of 2008-09 to 2019-20, such that each school is represented once in the data.
[c]City districts were excluded from the analytic sample because no city district was observed adopting a four-day school week.
Notes. School-level data are from the CCD. FRPL = Free- or reduced-price lunch. ELL = English Language Learner. IEP = Individualized Education Program.

Appendix Table A3: Effects of the Rural Four-Day School Week on Achievement and Growth

(Event Study)

	Spring achievement		Fall-to-spring gains	
	Math	Reading	Math	Reading
	(1)	(2)	(3)	(4)
3 years before	-0.003	0.016	0.025	-0.013
	(0.029)	(0.021)	(0.022)	(0.045)
2 years before	0.019	0.036*	0.021	0.033
	(0.026)	(0.019)	(0.040)	(0.049)
Adoption year	0.031	-0.009	0.021	-0.009
	(0.028)	(0.030)	(0.035)	(0.030)
1 year after	0.044	-0.028	-0.015	-0.040
	(0.043)	(0.042)	(0.030)	(0.025)
2 years after	-0.012	-0.068	-0.073*	-0.050
	(0.087)	(0.086)	(0.042)	(0.059)
3 years after	0.005	-0.092	-0.016	-0.057
	(0.104)	(0.101)	(0.076)	(0.079)
Observations	2804285	2753424	2486342	2443948
R-squared	0.861	0.832	0.310	0.300
p-value: (H_0: $\beta_{-3} = \beta_{-2} = 0$)	0.517	0.192	0.458	0.730
p-value: (H_0: $\beta_0 = \beta_1 = \beta_2 = \beta_3$)	0.012	0.483	0.019	0.674

Notes. All models include grade-term FE and student FE.
*p< 0.10, **p< 0.05, ***p< 0.01

Appendix Table A4: Effects of the Non-Rural Four-Day School Week on Achievement and Growth (Event Study)

	Spring achievement		Fall-to-spring gains	
	Math	Reading	Math	Reading
	(1)	(2)	(3)	(4)
3 years before	-0.018	-0.001	-0.021	0.015
	(0.077)	(0.107)	(0.062)	(0.084)
2 years before	0.051	0.041	0.009	0.031
	(0.062)	(0.101)	(0.035)	(0.072)
Adoption year	-0.050	-0.055*	-0.091***	-0.055
	(0.046)	(0.028)	(0.021)	(0.067)
1 year after	-0.069**	-0.137**	-0.090***	-0.096*
	(0.034)	(0.055)	(0.016)	(0.053)
2 years after	-0.103***	-0.202*	-0.095	-0.106
	(0.028)	(0.106)	(0.060)	(0.086)
3 years after	-0.110**	-0.179***	-0.068	-0.098**
	(0.049)	(0.044)	(0.047)	(0.039)
Observations	2802537	2749950	2485399	2441092
R-squared	0.861	0.832	0.310	0.300
p-value: $(H_0: \beta_{-3} = \beta_{-2} = 0)$	0.100	0.155	0.792	0.848
p-value: $(H_0: \beta_0 = \beta_1 = \beta_2 = \beta_3)$	0.592	0.846	0.070	0.059

Notes. All models include grade-term FE and student FE.
**p*< 0.10, ***p*< 0.05, ****p*< 0.01

Appendix Table A5: Effects of the Four-Day School Week on School Composition

	Dependent variables: School characteristics							
	School-level variables						District-level variables	
	Enroll-ment	% White	% Native American	% Hispanic	% FRPL	Student-teacher ratio	% IEP	% ELL
Math sample								
Fourday	1.175	0.726	-0.496	-0.409	0.125	0.401	-0.645*	-0.496
	(4.585)	(1.089)	(0.760)	(1.107)	(1.438)	(0.311)	(0.378)	(0.834)
Observations	12994	12964	11967	11967	12969	12619	11024	11957
R-squared	0.966	0.967	0.988	0.988	0.933	0.737	0.908	0.946
Reading sample								
Fourday	1.757	0.718	-0.497	-0.410	-0.025	0.382	-0.663*	-0.421
	(4.977)	(1.108)	(0.756)	(1.147)	(1.460)	(0.295)	(0.384)	(0.840)
Observations	12838	12807	11822	12708	12812	12466	10876	11807
R-squared	0.966	0.968	0.988	0.974	0.932	0.738	0.908	0.946
Grade-term FE	x	x	x	x	x	x	x	x
School FE	x	x	x	x	x	x	x	x

Notes. FRPL = Free- or reduced-price lunch. ELL = English Language Learner. IEP = Individualized Education Program.
**p*<.10, ***p*<.05, ****p*<.01.

Appendix Table A6: Effects of the Four-Day School Week on Achievement and Growth Using a Rural-Only Control Group

	Sample					
	Math			Reading		
	All four-day weeks	Rural four-day weeks	Non-rural four-day weeks	All four-day weeks	Rural four-day weeks	Non-rural four-day weeks
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Spring achievement						
Fourday	-0.013	0.052	-0.066**	-0.039	-0.006	-0.071**
	(0.037)	(0.041)	(0.027)	(0.033)	(0.043)	(0.031)
Observations	757924	744536	743278	773743	762078	744616
R-squared	0.841	0.840	0.841	0.817	0.817	0.817
Panel B: Fall-to-spring gains						
Fourday	-0.084***	-0.042	-0.117***	-0.086***	-0.064***	-0.107***
	(0.030)	(0.028)	(0.034)	(0.016)	(0.022)	(0.021)
Observations	666753	654644	654160	682757	672544	656669
R-squared	0.317	0.317	0.316	0.304	0.303	0.303
Grade-term FE	x	x	x	x	x	x
School FE	x	x	x	x	x	x
Student FE	x	x	x	x	x	x

Notes. *p<.10, **p<.05, ***p<.01

Appendix Table A7: Effects of the Four-Day School Week on Student Achievement and Growth (Event Study), Reweighted to Account for Variation in Treatment Timing

	Spring achievement		Fall-to-spring gains	
	Math	Reading	Math	Reading
	(1)	(2)	(3)	(4)
3 years before	-0.001	0.008	0.005	0.006
	(0.033)	(0.039)	(0.021)	(0.034)
2 years before	0.038	0.038*	0.014	0.038
	(0.028)	(0.028)	(0.015)	(0.022)
Adoption year	-0.011	-0.027*	-0.035*	-0.035
	(0.025)	(0.019)	(0.018)	(0.021)
1 year after	-0.021	-0.076***	-0.046***	-0.051***
	(0.018)	(0.027)	(0.016)	(0.017)
2 years after	-0.054*	-0.112***	-0.078***	-0.056**
	(0.028)	(0.046)	(0.021)	(0.014)
3 years after	-0.043	-0.128***	-0.031	-0.068***
	(0.030)	(0.048)	(0.032)	(0.025)
Observations	2817887	2765269	2498597	2454279
R-squared	0.8594	0.8305	0.3090	0.2995
p-value: ($H_0: \beta_{-3} = \beta_{-2} = 0$)	0.397	0.102	0.605	0.238
p-value: ($H_0: \beta_0 = \beta_1 = \beta_2 = \beta_3$)	0.640	0.141	0.420	0.658

Notes. All models include grade-term FE and student FE.
*p< 0.10, **p< 0.05, ***p< 0.01

Appendix Table A8: Effects of the Four-Day School Week on Achievement and Growth by Student Grade Level

	Grade							
	1st	2nd	3rd	4th	5th	6th	7th	8th
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Math spring achievement								
Fourday	-0.061	0.016	-0.140*	-0.022	-0.051	0.113*	-0.021	0.026
	(0.054)	(0.115)	(0.077)	(0.082)	(0.072)	(0.073)	(0.063)	(0.039)
Observations	261500	325463	484360	585095	592428	559340	580315	606547
R-squared	0.885	0.879	0.887	0.915	0.927	0.931	0.940	0.947
Panel B: Math fall-to-spring gains								
Fourday	-0.098	0.076	-0.121	0.009	-0.071	0.089	-0.047	0.054
	(0.089)	(0.095)	(0.078)	(0.100)	(0.122)	(0.082)	(0.073)	(0.051)
Observations	180668	274871	405885	533261	538554	500286	511424	532936
R-squared	0.513	0.536	0.535	0.530	0.523	0.522	0.518	0.520
Panel C: Reading spring achievement								
Fourday	-0.074	0.035	-0.086	-0.040	-0.048	0.058	-0.074	-0.044
	(0.062)	(0.094)	(0.056)	(0.061)	(0.065)	(0.064)	(0.078)	(0.056)
Observations	250959	308446	470308	575985	584583	548908	567278	597013
R-squared	0.874	0.880	0.893	0.905	0.907	0.904	0.906	0.910
Panel D: Reading fall-to-spring gains								
Fourday	-0.055	0.089	-0.194*	-0.040	-0.081	0.023	-0.100	0.030
	(0.111)	(0.065)	(0.110)	(0.097)	(0.072)	(0.084)	(0.124)	(0.088)
Observations	174841	260446	393973	524205	532458	490638	499363	527745
R-squared	0.517	0.530	0.534	0.526	0.513	0.508	0.502	0.502

Notes. $^*p< 0.10$, $^{**}p< 0.05$, $^{***}p< 0.01$

Appendix Table A9: Effects of the Four-Day School Week on Achievement and Growth by Student Gender and Race

	Dependent variables: Standardized NWEA MAP Growth test scores					
	Math			Reading		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Spring achievement						
Fourday	-0.033	-0.026	-0.019	-0.072**	-0.058	-0.048
	(0.037)	(0.041)	(0.039)	(0.034)	(0.039)	(0.032)
Fourday*Female		-0.013			-0.028	
		(0.017)			(0.022)	
Fourday*Native			0.028			-0.047
			(0.077)			(0.065)
Fourday*Hispanic			-0.053			-0.068
			(0.051)			(0.044)
Fourday*Other race			-0.041			-0.028
			(0.039)			(0.051)
Omitted subgroup	None	Male	White	None	Male	White
Observations	2817648	2817047	2817164	2765031	2764460	2764547
R-squared	0.861	0.861	0.861	0.832	0.832	0.832
Panel B: Fall-to-spring gains						
Fourday	-0.051*	-0.028	-0.054***	-0.062***	-0.041***	-0.062***
	(0.029)	(0.028)	(0.019)	(0.017)	(0.015)	(0.021)
Fourday*Female		-0.044***			-0.041**	
		(0.014)			(0.019)	
Fourday*Native			0.124***			0.054*
			(0.020)			(0.032)
Fourday*Hispanic			-0.069***			-0.038
			(0.023)			(0.027)
Fourday*Other race			0.008			0.010
			(0.022)			(0.061)
Omitted subgroup	None	Male	White	None	Male	White
Observations	2498362	2497898	2497898	2454045	2453590	2453577
R-squared	0.310	0.310	0.310	0.300	0.300	0.300

Notes. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$