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IZA DP No. 12204

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ISSN: 2365-9793

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ABSTRACT

Effects of Four-Day School Weeks on Student Achievement: Evidence from Oregon*

Due to increased financial pressures following the Great Recession, a growing number of school districts have switched from a traditional five-day school week to a four-day week schedule. While these shorter school weeks potentially help reduce costs, this study considers the implications these school schedules have on student achievement. This study uses a difference-in-differences analysis using a panel data set of student-level test scores to examine the effects of the adoption of these four-day school weeks on student achievement in the State of Oregon from 2007-2015. I find that these school schedules have detrimental impacts on student achievement, with declines of between 0.044 and 0.053 standard deviations in math scores and declines of 0.033 and 0.038 standard deviations in reading scores. The results suggest that four-day school weeks are more detrimental for the math and reading achievement of boys and the reading achievement of low-income students. Earlier school start times and lost instructional time of nearly three and a half hours a week appear to be the primary mechanisms underlying these achievement losses.

JEL Classification: I21

Keywords: four-day school weeks, student achievement, instructional time

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* The research reported in the article was made possible (in part) by a grant from the Spencer Foundation (201800081). The views expressed are those of the authors and do not necessarily reflect the views of the Spencer Foundation. A special thanks to Chelsea Clinton and Brian Reeder at the Oregon Department of Education for helping with accessing the student-level database for this project and to Madeleine Smith, Zack Buhlmann for expert research assistance on this project. The author is grateful to the participants of the 2017 Association for Education Finance and Policy Conference for their helpful comments and discussion.

1. Introduction

The aftermath of the Great Recession has seen large reductions in school funding, leading to increased financial pressures on many school districts. Between 2008 and 2013, state funding for schools fell by around $850 per pupil and local funding fell by around $175 per pupil (Leachman, Masterson, and Figueroa 2017). These financial pressures have persisted well after the Great Recession, due to difficulty in raising new taxes – both due to persisting declines in property values and tax limitation policies – and slowly recovering state funding levels. In fact, by 2016, twenty-five states had general formula aid that was still below 2008 levels (Leachman, Masterson, and Figueroa 2017). At the same time, expenditures have been rising in many districts. Most notably, employee benefits increased by 22 percent from 2005-2014 (Marchitello 2018) and pension/retirement costs increased from 4.8 percent of total per pupil expenditures in 2004 to 10.6 percent of total expenditures in 2018 (Costrell 2018).

Due to these financial pressures, school districts have had to find unique ways to reduce costs or increase expenditures. Traditionally, school districts have dealt with budgetary problems by cutting academic programs, increasing class sizes, reducing staff, and charging student activity fees (e.g., pay-to-play athletics). As an alternative to these types of cost-cutting measures, some, primarily rural, school districts, have championed four-day school weeks as a way to reduce costs and ease financial pressures. While the use of four-day school weeks in the United States dates back to the 1930s, the number of school districts using these types of school calendars has been steadily rising over the past two decades in many states.[1] Currently, there are approximately 1,500 schools in 600 school districts operating on a four-day school week and 24 states have at least one public school operating on a four-day school week (Thompson, et al., 2019).[2]

Despite the growing use of these school schedules, there is very little credible causal evidence of the effects of four-day school weeks on student achievement.[3] Much of the previous literature on four-day school weeks has largely focused on case studies of specific school districts adopting these

[1] According to Thompson, et al. (2019) fewer than 200 schools in 100 school districts had four-day school weeks in the 1998-1999 school year. By the start of the Great Recession that number had doubled to around 450 schools in 200 school districts. Since the Great Recession, the number of schools and school districts with four-day school weeks has nearly tripled from a decade earlier.

[2] These 24 states are Alaska, Arizona, California, Colorado, Georgia, Idaho, Iowa, Kansas, Louisiana, Michigan, Minnesota, Missouri, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming. Several other states have had four-day school weeks in the past, (Heyward 2018) but currently do not have any schools operating four-day school weeks.

[3] There is some quasi-experimental literature examining the impacts of other types of school calendars on student achievement, particularly relating to year-round schooling. Most notably, Graves (2010; 2011) finds that switching to a year-round school calendar may negatively impact student achievement. McMullen and Rouse (2012) find little, if any, impact of these year-round school calendars on student achievement. Similar to this study, they examine differential effects of these policies on racial subgroups, but find no evidence that any racial subgroup benefits from year-round schooling.

school calendars or more descriptive/cross-sectional studies of various states allowing four-day school weeks.[4] Anderson and Walker (2015) is the sole previous study that has used quasi-experimental evidence to uncover causal impacts of these four-day school week schedules on achievement.[5] Using a panel difference-in-differences approach they find a positive effect of four-day school weeks on 4th and 5th grade math and reading proficiency rates in Colorado.

Although the purpose of this paper is quite similar to that of Anderson and Walker (2015), this study has some notable contributions. First, by analyzing a different institutional setting, this study provides a comparison to the Anderson and Walker (2015) results and provides context for the generalizability of state-specific studies of four-day school weeks. Second, this is the first study to my knowledge to assess the effects of four-day school weeks using student-level data. Thus, it is also the first study to identify differential effects of four-day school weeks on various student subgroups to help determine whether these school schedules mitigate or exacerbate pre-existing achievement gaps in these school districts. Finally, this study conducts an extensive data collection, including primary data collection on school day start and end times for 80 percent of the schools in Oregon from 2007-2015, which enables this study to uncover the potential mechanisms driving these achievement effects.

This study uses a difference-in-differences analysis using a panel data set of student-level test scores to examine the effects of four-day school weeks on student achievement in the State of Oregon from 2007-2015. I generally find that student achievement declines following the switch to a four-day school week, as math test scores fall by between 0.044 and 0.053 standard deviations and reading scores fall by between 0.033 and 0.038 standard deviations. Looking at differential effects across student subgroups, I find that both math and reading achievement for boys is more negatively impacted by these school schedules than girls and find greater detrimental effects on reading achievement for low-income students. The study examines several potential mechanisms for these achievement effects and finds that slightly earlier start times and lost instructional time of nearly three and a half hours per week are the primary mechanisms for these achievement losses. While these negative achievement effects are some-

[4]This literature is quite extensive (McCoy 1983; Daly and Richburg 1984; Grau and Shaugnessy 1987; Reinke 1987; Sagness and Salzman 1993; Feaster 2002; Yarborough and Gilman 2006; Hale 2007; Bell 2011; Reeves 2014; Tharp 2014; Amys 2016; Hegwood 2016) and while useful for understanding the institutional settings, the debates that are at the forefront of these decisions, and the differences between four and five-day school week districts, these studies provide little, if any, credible causal evidence of the effects of these policies on achievement. For a thorough review of this literature, see Donis-Keller and Silvernail, 2009.

[5]Two recent papers (Fischer and Argyle 2018; Ward 2019) have examined the causal effect of four-day school weeks on non-academic outcomes. Fischer and Argyle (2018) finds that four-day school weeks led to an almost 20 percent increase in juvenile crime. Ward (2019) finds that mothers of primary school-aged children are less likely to be employed and work fewer hours as a greater percentage of local school enrollment switches to a four-day school week schedule.

what mitigated by reductions in the number of days missed due to student absences and disciplinary infractions, I find that changes in instructional time explain a substantial portion of the declines in math and reading scores.

2. Conceptual Framework

This study is interested in the impact of four-day school weeks on overall student achievement and achievement across various student subgroups. The theory underlying this analysis – the theory of education production function – provides a very nuanced view of the relationship between the adoption of a four-day school week and student achievement. Generally speaking, the education production function models student learning as both dynamic and cumulative (i.e., past experiences and past learning contribute to present learning) and includes all relevant past child, family, and school inputs):

$$Achievement_{it} = f(\text{child inputs}_{i,t0...T}, \text{family inputs}_{i,t0...T}, \text{school inputs}_{i,t0...T})$$

In the context of the four-day school week, the change in the school calendar could potentially impact the quantity and quality of these educational inputs and there are many potential mediating factors (e.g., amount of instructional time, teacher quality, school day start/end times, school expenditures, disciplinary incidents, student absences) that may be driving the effects of four-day school weeks on achievement. Previous literature has linked these various intermediate factors to changes in student achievement, but the effects are often not in the same direction, leading to a largely ambiguous overall effect of four-day school weeks on student achievement.

The most direct mediating factors affected by the four-day school week may be those relating to the calendar change themselves, including total instructional hours and school start times. In order to meet state-mandated minimum instructional hour requirements, school districts switching to a four-day school week likely need to have longer school days on the remaining four school days per week. Previous literature (Bellei, 2009; Hincapie, 2016; Jensen, 2013) generally finds that lengthening the school day has a positive effect on student achievement, although much of this is likely due to the resulting increased instructional time throughout the year. While changing the length of the school day may recover some of the hours lost from the removal of the fifth day, they may not feasibly be able to offset the loss of the fifth day entirely. Thus, it may be the case that the overall amount of instructional time decreases as a result of the switch to the four-day school week, a case that previous literature (Lavy, 2015; Cattaneo,

Oggenfuss, and Wolter, 2017) suggests would result in a reduction in student achievement.

In order to lengthen the school day, many schools likely engage in some combination of moving up the start of the school day and pushing back the end of the school day. A growing literature on the achievement effects of school start times has shown that starting the school day later has positive effects on achievement (Wahlstrom, et al., 1998; Carell, Maghakian, and West, 2011; Wong, 2011; Hinrichs, 2011; Edwards, 2012; Heissel and Norris, 2017). Most notably, Edwards (2012) finds that moving school start times one hour later increases reading test scores by 0.03 to 0.1 standard deviations and math test scores by 0.06 to 0.09 standard deviations. He finds smaller effects for elementary school students, but notes that this may be due to the fact that elementary schools in his sample generally have much later start times. Heissel and Norris (2017) find that moving school start times one hour later relative to sunrise would increase test scores by 0.073 standard deviations in math and 0.048 standard deviations in reading. These results suggest that if start times are moved earlier as a result of the switch to the four-day school week, then we would expect student achievement to fall as a result.

The greater flexibility provided by the four-day school week, however, may be one of the potential positive aspects of these policies for student achievement. In particular, four-day school week districts would have greater ability to reschedule school days canceled due to weather before standardized tests are administered than those on five-day school weeks. The flexible schedule may also help reduce student absences, by giving parents a day during which to schedule appointments, take students to athletic events, instead of during the actual academic week. Previous quasi-experimental research (Aucejo and Romano, 2013; Clotfelter, Ladd, and Vigdor, 2009; Fitzpatrick, Grissmer, and Hastedt, 2011; Gershenson, Jacknowitz, and Brannegan, 2017; Goodman, 2014; Gottfried, 2009; 2011; Hansen, 2011; Hayes and Gershenson, 2016; Leuven et al., 2010; Marcotte and Hansen, 2010; Parinduri, 2014; Pischke, 2007; Ready, 2010; Sims, 2008) generally finds that an additional day of schooling prior to the testing date has a positive effect on student achievement. In particular, days lost due to weather-related cancellations have been found to negatively impact performance due to missed instruction time prior to the standardized test (Marcotte, 2007; Marcotte and Hemelt, 2008), since districts on five-day school week schedules often only have the option of adding make-up days to the end of the school year. More flexible school schedules, such as the four-day school week, may allow school districts to more easily reschedule school days cancelled due to weather, meaning that districts may be able to make up missed days of instruction before standardized tests are administered, thereby increasing student achievement.

Finally, mechanisms such as changes in teacher quality and reductions in student services may result

from the switch to the four-day school week. The four-day school week may be attractive to some teachers, leading to compositional changes in the teacher pool. These changes could positively or negatively impact student achievement depending on the types of teachers that move into and out of these schools as a result of the four-day school week. The longer school day and the potential loss of overall instructional time, may present challenges for teachers to adapt their curriculum to the new school schedule. If teachers are unable to effectively use the longer school day or modify their coursework to fit within the change in overall instructional time, student learning may be negatively affected. The reduction of one day per week is often meant to save costs on things like food services, building operations, and student transportation, but it also means that students are losing access to food services and physical education, one day a week, which may also have implications for student academic performance.

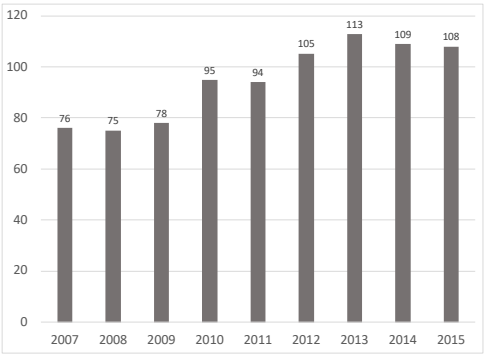
3. Background and Institutional Details

The use of four-day school weeks dates back to the 1930s in South Dakota, with more recent four-day school week policies starting in the 1970s (Donis-Keller and Silvernail, 2009). As of 2018-2019, 24 states have at least one public school operating on a four-day school week (Thompson, et al., 2019), up from 17 a decade earlier (Donis-Keller and Silvernail, 2009; Gaines, 2008). In total, approximately 1,500 schools in 600 school districts currently operate on a four-day school week (Thompson, et al., 2019). In Oregon, the first four-day school weeks began in 1983 and since then there has been a steady increase in Oregon in the number of school districts adopting these types of school schedules,[6] with two major periods of adoption – one between 1997 and 2003 and another between 2009 and 2013. As shown in Figure 1a, this study will be identifying the effect of the adoption of four-day school weeks by schools in this latter time period, during which the number of schools with a four-day school week increased from 75 in 2008 to a peak of 113 in 2013.

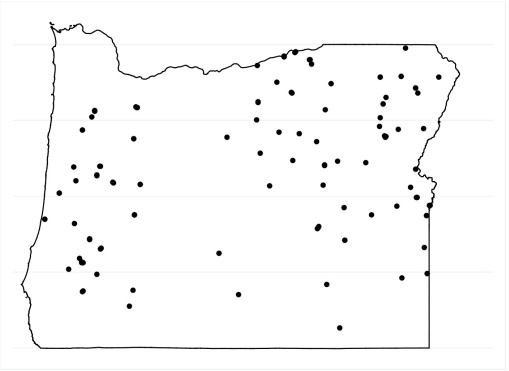
Across the many states that allow four-day school weeks, a majority of the districts that adopt these policies are small, rural districts – and Oregon is certainly no exception. As shown in Panel (b) of Figure

[6]In Oregon, the choice to adopt a four-day school week is largely up the discretion of the school district and the structure of these four-day school weeks can vary widely across districts. Districts interested in switching to a four-day school week must submit an application for an alternative school year (i.e., school year that offers below 175 days of instruction) to the Superintendent of Public Instruction at least 90 days prior to the upcoming school year. This essentially requests school districts to submit a waiver of OAR 581-22-502 that requires that Oregon school districts offer 175 days of instruction. Interested school districts also need to outline the basic plan for operating on a four day school week, including the needs addressed by the four day school week, the goals of the policy, and how those goals would be addressed. Particular items school districts must address include, the impact on student activities and support programs (e.g., counseling, safety), the estimated cost savings, and how the district will ensure instructional time is maintained. Regardless of the type of school schedule used, Oregon public schools have guidelines establishing minimum required hours of instructional time, which vary between 900 and 990 hours depending on grade level.

Figure 1: Yearly and Geographic Distribution of FDSW Schools in Oregon



(a) Number of FDSW schools, by year



(b) Map of schools with FDSW

1, which provides the geographical location of the schools that have adopted a four-day school week, the large majority of four-day school week schools are located in rural Eastern Oregon. The 13 districts (38 schools) that adopted a four-day school week in the 2007-2015 time span examined in this study are more evenly distributed across many regions of the state. The student populations in these districts represent only about 3 percent of the total number of grade 3-8 students in the state, a similar percentage as found in Colorado four-day school week districts (Anderson and Walker, 2015), making Oregon an interesting comparison state to Colorado.

4. Data Sources and Descriptive Statistics

4.1. Data

The four-day school week data come from an extensive data collection, which involved phone and email correspondence with all school districts in the state of Oregon. From this correspondence, the following information was collected: (a) the school years in which each school operated on a four-day school week, if ever; (b) if ever operated on a four-day school week, the services available for students on the fifth-day, if any, and the rationale for the switch to the four-day school week; (c) the daily school day start and end times from 2007-2015.[7] Through this data collection, four-day school week information has been collected from all of the known four-day schools and school day start and end time data has been collected from around 83 percent (70 percent with full data spanning 2007-2015) of the schools in Oregon. This four-day school week information is augmented with information on

[7]The year in this study refers to the school year and thus the data spans the 2006-2007 school year to the 2014-2015 school year.

student test scores, student-level characteristics, school-level teacher characteristics, and district-level financial and demographic characteristics.

From the Oregon Department of Education, I obtain student-level and teacher-level records from 2007-2015. The main variables of interest are student-level math and reading standardized test scores for grades 3 through 8 from the Oregon Assessment of Knowledge and Skills (OAKS) tests. In order to make test scores comparable across grades and years, I use a common convention in the literature (see Bifulco and Ladd, 2006 or McMullen and Rouse, 2012) and standardize these test scores within grade and school year so that the grade-by-year test scores have means of zero and standard deviations of one. These data also include a host of other student-level information, including the student's gender, race, free and reduced priced lunch eligibility status, English as a second language program participation, special education or gifted status, number of absences, and the number of days missed due to disciplinary incidents. The teacher level data set includes a host of teacher characteristics, including race, experience, licensure, educational attainment, and base salary. Unfortunately, during the time period of this study, student and teacher data are not linked and thus, I aggregate the teacher data to the school-level to match to the student-level data. In total, this study analyzes 1,850,238 individual test scores from 471,518 students in grades 3 to 8 during 2007-2015. Additional data on school district enrollment and pupil-teacher ratio is obtained from the National Center for Education Statistics (NCES) Common Core of Data.

4.2. Descriptive Statistics

Table 1 presents summary statistics for both four-day and five-day school week schools and there are some notable differences in achievement. Students in four-day school weeks have standardized math and reading test scores that are substantially lower than students in five-day school weeks. On average, students in four-day school weeks have math test scores that are 0.144 standard deviations below the average in the sample and reading test scores that are 0.092 standard deviations below the sample average, while students in five day school weeks have test scores that are 0.11 to 0.13 standard deviations above the sample average. Schools with four-day school weeks also have a smaller fraction of students meeting proficiency thresholds in math (64.2 percent compared to 69 percent) and reading (73.1 percent compared to 74.9 percent).

There are some other key differences between four-day and five-day schools that could be contributing to the differences observed in achievement. As discussed before, school districts with four-day schools tend to be largely rural districts and thus, on average, have much smaller average student en-

Table 1: Summary Statistics

	Full Sample	Four-Day Only	Five-Day Only
Achievement Outcomes			
Standardized math score	0.014	-0.147	0.020
	(0.996)	(0.850)	(1.000)
Standardized reading score	0.015	-0.095	0.019
	(0.991)	(0.898)	(0.994)
Fraction of Students Proficient in Math	0.692	0.641	0.694
	(0.462)	(0.480)	(0.461)
Fraction of Students Proficient in Reading	0.755	0.731	0.756
	(0.430)	(0.443)	(0.430)
Mechanisms			
Start time	8:17	7:58	8:20
	(0:27)	(0:13)	(0:27)
Length of school day (minutes)	6.693	7.528	6.568
	(0.449)	(0.284)	(0.316)
Length of school week (minutes)	32.214	30.113	32.529
	(1.788)	(1.137)	(1.650)
Days Absent	9.926	8.438	9.978
	(9.920)	(8.213)	(9.970)
Number of Discipline Incidents	0.341	0.193	0.346
	(3.969)	(2.360)	(4.013)
Student Characteristics			
Enrollment	15402	1351	15892
	(15219)	(1451)	(15248)
Fraction of White Students	0.667	0.790	0.662
	(0.471)	(0.408)	(0.473)
Fraction of Black Students	0.026	0.004	0.027
	(0.159)	(0.062)	(0.162)
Fraction of Hispanic Students	0.202	0.154	0.204
	(0.402)	(0.361)	(0.403)
Fraction of Asian Students	0.047	0.006	0.048
	(0.211)	(0.078)	(0.214)
Fraction of Indian Students	0.017	0.014	0.018
	(0.131)	(0.119)	(0.131)
Fraction of Multi race Students	0.041	0.032	0.042
	(0.199)	(0.175)	(0.200)
Fraction of Female Students	0.491	0.491	0.491
	(0.500)	(0.500)	(0.500)
Fraction of FRL Eligible Students	0.487	0.584	0.484
	(0.500)	(0.493)	(0.500)
Fraction of ESL Students	0.048	0.023	0.049
	(0.215)	(0.150)	(0.216)
Fraction of Special Education Students	0.143	0.148	0.142
	(0.350)	(0.355)	(0.349)
Fraction of Talented in Reading Students	0.036	0.011	0.037
	(0.186)	(0.104)	(0.188)
Fraction of Talented in Math Students	0.034	0.011	0.034
	(0.180)	(0.105)	(0.182)
Number of Observations	1,850,238	62,379	1,787,859
Number of Students	471,518	15,745	455,773
Number of Schools	1161	156	1005
Number of Districts	177	57	120

Note: Full sample includes all student test score observations; Four-day Only sample includes student test score observations from school years in which the district operated on a four-day school week; Five-day Only sample includes student test score observations from school years in which the district operated on a traditional five-day school week. Standard Deviations are given in parentheses.

rollments (385 students to 3,676 students), greater populations of white students (71 percent to 59.3 percent) and students eligible for free and reduced priced lunch (57.7 percent to 48.3 percent) than five day school week districts. Four-day school week districts spend more per-pupil on educational services than do five-day school week districts on operating expenditures, food services, and operations and maintenance. Students in four-day school week districts have fewer student absences (8.5 compared to 10) and discipline incidents (0.188 to 0.333), on average, than five-day school week districts. Finally, the composition of instructional time is also substantially different between four-day and five-day school weeks. Four-day schools start their school day almost 25 minutes before five-day schools and have school days that are nearly an hour longer than five-day schools. Despite the longer school day, however, the weekly time in school is nearly two and a half hours less in four day schools than five day schools.

5. Impact of Four-Day School Weeks on Student Achievement

5.1. Difference-in-Differences Estimation Strategy

Although the descriptive statistics presented in Table 1 show there are noticeable differences in math and reading test scores, student absences, discipline incidents, and instructional time between four-day school week districts and those with five-day school weeks, it is hard to determine whether these differences are causally linked to the adoption of a four-day school week. Given the differences in the size and demographic make-up of these four-day school week districts, these differences in the raw summary statistics could be driven by underlying differences in the types of students, preferences for education, or other factors. Thus, to analyze the causal effect of four-day school weeks on student standardized test score performance, I estimate the following difference-in-differences regression:

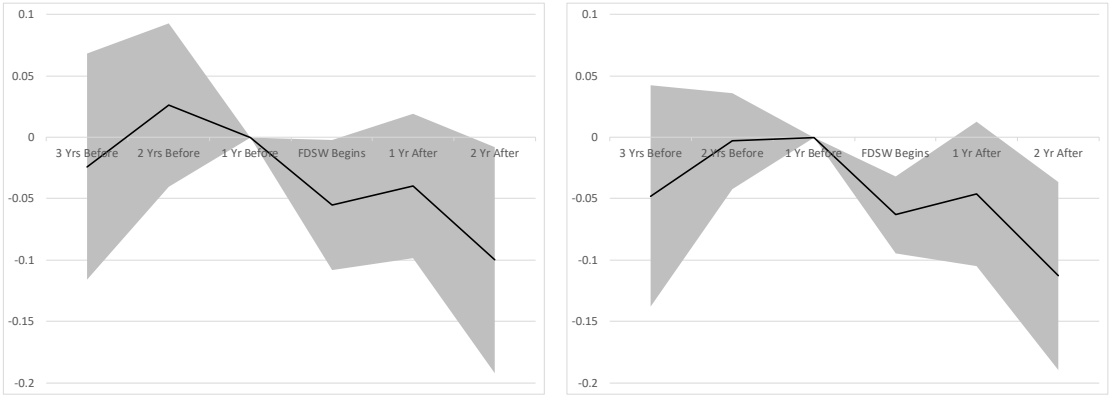
$$A_{igsdt} = \alpha + \beta_1 FDSW_{sdt} + \gamma \mathbf{X}_{igsdt} + \delta \mathbf{Z}_{sdt} + \phi_i + \rho_s + \theta_{gt} + \epsilon_{igsdt} \quad (1)$$

where A_{igsdt} is student i's standardized math or reading test score in grade g in school s in district d during school year t. Test scores are standardized within subject, grade, and school year. The $FDSW_{sdt}$ variable is a dummy variable that is equal to one if school s was operating on a four day school week during school year t. The $\mathbf{X}_{isdt}$ vector contains student-level characteristics including the student's gender, race, special education/gifted status, English as a second language (ESL) status, free and reduced price lunch (FRL) eligibility status, number of days absent, number of discipline incidents. The $\mathbf{Z}_{sdt}$ vector contains

school-level and district-level controls including the fraction of teachers in the school with 0-3, 4-10, and 11 or more years of teaching experience, the fraction of teachers in the school with an advanced degree, the fraction of teachers in the school who are licensed, the school's teacher turnover rate, and total district enrollment. The ϕ_i, ρ_s, and θ_{gt} vectors include student, school, and grade-by-year fixed effects, respectively, while ϵ_{igsdt} is an idiosyncratic error term.

For this empirical strategy to be valid, the parallel trends assumption must hold. For this assumption to be satisfied in this context, test scores should not be trending differentially for students in four-day school week schools prior to the adoption of the four-day week. To test this assumption, I estimate an event study version of equation (1) to capture the differences in achievement between students in four-day and five-day schools before and after the four-day school week implementation. Due to the short time window examined in the study, I am only able to conduct an event study that includes separate effects for the three years before the adoption of the four-day school week through the second year after the implementation. The results of this analysis are presented in Figure 2 and show a slight, but statistically insignificant, upward trend in test scores prior to the introduction of the four-day school week. In the first year of the four-day school week there is a noticeable, approximately, 0.06 standard deviation drop in math and reading test scores. This negative effect persists and gets slightly larger in the subsequent academic years after the switch to the four-day week, with a total reduction of 0.1 standard deviations in math and 0.11 standard deviations in reading two years after the switch to a four-day school week. Thus, it appears that switching to the four-day school week has immediate and persistent detrimental impacts on student test score performance.

Figure 2: Achievement Differences Between Four-Day and Five-Day Schedules



(a) Math Achievement

(b) Reading Achievement

5.2. Difference-in-Differences Results

The results of difference-in-differences analysis outlined in equation (1) are presented in Table 2. Similar to the event study analyses, these results suggest that student test score performance falls as a result of the switch to four-day school weeks. Math scores fall by 0.044 to 0.053 standard deviations, while reading scores fall by 0.033 to 0.038 standard deviations.[8] To put the size of these effects in perspective, they are comparable to the achievement effects of a loss of about 35 to 55 minutes of math or reading instruction per week[9] or about a fourth to a sixth of the size of the achievement loss that would occur from switching a student from a small class size to a large class size.

Table 2: Effects of FDSW on Math and Reading Achievement

	Panel A: Math Achievement		**Panel B: Reading Achievement**	
	(1)	(2)	(3)	(4)
FDSW	-0.053***	-0.044**	-0.038**	-0.033***
	(0.020)	(0.017)	(0.019)	(0.011)
School FE	X	X	X	X
Student FE		X		X
Observations	1,850,238	1,850,238	1,844,010	1,844,010
R-squared	0.354	0.841	0.351	0.845

Each column of the table presents results from a separate regression containing the specified dependent variable. Each specification contains student-level characteristics, school-level and district-level controls, and school year, grade, school, and student fixed effects. Robust standard errors, clustered at the school-level are given in parentheses. *** p<0.01, ** p<0.05, * p<0.1

I test the sensitivity of these baseline results in several ways. I first test the robustness of these baseline results to changes in the specification of equation (1), with the results of these analyses presented in Panel A of Table 3.[10] As the event study shows a slight upward, albeit statistically insignificant,

[8] In addition to changes in the overall achievement scores, from a school district accountability perspective, the number of students meeting proficiency targets is of particular importance. I find that students are 1.9 percentage points less likely to score above the proficiency cutoff in math and 1.7 percentage points less likely to score above the proficiency cutoff in reading. Therefore, these achievement losses may have negative implications for these schools meeting adequate yearly progress and other accountability benchmarks.

[9] Studies (Lavy, 2015; Cattaneo, Oggenfuss, and Wolter, 2017) find that reducing subject-specific instructional time by one hour per week reduces achievement in that subject by 0.06 standard deviations.

[10] Although not shown in the main text, I also test the sensitivity of the results of the level score specification given in equation (1) using a gain score and dynamic score specification. The gain score specification is of the form:

$$A_{igsdt} - A_{igsd,t-1} = \alpha + \beta_1 FDSW_{sdt} + \gamma \mathbf{X}_{igsdt} + \delta \mathbf{Z}_{sdt} + \rho_s + \theta_{gt} + \epsilon_{igsdt} \tag{2}$$

while the dynamic score specification is of the form:

$$A_{igsdt} = \alpha + \lambda A_{igsd,t-1} + \beta_1 FDSW_{sdt} + \gamma \mathbf{X}_{igsdt} + \delta \mathbf{Z}_{sdt} + \rho_s + \theta_{gt} + \epsilon_{igsdt} \tag{3}$$

While the results of these specifications are insignificant for math scores, the point estimates suggest that math scores fall by 0.033 standard deviations (dynamic) and 0.065 standard deviations (gain score). These results show statistically significant

pre-trend, I further test the parallel trend assumption through the inclusion of two leads of the FDSW indicator in equation (1). The results of this analysis show that none of the leads are statistically significant at the 5% level. I also include school district-specific time trends into equation (1) to further test the sensitivity of the main results and account for the potential of pre-trends influencing the main difference-in-difference results. The inclusion of these time trend variables dampens the size and precision of these effects somewhat. In particular, these results find that as a result of the switch to a four-day school week, math test scores, although statistically insignificant, fall by 0.028 standard deviations (down from 0.044 in baseline D-in-D) and reading scores fall by 0.019 standard deviations (down from 0.033 in baseline D-in-D). Finally, I include separate indicators in equation (1) for the the switch to the four-day school week and the switch back to a five-day school week, if applicable. When including these separate indicators, I find that switching to a four-day school week lowers math scores by 0.045 standard deviations and reading scores by 0.038 standard deviations. These results find that there are no statistically significant lasting negative impacts of the four-day school week on achievement after switching back to the five-day school week.

I also assess the robustness of the baseline results to changes in the overall sample or changes in the specification of the treatment group. When restricting the sample to include only schools in remote areas, only four-day school week schools, or only those schools outside of the Portland metro area, I continue to find reductions in test scores, although the precision is somewhat reduced due to the smaller sample sizes in these restricted samples. In particular, I find that math scores fall by between 0.026 and 0.045 standard deviations and reading scores fall by between 0.027 and 0.035 standard deviations. When restricting the treatment group to only those four-day school week districts that never switch back to a five-day week, I find even stronger negative effects than those found in the baseline analysis. Specifically, I find that math scores fall by 0.076 standard deviations and reading scores fall by 0.055 standard deviations as a result of the switch to a four-day school week.

To observe whether these negative achievement effects accumulate over time or begin to fade out – as students and schools figure out how best to maximize achievement under the new system – I also examine differential effects by the number of years students have been exposed to the four-day school week model. To estimate this dosage-type effect, I include separate dummy variables for each year of exposure to the four-day school week (using zero years of exposure as the omitted group) in place

effects for reading scores, finding that reading scores fall by 0.027 standard deviations (dynamic) and 0.073 standard deviations (gain score). Full results of these analyses are available upon request.

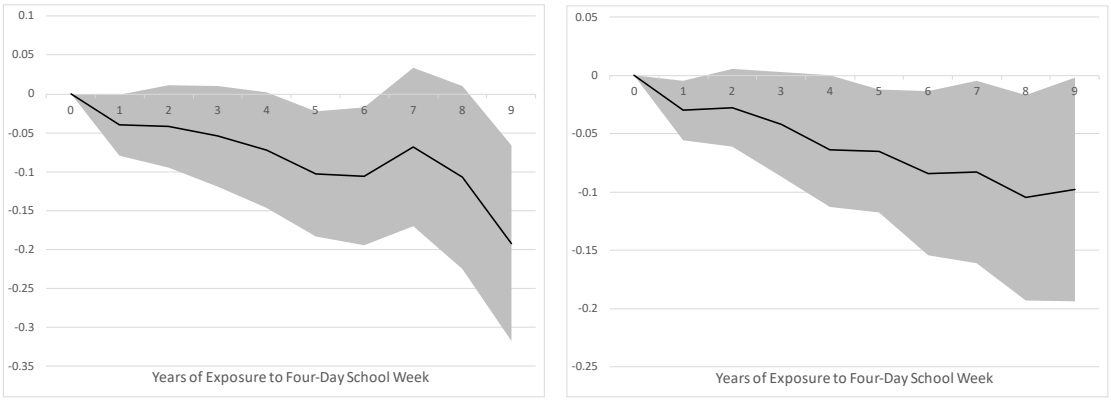
Table 3: Sensitivity Analyses

	Panel A: Specification Changes				Panel B: Sample Changes			
	Baseline	Leads Included	District Time Trends Included	Separate indicators for FDSW Start/Removal	Remote Areas Only	FDSW Only	Non-Portland Metro Only	Permanent FDSW Schools Only
				Math Scale Score				
FDSW	-0.044**	-0.046***	-0.028	-0.045**	-0.045*	-0.026	-0.041**	-0.076***
	(0.017)	(0.017)	(0.018)	(0.020)	(0.025)	(0.018)	(0.017)	(0.021)
FDSW (t-1)		-0.005						
		(0.013)						
FDSW (t-2)		-0.011						
		(0.011)						
FDSWremoved				0.048				
				(0.033)				
Observations	1,850,238	1,692,874	1,850,238	1,850,238	375,666	133,250	973,666	1,818,493
R-squared	0.841	0.842	0.842	0.841	0.820	0.820	0.826	0.841
				Reading Scale Score				
FDSW	-0.033***	-0.037***	-0.019*	-0.038***	-0.028*	-0.027**	-0.035***	-0.055***
	(0.011)	(0.011)	(0.011)	(0.012)	(0.014)	(0.013)	(0.011)	(0.018)
FDSW (t-1)		-0.009						
		(0.009)						
FDSW (t-2)		-0.017*						
		(0.009)						
FDSWremoved				0.001				
				(0.012)				
Observations	1,844,010	1,689,783	1,844,010	1,844,010	375,324	133,222	970,890	1,812,303
R-squared	0.845	0.845	0.845	0.845	0.835	0.837	0.837	0.845

Each column of the table presents results from a separate specification of equation (1) with the modification to the specification or sample noted in the column header. Each specification contains student-level characteristics, school-level and district-level controls, and school year, grade, school, and student fixed effects. Robust standard errors, clustered at the school-level are given in parentheses. *** p<0.01, ** p<0.05, * p<0.1

of the $FDSW_{sdt}$ in equation (1). The results of this analysis are presented in Figure 3. The results generally depict an initial drop in the first year of exposure, similar to that in the event study, and then smaller incremental reductions in achievement as a result of each subsequent year of exposure. While the decline is rather gradual and smooth for reading achievement, there is a noticeable drop off in math achievement for those exposed to four-day school weeks for eight or nine years. Given that students with this amount of exposure are 7th and 8th graders, the drop off may speak more to the more challenging math curriculum students may face in those grades (pre-algebra, algebra, geometry) – subjects in which the loss of a day of instruction may have greater impacts than those found for reading or math curriculum in younger grades.

Figure 3: Differential Effects of Years of Treatment Exposure



(a) Math Achievement (b) Reading Achievement

5.3. Differential Effects by Student Types

In addition to the aggregate effects of four-day school weeks, assessing the heterogenous effects of these policies for different types of students is also of great importance. There are many reasons to think that certain types of students would be more greatly affected by this change than others. For example, students who require much greater in-school intervention in their learning, such as special education and English as a second language students, may suffer more than other students if the instruction they receive in school cannot be simulated in other settings on the day off. Low-income and minority students may also fare worse if resource constraints limit the amount of educational activities these students are able to pursue on the additional day off, although anecdotal evidence suggests that community organizations may provide some of the school functions for these students, such as providing meals to free and reduced priced lunch students on the off day. To examine heterogeneous effects of four-day school weeks on

different types of students, I estimate the following equation:

$$A_{igsdt} = \alpha + \beta_1 FDSW_{dt} + \beta_k(FDSW_{dt} * \mathbf{X}_{igsdt}) + \gamma\mathbf{X}_{igsdt} + \delta\mathbf{Z}_{sdt} + \phi_i + \rho_s + \theta_{gt} + \epsilon_{igsdt} \quad (4)$$

where $FDSW_{dt} * \mathbf{X}_{igsdt}$ is the interaction of the $FDSW_{dt}$ variable with specific student characteristics from the $\mathbf{X}_{isdt}$ vector. Here, β_1 is interpreted as the effect of the four-day school week on the omitted group's achievement, while the β_k's are interpreted as the differential effect of the four-day school week on the particular student subgroup of interest's achievement relative to that of the omitted student group.

The results of this analysis are presented in Table 4. While many of the effects along racial dimensions are insignificant, I do find differential impacts of four-day school weeks on black students in math and American Indian and Pacific Islander students in reading. Black students have math scores that are 0.104 standard deviations below that of comparable white students. American Indian and Pacific Islander students have reading scores that are 0.061 standard deviations above that of comparable white students. Some caution should be taken in interpreting these results, however, due to the limited number of students in these racial subgroups in four-day school week districts in Oregon. Specifically, black and American Indian and Pacific Islander students make up less than two percent of the student body in these schools and, therefore, these effects may be driven by a very small number of students. Future work analyzing other states with four-day school week school districts with larger minority populations may be more fruitful in uncovering meaningful differential impacts of these school schedules across different racial subgroups.

The strongest heterogenous effects appear to be across gender dimensions, where girls are found to be less negatively impacted by these schedule changes than boys. In particular, girls have scale scores that are 0.046 standard deviations higher in math and 0.024 standard deviations higher in reading than comparable male students. These results indicate that girls may be better equipped than boys to handle the structural changes caused by the switch to a four-day school week. Finally, the loss of free and reduced priced lunch services and specialized educational curricula one day per week may cause low-income students and students participating in these specialized curricula (e.g., special education, gifted education, and English as a second language) to perform worse on standardized tests. I find evidence that free and reduced lunch eligible students have reading scores that are 0.016 standard deviations below that of comparable non-free and reduced lunch eligible students, but find no statistically significant differences in math. If more reading instruction is likely to go on in the home than math instruction,

Table 4: Heterogeneous Achievement Effects of FDSW Across Student Subgroups

	Panel A: Math Achievement				Panel B: Reading Achievement			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
FDSW	-0.046***	-0.067***	-0.045**	-0.044**	-0.031***	-0.044***	-0.023**	-0.035***
	(0.017)	(0.018)	(0.018)	(0.017)	(0.011)	(0.013)	(0.011)	(0.011)
FDSW*Black	-0.104**				-0.063			
	(0.050)				(0.057)			
FDSW*Hispanic	0.003				-0.018			
	(0.016)				(0.018)			
FDSW*Asian	0.002				-0.054			
	(0.050)				(0.047)			
FDSW*AmerIndian	0.035				0.061**			
	(0.033)				(0.028)			
FDSW*Multi Race	0.034				0.000			
	(0.025)				(0.018)			
FDSW*Girls		0.046***				0.024**		
		(0.010)				(0.010)		
FDSW*FRL Eligible			0.001				-0.016**	
			(0.008)				(0.008)	
FDSW*Special Ed				0.001				0.011
				(0.015)				(0.013)
FDSW*Gifted Ed				0.017				0.045
				(0.055)				(0.056)
FDSW*ESL				-0.031				-0.023
				(0.019)				(0.014)
Omitted subgroup	White	Boys	Non-FRL	General Ed	White	Boys	Non-FRL	General Ed
Observations	1,850,238	1,850,238	1,850,238	1,850,238	1,844,010	1,844,010	1,844,010	1,844,010
R-squared	0.841	0.841	0.841	0.841	0.845	0.845	0.845	0.845

Each panel of the table presents results from a separate regression containing the specified dependent variable. Each specification contains student-level characteristics, school-level and district-level controls, and school year, grade, school, and student fixed effects. Robust standard errors, clustered at the school-level are given in parentheses. *** p<0.01, ** p<0.05, * p<0.1

it may not be surprising that students in families with fewer resources (e.g., home libraries) see an increased detriment relative to students from better financial situations who may have more access to reading instruction at home on the off day. I also do not find any statistically significant differences in the achievement outcomes of special education, gifted education, or English as a second language students relative to general education students.

6. Analysis of Potential Mechanisms

So what mechanisms may be driving these negative achievement effects? While the conceptual framework section identified several intermediate factors that may be driving these negative achievement effects, this analysis will focus on the role of instructional time, student absences, and disciplinary incidents.[11] Changes to instructional time are likely to the factor most directly influenced by the switch to a four-day school week. To compensate for the loss of one school day per week and continue to meet

[11] While this mediation analysis focuses on changes in the amount and composition of instructional time, student absences, and disciplinary incidents, the conceptual model section also mentions teacher quality and school expenditures as possible mediating factors. Conducting a similar analysis for these other factors, I find very little statistically significant evidence that switching to a four-day school week schedule has impacts on teacher characteristics or overall school spending per pupil.

minimum hours requirements, the remaining school days are often lengthened within a four-day school week schedule. So why might this change in the composition of school instructional time negatively affect achievement? First, to accommodate the longer school day, school start times may be moved earlier, which previous literature has shown to be detrimental to student achievement (Carell, Maghakian, and West, 2011; Hinrichs, 2011; Edwards, 2012; Heissel and Norris, 2017), due to both waking up earlier for school each day and taking these standardized tests starting earlier in the morning. Second, longer school days may be inefficiently used by teachers or by school officials when determining where to allocate the extra time. Third, the longer school days may not be sufficiently lengthened to make up for the loss of one school day per week. Thus, the aggregate effect may be a net reduction in the weekly amount of time kids are in school, which previous literature (Lavy, 2015; Cattaneo, Oggenfuss, and Wolter, 2017) has shown may have detrimental impacts on test scores. These detrimental achievement effects caused by instructional time changes, however, may be somewhat mitigated by reductions in the number of days lost due to absences and student disciplinary infractions.

To examine the effects of four-day school weeks on these intermediate factors, I estimate equation (1) using absences and days lost due to discipline as the dependent variables and the following difference-in-differences regression at the school-level:

$$Y_{sdt} = \alpha + \beta_1 FDSW_{sdt} + \gamma \mathbf{X}_{sdt} + \rho_s + \theta_t + \epsilon_{sdt} \tag{5}$$

where Y_{sdt} is either school start time, school day length, or weekly school length, all of which are measured in minutes; $FDSW_{sdt}$ is a dummy variable that is equal to one if the school was operating on a four day school week during school year t; $\mathbf{X}_{sdt}$ is a vector of school and district characteristics; ρ_s and θ_t are vectors of school and school year fixed effects, respectively; and ϵ_{sdt} is an idiosyncratic error term.

The results of equation (1) using days missed due to absences and days missed due to discipline incidents as dependent variables are presented in Panel A of Table 5. I find that the number of days missed due to absence is decreased by 1.325 days, while discipline days decreased by 0.175 days. Based on the findings and the coefficients on these variables in equation (1),[12] I find that the changes in absences

[12]In the baseline specification without student fixed effects, an additional absence is found to increase math scores by 0.015 standard deviations and reading scores by 0.01 standard deviations. An additional day missed due to student discipline is found to increase math by 0.008 standard deviations and reading scores by 0.007 standard deviations. In the baseline specification with student fixed effects, an additional absence is found to increase math scores by 0.005 standard deviations and reading scores by 0.003 standard deviations. An additional day missed due to student discipline is found to increase math by 0.004 standard deviations and reading scores by 0.003 standard deviations.

Table 5: Possible Mechanisms for Achievement Effects

	Panel A: Days Missed		**Panel B: Instructional Time (in minutes)**		
	(1)	(2)	(3)	(4)	(5)
	Due to Absences	Due to Discipline	School Day Start Time	School Day Length	Weekly Time in School
FDSW	-1.355***	-0.184***	-6.016***	37.657***	-215.817***
	(0.284)	(0.084)	(1.760)	(2.858)	(14.843)
Observations	2,062,430	2,062,430	7,976	7,976	7,976
R-squared	0.702	0.333	0.959	0.972	0.945

Each column of the table presents results from a separate regression containing the specified dependent variable. Each specification in Panel A contains student-level characteristics, school-level and district-level controls, and school year, grade, school, and student fixed effects. Each specification in Panel B contains school-level and district-level controls, school fixed effects, and school year fixed effects. Robust standard errors, clustered at the school-level are given in parentheses. *** p<0.01, ** p<0.05, * p<0.1

and discipline days as a result of the four-day school week account for an increase of between 0.008 and 0.021 standard deviations in math and between 0.005 and 0.014 standard deviations in reading. Thus, finding negative achievement effects overall as a result of the four-day school week suggests that these other (observed and unobserved) intermediate factors are cancelling out any positive impacts the four-day school weeks may have along these dimensions.

As mentioned previously, instructional time changes may be a primary component of these negative effects and results of these changes are presented in Panel B of Table 5. While the results suggest that schools are lengthening the other four school days when switching to a four-day school week, it does not appear that schools are moving the start time much earlier. Specifically, I find that the school day is started an average of six minutes earlier as a result of the four-day school week. In total, the school day is lengthened by about 38 minutes as a result of the switch to the four-day school week. Thus, much of the extra instructional time each day is coming from moving the school day end time later.

Despite the half an hour increase in each of the remaining school days in the four-day school week, the overall weekly time in school falls considerably after the switch to a four-day school week. Specifically, I find that following the switch to a four-day school week, weekly time in school falls by 216 minutes (3.6 hours). Overall, these results along with the coefficients on these variables in equation (1)[13]

[13]In the baseline specification without student fixed effects, starting school an hour earlier is found to decrease math scores by 0.06 standard deviations and reading scores by 0.05 standard deviations. An hour reduction in time in school each week is found to decrease math scores by 0.014 standard deviations and reading scores by 0.004 standard deviations. In the baseline specification with student fixed effects, starting school an hour earlier is found to decrease math scores by 0.035 standard deviations and reading scores by 0.034 standard deviations. An hour reduction in time in school each week is found to decrease math scores by 0.003 standard deviations and reading scores by 0.002 standard deviations.

suggest that these compositional changes in instructional time account for a decrease in math achievement of between 0.015 and 0.052 standard deviations and a decrease in reading achievement of between 0.009 and 0.019 standard deviations. These findings suggest that instructional time changes explain nearly all of the reduction in math achievement without controlling for student fixed effects and about one-third of the reduction in math achievement when controlling for student fixed effects. Similarly, I find that instructional time changes explain nearly one half of the reduction in reading achievement without controlling for student fixed effects and about one-fourth of the reduction in reading achievement when controlling for student fixed effects. This difference across the subjects may reflect the adage that math is taught in school while reading is taught in the home, suggesting that lost school instruction should have less of a detrimental impact on reading achievement.

While this study identifies overall weekly time in school, it is likely the composition of the time spent in specific subjects is truly driving the reduction in student test achievement. Unfortunately, from the data, I am unable to ascertain which subjects are impacted by this reduction in overall time in school. Future work will hopefully be able to better determine which subjects are being reduced, and by how much, as a result of these weekly reductions in instructional time. This will help establish whether these instructional time effects are having a direct impacts on math and reading achievement, through the loss of math and reading instruction, or whether these achievement effects may be the result of negative spillover effects into math and reading performance from reductions in other aspects of a holistic education (e.g., music, art, physical education).

7. Conclusion

This paper used a difference-in-differences analysis to analyze panel data on student-level test scores to examine the effects of four-day school weeks on student achievement in Oregon. The results find that four-day school weeks have detrimental impacts on student achievement, with greater negative impacts for boys and low-income students. Given that traditional cost-cutting measures, such as class size increase and school closures, also are found to negatively impact achievement, might the four-day school week actually be a viable option for some school districts? Research on the impact of four-day school weeks on cost savings suggest that, on average, school districts are seeing reductions in expenditures of between 0.5 and 2.5 percent (Griffith, 2011; Thompson, 2019). Given the average level of per-pupil expenditures, this amounts to a savings of between $75 and $350 per pupil as a result of the switch to the four-day school week. Alternatively, a class size increase of one student per class, yields

a savings of around $250 per pupil and a reduction in achievement of around 0.03 standard deviations (Whitehurst and Chingos, 2011). Given the sizes of the effects found in this study – reductions of between 0.033 and 0.053 standard deviations – for some districts that see cost savings on the upper end of this range, the four-day school week may be a viable option in the array of cost cutting choices. Four-day school weeks may become an even more viable options if school districts are able to mitigate achievement losses or realize achievement gains as a result of the change in the school calendar.

The results of Anderson and Walker (2015) suggest that positive achievement effects may be possible. So what might be underlying this difference in the achievement effects of four-day school weeks in Oregon and Colorado? Given that I find that instructional time is the primary mechanism driving the achievement effects, one explanation for the differences in findings between the two studies may be that Colorado schools do a better job of minimizing instructional time reductions than Oregon schools when switching to these school schedules. Recent data collection from the 2018-2019 school year on school day start times and overall instructional time suggests this may be the case. On average, students in four-day schools in Colorado attend one and a half more hours of school per week than students in Oregon. Despite the longer school days, Colorado schools only start the school day an average of four minutes earlier than Oregon schools, suggesting that the earlier start time effects may be negligible. Another explanation for the differences in findings between the two studies may be that some Colorado districts, once financial pressures diminish, offer programs for gifted students, remedial programs, and disciplinary programs (Dam, 2006) during the non-school day of the week. These types of programs essentially provide additional instruction beyond the typical in-class instruction time and this increase in overall instruction time is likely to have a positive effect on student performance. Qualitative data collected from Oregon school districts on how the fifth-day is used suggests that these types of enrichment programs are sparsely used. Thus, for policymakers and school officials considering these types of policies, maintaining overall instructional time and providing some fifth day enrichment opportunities may be essential in promoting positive achievement effects in four-day school week schools. However, the fact that these two studies obtain contradictory results suggests that more research in other states and further analysis on the mechanisms driving the achievement results is warranted before strong policy recommendations can be made.

Another important caveat is that achievement on standardized tests is also only one metric on which to gauge the effectiveness of these school calendars. Future work examining other educational outcomes, such as graduation and dropout decisions, and child health and well-being outcomes, including nutrition,

sleep, physical activity, and social-emotional development, will be important for understanding how four-day school weeks impact the whole child. Four day school weeks may also have potentially large implications for families, as they shift the financial burden of childcare and other activities (e.g., food service) from the school district to the parents and local communities. Future work examining the effect of these school schedules on food insecurity, childcare decisions, and housing prices in the local community will be critical for assessing these family and community impacts. Determining the overall amount of cost savings achieved through these calendar changes will be key in assessing whether four-day school weeks may be a viable alternative to other cost savings approaches, such as increasing class sizes, which may have larger detrimental effects on achievement. Given the growing use of four-day school weeks and how little we know regarding their effects, the need for future work is great in order to better inform policymakers about whether these school schedules should be a viable alternative to other cost-saving measures and, if so, how can they be best implemented in order to maximize financial savings and minimize costs imposed on students, families, and communities.

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