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Effects of School Shift Change on Sleep and Academic Performance: A Quasi-Experimental Evaluation for Adolescent Students in Brazil

Isabel Pessoa de Arruda Raposo[1], Adriana Leite dos Santos[2], Tatiane Almeida de Menezes[3], Andrewen Felipe Santos Bezerra[4], Michela Barreto Camboim Gonçalves[5]

[1]Researcher at the Fundação Joaquim Nabuco – Ministry of Education, Brazil (FUNDAJ/ MEC), Brazil

[2]Master's Degree at the Graduate Program in Healthcare Management and Economics of the Universidade Federal de Pernambuco (UFPE), Recife, Brazil

[3]Associate Professor of Economics Departament of UFPE, Recife, Brazil

[4]Doctoral Student in Economics at the Graduate Program in Economics (PIMES) of UFPE, Recife, Brazil

[5]Doctor of Economics and Research Fellow at Fundação Joaquim Nabuco / Ministry of Education, Recife, Brazil

Correspondence: Isabel Pessoa de Arruda Raposo, Researcher at the Fundação Joaquim Nabuco – Ministry of Education, Brazil (FUNDAJ/ MEC), Brazil.

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Abstract

This paper investigates the influence of the school shift change on the academic performance of 6th and 7th graders (lower secondary education) of public schools in the city of Recife, Brazil. The empirical analyses use educational data from a panel of the Brazilian Ministry of Education, with a sample of 4,500 students, 3,468 parents or guardians, 85 principals, and 137 teachers working in 87 public schools that were spatially distributed. The identification strategy explores a quasi-experiment in which some classes of the investigated sample had their school shifts changed between the two years, which occurred exclusively due to the school logistics and regardless of the parents' preferences. Difference-in-differences models combined with propensity score matching demonstrate that students who shifted from morning to afternoon between the two years analyzed improved their Portuguese test scores, and that those who experienced the opposite change, from afternoon to morning, had a drop in the performance. Estimations in intermediary outcomes also reveal that the changes in the students' sleeping habits are an important mechanism that explains the relation between the scores and the school shift.

Keywords: school shifts, academic performance, sleep, policy evaluation, difference in differences

1. Introduction

Are there times considered ideal for adolescents to attend school and have better academic performance? Adolescence involves several biological and behavioral changes. One of these changes is associated with sleep, more specifically with the quantity and quality of hours of sleep, as, at this stage of development, there is a change in patterns, indicated by a preference for times to go to bed and wake up later. (Lufi et al., 2011).

The objective of this article is to measure the impact of school shift changes on sleep and academic performance. Indeed, the school start time literature is fairly abundant for developed countries, such as the United States and European countries; in spite of that, only a small part of these studies is based on exogenous changes in school start times and, therefore, is able to establish causal links between start time and academic performance. For developing countries, evidence is even more scarce, if not inexistent (as far as we know), for countries like Brazil (Cardenas & Cruz, 2017; Arrona-Palacios & Díaz-Morales, 2018, Reynoso & Rossi, 2019).

Historically, developing countries adopt a shift schooling system in most of their public and private facilities of primary and secondary education. This educational practice consists of dividing students into groups that study in the morning, afternoon, or at night. In Brazil 86% of Brazilian students in Lower Secondary Education[1] attend part-time schools[2]

[1] Brazilian education is organized into two levels: primary and secondary education. The primary and secondary education is composed of early childhood education (pre-school comprises the period prior to literacy with students up to

(BRASIL, 2018). The main purpose of school shifts is to meet the demand in a scenario of insufficient places, as they enable to double the number of students enrolled in the institutions, by reusing the existing sets of buildings and facilities, as well as the same faculty to cater for different cohorts of students (SAGYNDYKOVA, 2015). Therefore, if, on the one hand, the shift schooling system has the virtue of promoting increased access to education, on the other hand, this model meets a rationale external to the individual's endogenous and biological rhythms.

Several studies show that school performance is related to the circadian cycle and that there would be, therefore, times considered "ideal" to start school (Cardinalli, 2008; Carrell et al.., 2011; Diette & Raghav, 2017; Groen & Pabilonia, 2019; Lenard et al.., 2020; Pope, 2016). In adolescents, for example, the secretion of melatonin, the sleep-inducing hormone, ends on average around 10 a.m., so this group of students would have learning gains if classes started after that time (American Academy of Pediatrics, 2014; Crowley et al, 2016). In 2014, the American Academy of Pediatrics (AAP) recommended that schools set school start times no earlier than 8:30 a.m. to improve the physical and mental health, safety, and academic performance of older students (Owens, et al., 2014).

In view of the foregoing, the objective of this study is to assess the influence of different school shifts on the academic performance of 6th and 7th graders in public schools in the city of Recife, the main capital city of the Brazilian Northeast region.[3] The hypothesis investigated is that adolescents, because they are considered to be "afternoon people" (Evans et al, 2017), tend to have better academic performance in the afternoon, and sleep would be the main mechanism that would explain the educational differences by shift in this study (although there are other possible mechanisms).[4]

Data come from a panel research with 6th and 7th graders from Recife public schools that follows the same cohort of adolescents between 2017 and 2018. Difference-in-Differences method (DID), in a quasi-experiment setup, is applied in order to control for endogenous issues. The identification strategy explores the fact that these changes in school shifts happened exogenously to the preferences of parents. Indeed the enrollment of students, according to different shifts, was based on factors to improve school management. We tested the hypothesis that students enrolled in the afternoon shift sleep better[5] and consequently achieve higher academic performance. The treatment group is composed of students that changed shifts in the period under study, and the control group is composed of students that remained in the same shift in the different years. The observable variables are also previously matched through Propensity Score Matching (PSM) to ensure the balancing of the heterogeneities between the groups.

This paper offers several contributions to the school start time literature versus academic performance. First, it brings unprecedented evidence to Brazil, establishing a relationship between school performance and period of classes (morning and afternoon) based on exogenous shift changes. Second, the study uses panel data, which allows for better controlling for individual fixed effect, and it also explores an extensive set of variables related to the student (which includes the time the adolescent goes to sleep), their parents or guardians, teachers, and school principals. Third, unlike other studies based on marginal changes in school start times, this study brings an analysis for the effect of different shifts. And finally, our unique quasi-experiment also provides the possibility of analyzing the effect of two types of treatments, the best- and the

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5 years of age), primary education (1st to 5th grades, from 6 to 10 years old), lower secondary education (6th to 9th grades, from 11 to 14 years old), and upper-secondary education (1st to 3rd years, from 15 to 17 years old). Schooling is compulsory from 4 to 17 years old.

[2] Part-time students that go to school in the morning start their classes, on average, at 7:30 a.m. and finish at noon, with a 30-minute snack time. The afternoon shift goes from 1:30 p.m. to 6:00 p.m., also with a 30-minute snack time. The night shift is shorter, going from 7 p.m. to 11 p.m., and generally includes older students above school age.

[3] The city of Recife is the capital of the State of Pernambuco. Brazil has 26 states distributed in 5 large regions; the city of Recife belongs to the Northeast Region and stands out as the wealthiest capital city of that region in terms of GDP per capita.

[4] Lenard, et al. (2020) bring an extensive review of studies that point out to sleep as the main mechanism that explain the educational differences according to the time the class starts, among which: Boergers, Gable, & Owens, 2014; Bowers & Moyer, 2017; Chan, et al., 2017; Danner & Phillips, 2008; Dewald, et al., 2010; Gariépy, et al.2017; Groen & Pabilonia, 2019; Hansen, et al., 2005; Kirby, Maggi, & D'Angiulli, 2011; Meltzer, Shaheed, & Ambler, 2016. Evidence of the American educational system demonstrates that starting classes 1 hour later is associated with about an additional half hour of sleep (Boergers, et al., 2014; Groen & Pabilonia, 2019).[5] Studies demonstrate that in Brazilian high school students frequency of short sleep was lowest in the afternoon shift and highest in the morning shift and full-day students (Felden et al., 2016; Alves et al., 2020)

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worst-case scenarios, as four investigated classes shifted from morning to afternoon, what is allegedly beneficial to them, considering the adolescent circadian rhythm, and three classes experienced the opposite change, shifting from afternoon to morning. This unique outlook enables a complete assessment of the effects of the school shifts change, measuring not only the gains, but also the losses in the cases in which the student does not go to school in the best time.

In addition to this introduction, the paper is structured into four more sections. A review of the related literature is presented in the second section. The empirical strategy and dataset are described in Section 3. The results and discussion are presented in Section 5. Finally, the last section presents the final considerations of the paper.

2. Literature Review

Sleep results from two mechanisms that regulate the sleep-wake cycle, the circadian rhythm and the homeostatic drive for sleep. Light and photoperiodism resulting from the alternation of day-night are the most important factors in synchronizing the circadian clock with the external environment, also varying based on age, sex, and individual characteristics, and its regulation involves several cytokines and neurohumoral and endocrine factors. Light information is brought to the suprachiasmatic nucleus by the retinohypothalamic tract, where the endogenous circadian cycle is regulated by controlling the secretion of melatonin, a hormone acting both in the beginning and in the maintenance of sleep (Araújo, 2002; Duarte, 2008; Chokroverty, 2010; Neves, et al., 2013;). As light decreases, the plasma levels of melatonin begin to increase (GUYTON & HALL, 2011), around 1 and 3 hours before the normal sleep time, and peaks close to the nadir, the lowest point in core body temperature (Gulyani, et al., 2012).

The homeostatic drive refers to increased sleepiness after prolonged wakefulness, and adenosine is the main metabolic molecule. In the morning, the homeostatic sleep drive is practically null, and the circadian factor generates increasingly strong excitatory synapses causing you to wake up. Throughout the day, the homeostatic drive increases, as well as the circadian excitatory activity; however, this excitatory activity is reduced at night, resulting in sleep onset (Chokroverty, 2010; Neves et al., 2013).

Researches have been done taking into account the importance of sleep for the physical and intellectual development of children and adolescents. Reduction in sleep duration or quality can lead to excessive daytime sleepiness and it has been reported as a public health problem considering the high prevalence identified in the population, especially among adolescents, possibly reaching a percentage of 68% of reports in this age group (Gibson et al., 2006). The most accepted explanation is that adolescents are subject to changes in their sleep pattern, as they are still in the process of neuropsychic maturation and also due to the times and demands established, especially by educational institutions, which schedule disregards the circadian patterns of young people. (Pereira et al., 2010; Pereira, et al., 2014) Additionally, other environmental factors, like increased school and out-of-school activities, increased screen time (TV and Internet), and part-time jobs are also reported as factors harming students' sleep (Carskadon, 1998; Groen & Pabilonia, 2019).

The related literature demonstrates that there are statistical associations between the school start time and academic performance, and the main inducing mechanism would be sleep. In general, the evidence found establishes that later start times are more beneficial for the adolescents' learning, although there is no consensus. Lenard et al. (2020) explore a quasi-experiment in which five high schools of Wake County in the United States anticipated school start times by 45 minutes earlier and find an increase in absenteeism and tardiness rates, as well as higher rates of dropout from high school. Groen and Pabilonia (2019) use American high school students' time diaries to examine the effects of the school start time on the allocation of students' time to explore the mechanisms by which the change in school start times affects learning. Students who attend schools with later start times sleep more and score higher on reading tests, specially female students. Male students sleep more at night when school starts later, but their daily sleep remains unchanged due to decreased nap time; their test scores do not change. Wong (2011), based on the influence of light on *circadian rhythm*, demonstrates that the average light time before classes start has a positive effect on school test scores. Using a random assignment of college classes, Carrell et al. (2011) find that earlier school start time lowers the Grade Point Average (GPA). Diette and Raghav (2017) use students' data collected from an American college that also randomly allocates its students to different shifts in the same course and find that students in the morning, especially males, get lower scores than students in end-of-day shifts.

Contrariwise, Pope (2016) finds that, with school start time constant, Los Angeles County elementary and middle school students learn more in the morning than at the end of the school day, as they experience diminishing returns in learning throughout the day. Taking Math or English classes in the morning, instead of in the afternoon, increases a student's GPA by 0.072 and 0.032, respectively. Lusher and Yasenov (2016) explore a quasi-experiment in an Eastern European country, in which students monthly alternate class shifts between morning and afternoon and find a small drop in the academic performance of afternoon students. Lusher and Yasenov (2018), by exploring the same quasi-experiment, find that, in the morning, male students are more benefited from a later school start time than female students. Hinrichs (2011), in his turn, find no statistically significant relationship between a 25-minute delay in school start time and the academic performance of students in public schools of Minneapolis.

By reviewing the related literature for developing countries, we found four main studies, being three for Mexico and one for Argentina. Reynoso & Rossi (2019), by exploring a random allocation of students between morning, afternoon, and night shifts at a large high school in Buenos Aires, Argentina, find that night-time students are more likely to engage in risky behaviors. Female adolescents allocated to the night shift have higher chances of having sex earlier and undergoing abortions, and the lack of parental supervision would be the main mechanism explaining these findings. In Mexican schools, Sagyndykova (2015) in a cross-section study find a statistically significant and positive relationship between academic performance and studying in the morning. The Oaxaca decomposition shows that the selection of students for different shifts are based on principal's preferences and individual characteristics, which explains the academic inequality among students in different shifts. Cardenas & De la Cruz (2017) confirm this hypothesis that, in Mexico, the allocation of students by shift would not be random, and be based on the discretionary power of school principals. In the investigation, the authors explore an exogenous change in local laws and regulations governing the allocation of students in afternoon and morning shifts in public primary schools located in a Mexican state. The results evidence that, upon implementation of the new rule, there was a more equal distribution of the poorest students between school shifts. Arrona-Palácios and Diaz-Morales (2018), by carrying out a case study with students of a primary and lower secondary school in northeastern Mexico, find that the adolescents in both school shifts show no difference in terms of academic performance and intelligence tests.

Finally, specific literature reports that sleep differs in many aspects between females and males and will motivate the analyzes by gender performed in this article. The loss of sleep resulting from the modern lifestyle, psychological stress, use of electronic devices, and the Internet during bedtime can have many repercussions on the health and well-being of all; however, women usually have more complaints and sleep disorders, such as insomnia, than men, due to the influence of physiological and cyclic hormonal variation in the female body. Nightmares are twice more prevalent in women than men, considering that REM sleep latency is greater in women than men, which has been attributed to hormonal variations during menstrual cycles. This has a substantial impact on sleep quality and the number of hours slept, and, therefore, a greater amount of free time to sleep would help to compensate for these difficulties. (Moreira et al, 2013)

3. Data and Methods

3.1 Data

Data for this study derive from a survey carried out in 2017 and 2018 by the *Fundação Joaquim Nabuco – FUNDAJ*, a research institute that integrates the Brazilian Ministry of Education. The research was carried out with 6th and 7th graders in public schools of the city of Recife and consists of a panel with students that were closely monitored during the two years of this survey.

For each year of the research, the complete sample includes 4,500 students in 167 classrooms, 3,800 parents or guardians, 85 principals, and 137 Portuguese teachers belonging to 87 public schools randomly distributed in the city of Recife. Students, parents/guardians, Portuguese teachers, as well as school principals answered a detailed questionnaire that resulted in a very complete set of information related to school and out-of-school aspects. In order to measure student performance, this survey applied four Portuguese Language tests following the Item Response Theory (IRT) in the years of 2017 and 2018. Table A1 of the appendix presents the descriptive statistics for the variables used in the empirical models.

In the subsample used in the article, 7 classes of 6 schools changed school shift during the study period and were classified into the treatment group; 71 schools had no shift change, being classified into the control group. Among the treatment schools, 4 classes changed from morning to afternoon (called treatment 1), while 3 classes experienced the opposite change, afternoon to morning (called treatment 2). In the treatement 1 schools, classes from 7th grade are available only in the afternoon, due to limited classroom spaces, while in the treatment 2 units, classes shifted from afternoon to morning with an attempt to reduce youth violence, placing younger students in the morning and those in more advanced grades and older in the afternoon. In latter case, we have an event that may compromise the identification of the intended effect, since we may be dealing with more disrupted school environment. Table 1 describes the characteristics of schools with treated classes (treatment 1 and 2), as well as those in the control group. In general there are not marked differences among groups, however all the three principals from treatment 2 schools related the use of drugs in the areas surrounding the school. In Figure 1, we plot the geographic distribution of treatment and control schools in the city of Recife and, in spite of principals' perception, schools of treatment 2 are randomly distributed and do not concentrated in the same neighborhood.

Table 1. Characteristics of the Treatment and Control Schools

Variables	Treatment 1 (morning-afternoon)	Treatment 2 (afternoon - morning)	Control
Proportion of male students	0.51 (0.01)	0.54 (0.01)	0.52 (0.01)
Students' average age	12.03 (0.06)	12.25 (0.07)	12.18 (0.04)
Proportion of students who identify themselves as black	0.15 (0.02)	0.16 (0.01)	0.17 (0.01)
Parents'/guardians' average education level[a]	12 (0.06)	11 (0.33)	12 (0.19)
Parents'/guardians' income level[b]	773.97 (6.67)	751.44 (89.46)	738.02 (29.00)
Level of education of the Portuguese teachers[c]	18 (0.16)	18 (0.13)	18 (0.09)
Proportion of teachers holding a degree in Languages and Literature	1 (0)	1 (0)	0.99 (0.01)
Student/teacher ratio	21 (0.35)	20 (4.61)	25 (1.41)
Attack against the life of members of the school community inside the school	0 (0)	0 (0)	0.03 (0.01)
Use of drugs in the premises or areas surrounding the school	0.63 (0.36)	1 (0)	0.70 (0.03)
Number of students	246	232	3,701
Number of classes	4	3	154
Number of schools	3	3	71

Source: prepared by the authors.
a: The education levels 11 and 12 are equivalent to the 8th and 9th years of lower secondary school, respectively.
b: Individual income in BLR, at current prices of 2018
c: Education level 18 is equivalent to post-graduation (specialization).
Standard errors in parentheses.

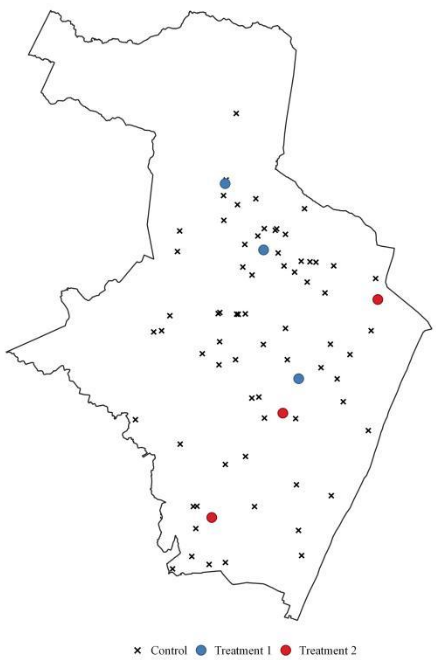

Figure 1. Distribution of Treatment and Control Schools in The City of Recife

3.2 Empirical Strategy

The analysis of the effect of school shift change on the student's academic performance can be described by equation (1), which will be estimated by difference in differences with previous matching through propensity scores[6] to equalize any imbalances in observable variables between the groups.

$$Y_{ict} = \beta_0 + \beta_1 T_{ic} x Year_t + \beta_2 T_{ic} + \beta_3 Year_t + \beta_4 X_{ict} + \varepsilon_{ict} \quad (1)$$

Variable Y_{ict} represents the main educational outcome of interest, the students' scores in Portuguese tests applied at the end of each school year. The subscripts indicate student *i* in class *c* and in year *t*. The classes considered for treatment are those that changed shifts between the 6th and 7th grades due to logistics of the school, i.e., all of their students had no other option but to change the shift to remain in the same school. In the equation, the treatment is denoted by *T*, a binary variable equal to 1 in cases which students belong to the treatment class and equal to 0 in cases which they belong to the control class. As already discussed two types of treatments are being considered here: treatment 1 (school shift changes from morning to afternoon) and treatment 2 (school shift changes from afternoon to morning). The moment describing the intervention or treatment is defined by the binary variable *Year*, in which value 0 represents the year 2017, the period before the shift change, and the value equal to 1 represents the year 2018, representing the moment when this change occurs. The DID estimator is given by $\beta 1$, coefficient linked to the interaction between the treatment and the moment of intervention, $T_x Year$. Vector X contemplates the control variables of the students, parents or guardians, and Portuguese teachers, described in Table A1 of the appendix.

To assess our hypothesis that sleep acts as the main mechanism for the variation in school performance due to the shift in which the student is enrolled, we will estimate some *outcomes* considered to be intermediate to better identify the possible factors that may contribute to explain such variations. We will detail a discussion for this exercise in the robustness section.

4. Results and Discussion

This section presents the main results of the effect of school shifts change on student performance in Portuguese tests. As the study was conducted with a balanced panel it was possible to estimate the effect of the shift change for each student. Table 2 shows the estimates for both types of treatments considered. We estimated three specifications for Equation (1). In the first model, column (1) of Table 2, the specification adopted is DID without the inclusion of any control variable. The results reveal that the students of treatment 1, shift change from morning to afternoon, present a significant difference in the Portuguese evaluation, showing an average increase of 6.67 points (or 16%) in the test scores. In this first specification, we did not obtain a significant impact of treatment 2, shifting from afternoon to morning.

Table 2. Effects of School Shift Change on The Performance in The Portuguese Language

	Treatment 1 (morning to afternoon)			Treatment 2 (afternoon to morning)		
Variables	(1)	(2)	(3)	(1)	(2)	(3)
Treatment x Year (DID)	6.67*	4.74*	13.51***	2.56	-8.95**	-11.88**
	(3.51)	(2.68)	(4.86)	(5.94)	(4.23)	(5.28)
Treated dummy	3.23*	-6.05***	-8.30	-2.20	-3.06	8.90
	(1.91)	(0.95)	(5.04)	(3.83)	(4.50)	(6.13)
Year Dummy	-10.31***	-10.51***	-18.00***	-9.76***	-6.45***	-3.52
	(1.07)	(1.03)	(2.87)	(1.50)	(2.16)	(3.79)
Lagged Portuguese score	No	Yes	Yes	No	Yes	Yes
Student and his/her family controls	No	Yes	Yes	No	Yes	Yes
Teachers and school controls	No	No	Yes	No	No	Yes
R^2	0.08	0.06	0.12	0.06	0.14	0.10
Number of observations	2,763	1,587	967	1,985	524	212

Notes: Column 1 represents the diff-in-diff model without control variables; model 2, diff-in-diff with PSM controlling through the characteristics of students and their guardians; model 3, diff-in-diff with PSM controlling through the characteristics of students, guardians, teachers, and school. Standard errors clustered by school in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

6 The Proponsity Score Matching seeks to construct a control group similar to the treatment group in terms of certain observable characteristics. According to the assumptions of this method, each member of the treatment group would have a pair in the control group that represents the result he would have obtained if he were not treated. Otherwise, the pairing hypotheses postulate that, when comparing two individuals, one in the control group and another in the treatment group, with the same observable characteristics, the only factor that could differentiate the educational results of these individuals, in the case studied here , would be the effect of changing the school shift.

In the following two specifications, columns (2) and (3) of Table 2, we used the combination of PSM and DID methods. Balancing tests for the variables used in the estimates were then performed and can be requested from authors. The tests demonstrate that there is expected similarity between groups for most of the variables; however significant differences are identified regarding the characteristics of the teachers between treatment and control groups, for this reason, we chose to use the combined methods of propensity scores matching and DID to make groups more comparable.

The specification in column (2) of Table 2 matches the groups with the variables of students and their parents or guardians. Students in treatment 1 group show an increase in Portuguese scores of 4.74 points. The effect of treatment 2 gains statistical significance in the specification for matching with differences. Those students who stop studying in the afternoon and are moved to the morning show a reduced performance in Portuguese of 8.95 points. When teacher and school controls are added, column (3), the shift change effect is significant for both interventions considered. Students who experience shift change from morning to afternoon benefit from an improvement in their Portuguese score of 13.51 points, while the opposite change causes students to show a reduced performance of 11.88 points. The intervention effect becomes stronger with the inclusion of teacher controls, as the groups differ, above all, in terms of the attributes of teachers. This suggests that the estimates of specifications (1) and (2) underestimate the treatment effect, as the variations in academic performance may also be capturing the effect of faculty heterogeneities, which might vary between the two years.

Next, in Table 3, the samples are separated by gender and the estimates reveal heterogeneity as to the effect of the intervention. Female students benefit more from shift schooling change than male students. Coincident results were also found by Groen and Pabilonia (2019).

Table 3. Effects of School Shift Change on The Performance in The Portuguese Language

	Treatment 1 (morning to afternoon)			Treatment 2 (afternoon to morning)		
Variables	(1)	(2)	(3)	(1)	(2)	(3)
Female sample						
Treatment x Year (DID)	8.77***	9.79***	21.34***	4.37	-2.94	-19.52*
	(2.60)	(1.55)	(5.72)	(13.17)	(8.75)	(9.74)
Treated dummy	1.94	-5.73***	-7.93	-6.80	10.99	-0.21
	(2.02)	(1.22)	(5.99)	(9.00)	(12.39)	(12.57)
Year Dummy	-11.17***	-9.72***	-21.65***	-9.88***	-6.83**	8.37*
	(1.93)	(1.32)	(5.62)	(1.75)	(3.29)	(4.18)
Lagged Portuguese score	No	Yes	Yes	No	Yes	Yes
Student and his/her family controls	No	Yes	Yes	No	Yes	Yes
Teachers and school controls	No	No	Yes	No	No	Yes
R^2	0.09	0.03	0.11	0.06	0.14	0.16
Number of observations	1,390	852	100	950	136	49
Male sample						
Treatment x Year (DID)	4.25	1.56	18.26	-0.06	-3.57	-10.74
	(5.78)	(5.20)	(13.72)	(2.56)	(5.12)	(11.88)
Treated dummy	4.28*	-8.11***	-13.69***	2.46	2.11	15.20
	(2.36)	(1.85)	(4.57)	(3.67)	(5.44)	(9.09)
Year Dummy	-9.61***	-13.08***	-31.91***	-9.60***	-9.49**	-2.31
	(1.44)	(1.75)	(8.54)	(2.01)	(4.28)	(11.48)
Portuguese score lag	No	Yes	Yes	No	Yes	Yes
Student and his/her family controls	No	Yes	Yes	No	Yes	Yes
Teachers and school controls	No	No	Yes	No	No	Yes
R^2	0.06	0.14	0.38	0.06	0.10	0.15
Number of observations	1,368	584	265	1,031	206	35

Notes: Column 1 represents the diff-in-diff model without control variables; model 2, diff-in-diff with PSM controlling through the characteristics of students and their guardians; model 3, diff-in-diff with PSM controlling through the characteristics of students, guardians, teachers, and school. Standard errors clustered by school in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.1 Robustness: Identification of Intermediate Mechanisms

Some underlying mechanisms may guide the relationship between students' school performance and school start time (or school shift). The objective here is to explain such mechanisms based on the approach proposed by Groen and Pabilonia (2019), whose main idea is to estimate intermediate outcomes beyond academic results, each of which can be affected by school shift. With this exercise, we seek to investigate which factors can intermediate the relationship between school start times and academic performance, identifying the extent to which sleep is a significant mechanism.

In this study, the sleep time estimate was assumed based on three questions asked to parents or guardians: "time that the student goes to sleep", "student has to wake up at a specific time (dummy 1 = yes)", and "student has to go to sleep at a specific time (dummy 1 = yes)". Based on this information, we cannot calculate the exact number of hours of sleep, but it is possible to know if the adolescent would have the flexibility (or not) to adjust his/her hours of sleep. On average, morning students go to bed at 9:40 pm and afternoon students at 10:00 pm, and this 20-minute difference is statistically significant.

As for the variable "time that the student goes to sleep", the estimates in Table 4 reveal that the students in the treatment 1 group, by shifting from morning to afternoon, started to sleep later and no longer had a specific time to wake up and sleep, enabling students to respect their endogenous rhythms of number of hours slept. The students in the treatment 2 group (afternoon-morning) showed the opposite, and the times to wake up and sleep started to be defined by the parents/guardians due to school start time.

Table 4. DID Estimates for the Effect ff School Shift Change on Intermediate Outcomes

	Treatment 1 (morning to afternoon)			Treatment 2 (afternoon to morning)		
Outcomes	(1)	(2)	(3)	(1)	(2)	(3)
Time that the student goes to sleep	0.34***	0.23***	0.16	-0.37***	-0.56**	-0.60*
	(0.10)	(0.08)	(0.16)	(0.13)	(0.27)	(0.31)
The student has to wake up at a specific time (dummy 1 = yes)	-0.17	-0.31***	-0.28**	0.29***	0.25***	0.25**
	(0.11)	(0.11)	(0.12)	(0.05)	(0.07)	(0.10)
The student has to go to sleep at a specific time (dummy 1 = yes)	0.01	-0.24**	-0.05	0.23***	0.02	0.02
	(0.16)	(0.12)	(0.14)	(0.05)	(0.11)	(0.16)
Frequency at which the student does his/her Portuguese homework	-0.08	-0.07	0.06	-0.01	-0.21**	-0.15
	(0.06)	(0.05)	(0.15)	(0.08)	(0.09)	(0.14)
Frequency at which the student studies school subjects	-0.50	0.01	0.16	-0.56*	0.18	-0.11
	(0.34)	(0.08)	(0.16)	(0.30)	(0.42)	(0.52)
Number of hours that the student watches TV on school days	-0.56	-0.12	-0.31	0.09	0.45*	0.53*
	(0.50)	(0.20)	(0.22)	(0.11)	(0.25)	(0.31)
Number of hours that the student spends on the Internet browsing content not related to school, on school days	-0.28	0.03	-0.17	0.05	1.03**	1.30***
	(0.17)	(0.21)	(0.26)	(0.33)	(0.47)	(0.39)
On school days, how long does the student take to do housework	-0.01	-0.04	-0.42*	0.22	0.30	0.35
	(0.08)	(0.12)	(0.23)	(0.25)	(0.24)	(0.30)
On school days, how many hours the student spend working	-0.00	-0.02**	-0.02	0.06	0.12**	0.14**
	(0.02)	(0.01)	(0.02)	(0.04)	(0.05)	(0.06)
Commuting time (home-school)	0.20	-0.64	-4.75	0.64	-3.48	-8.23*
	(2.64)	(2.35)	(2.75)	(5.45)	(3.18)	(4.30)
Commuting time (school-house)	1.54	-0.51	-4.68	5.94	-2.37	-6.63
	(2.63)	(2.00)	(3.38)	(4.33)	(4.63)	(6.30)

Notes: Column 1 represents the diff-in-diff model without control variables; model 2, diff-in-diff with PSM controlling through the characteristics of students and their guardians; model 3, diff-in-diff with PSM controlling through the characteristics of students, guardians, teachers, and school. Standard errors clustered by school in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Being 10 p.m. the main time for going to sleep, morning students manage to have an amount close to eight hours a day of night sleep, identified in the literature as the minimum number of hours a teenager should sleep to maintain healthy habits. On the other hand, students who attend afternoon classes can enjoy the benefit of waking up later and, thus, actually wait for the dosage and effect of the circadian cycle and melatonin to decrease in the body, taking a more synchronous path with their physiological condition, managing to stay more alert and less sleepy. In short, we suggest that afternoon students tend to sleep more hours than students who attend school in the morning, which in turn results in better performance in the Portuguese tests.

Data on sleep time were also seen by Arrona-Palácios and Diaz-Morales (2018) in a study on morning-evening preferences, in which the results indicated that the time to sleep is reduced more for students attending morning classes than afternoon classes, being 7 hours and 16 minutos versus 9 hours and 14 minutes respectively. Wahlstron (2002) also reports that students who study at a later time, giving the example of school start time at 8:30 am, can sleep around 8 hours against 7 for students who start the school day at times close to 7:30 am, and this one-hour difference caused scores on questions measuring daytime sleepiness, struggle to stay awake in classroom, and sleepiness while doing homework to show better results with meaningful statistics for students whose school day started later.

As for the other estimates of intermediate outcomes - screen time and housework or work outside the home - they also proved to be mechanisms capable of mediating the link between the school start time and academic performance. Students in the treatment 1 group do not have their screen time affected, but they reduce work time in the year of shift change, while students in the treatment 2 group increase screen time and work outside their home. Whatever the mechanism, attending school in the afternoon seems to be more beneficial, either because of the improvement in the students' sleep quality or the reduction in screen time and work caused by the change, as the free time in the morning becomes relatively scarcer, especially if the adolescent starts to wake up later.

5. Final Considerations

By using panel data and a quasi-experiment based on exogenous school shift changes, this article identifies a relationship between the period of the day in which students attend school and their academic performance. Estimates with DID models combined with propensity score matching demonstrate that students who shifted from morning to afternoon are benefited from an improvement in Portuguese test scores of up to 13.51 points and that the opposite change, from afternoon to morning, causes a drop in the performance of up to 11.88 points. Heterogeneous effects were also found, and the estimates in different samples by gender reveal statistically significant effects only for girls. The study shows that school shift change causes a modification in the adolescents' waking and sleeping time habits and that the quality of sleep appears as one of the main mechanisms explaining the relationship found.

This paper offers several contributions to the school start time literature versus academic performance. First, it brings unprecedented evidence to Brazil; second, unlike other studies based on marginal changes in school start time, this study brings an analysis for the effect of different shifts. And finally, our unique quasi-experiment also provides the possibility of analyzing the effect of two types of treatments, the best- and the worst-case scenarios, as four investigated classes shifted from morning to afternoon, what is allegedly beneficial to them, considering the adolescent circadian rhythm, and three classes experienced the opposite change, shifting from afternoon to morning. This unique outlook enables a complete assessment of the effects of the shifts, measuring not only the gains, but also the losses in the cases in which the student does not go to school in the best shift.

Our evidence has the potential to inform the design of educational policies aimed at school start time, which focus more on a legitimate concern for optimizing school costs and less on equally important issues such as school results of adolescents being affected by their biological rhythms. Innovative and low-cost policies should be the target of this assessment and implementation. Changes in school start times, priority allocation of teenagers to later school shifts, or aptitude tests for morning and afternoon individuals are some of the measures that can be evaluated as a way to improve teenagers' school results.

Appendix

Table A1. Descriptive Statistics of The Variables Used in The Estimated Models

Variables	Average	Standard error
Portuguese score at the end of the school year (average of the 6^{th} and 7^{th} grades)	41.28	0.91
Portuguese score at the beginning of the school year (average of the 6^{th} and 7^{th} grades)	51.86	1.39
Proportion of male students	0.53	0.02
Proportion of students who identify themselves as black	0.17	0.01
Students's average age	12.06	0.05
Time that the student goes to sleep	21.62	0.04
The student has to wake up at a specific time (dummy 1 = yes)	0.84	0.02
The student has to go to sleep at a specific time (dummy 1 = yes)	0.76	0.03
Frequency at which the student studies school subjects[a]	3.38	0.06
Frequency at which the student does his/her Portuguese homework (dummy 1 = always)	0.28	0.02
Proportion of students that never failed a school year	0.74	0.02
Proportion of new students	0.74	0.03
Frequency at which the student suffered bullying at school[b]	1.36	0.03
Number of hours the student watches TV on school days[c]	2.98	0.04
Number of hours the student spends on the Internet browsing content not related to school, on school days[c]	3.58	0.07
On school days, how many hours the student spend doing housework[d]	2.15	0.04
On school days, how many hours the student spend working[d]	1.04	0.01
Commuting time in minutes (home-school)	17.63	1.13
Commuting time in minutes (school-house)	19.38	1.29
Proportion of male parents or guardians	0.15	0.01
Average age of parents or guardians	40.09	0.27
Parental/guardians education	11.83	0.22
Monthly income of the parents/guardians[e]	792.50	35.21
Proportion of guardians who receive government assistance	0.59	0.02
Proportion of guardians who always see the student's report card	0.89	0.01
Proportion of teachers who identify themselves as black	0.13	0.03
Proportion of male teachers	0.16	0.05
Age of the Portuguese teacher	46.47	0.99
Proportion of teachers holding a degree in Languages and Literature	0.99	0.01
Proportion of postgraduate teachers	0.15	0.06
Proportion of teachers with temporary employment contract	0.27	0.05
Experience of the teacher with 6^{th} and 7^{th} graders[f]	3.03	0.12
Attack against the life of members of the school community inside the school	0.03	0.02
Use of drugs in the premises or areas surrounding the school	0.77	0.06
Number of observations (n = 4,179)		

Notes:

a: The study frequency levels 3 and 4 correspond to "less than 3 days a week" and "3 days a week", respectively.

b: The bullying frequency levels 1 and 2 correspond to "none" and "1 or 2 days", respectively.

c: The frequency levels 2, 3, and 4 with watch TV or spend time on the Internet correspond to "1 hour or less", "more than 1, up to 2 hours", and "more than 2, up to 3 hours", respectively.

d: The frequency levels 1, 2, and 3 with do housework or work outside the house correspond to "he/she doesn't", "1 hours or less", and "more than 1, up to 2 hours", respectively.

e: Individual income in BLR, at current prices of 2018.

f: The experience levels 3 and 4 correspond to "8 to 14 years" and "15 to 20 years".

References

Alves, F. R., Souza, E. A., Ferreira, L. G. F., Vilar Neto, J. O., Bruin, V. M. S., & Bruin, F. C. (2020). Sleep duration and daytime sleepiness in a large sample of Brazilian high school adolescents. *Sleep Medicine*, *66*, 207-215. https://doi.org/10.1016/j.sleep.2019.08.019

American Academy of Pediatrics (2014). School Start Times for Adolescents. *PEDIATRICS*., *134*(3), 642-649. https://doi.org/10.1542/peds.2014-1697

Araújo, J., & Marques, N. (2002). Cronobiologia: uma multidisciplinaridade necessária. *Revista Margem, São Paulo*, *32*(15), 181-186.

Arrona-Palacios, A., & Díaz-Morales, J. (2018). Morningness–eveningness is not associated with academic performance in the afternoon school shift: Preliminary findings. *The British Psychological society, 88*, 480-498. https://doi.org/10.1111/bjep.12196

Boergers, J., Gable, C. J., & Owens, J. A. (2014). Later school start time is associated with improved sleep and daytime functioning in adolescents: *Journal of Developmental & Behavioral Pediatrics*, *35*(1), 11-17. https://doi.org/10.1097/DBP.0000000000000018

Bowers, J. M., & Moyer, A. (2017). Effects of school start time on students' sleep duration, daytime sleepiness, and attendance: A meta-analysis. *Sleep Health*, *3*(6), 423-431. https://doi.org/10.1016/j.sleh.2017.08.004

BRASIL. (2018). Relatório do 2º Ciclo de Monitoramento das Metas do Plano Nacional de Educação – Brasília: INEP, 2018. Retrieved from http://fne.mec.gov.br/images/resumo_relatorio_inep_-_pne_2018_-_principais_conclusoes_.pdf

Cardenas, S., & De la Cruz, E. E. R. (2017). Controlling administrative discretion promotes social equity? Evidence from a natural experiment. *Public Administration Review, 17*(1), 80-89. https://doi.org/10.1111/puar.12590

Cardinali, D. P. (2008). Chronoeducation: How the Biological Clock Influences the Learning Process. In *The Educated Brain: Essays in Neuroeducation*, ed. Antonio M. Battro, Kurt W. Fischer, and Pierre J. Léna, 110–26. Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/CBO9780511489907.009

Carrell, S. E., Maghakian, T., & West, J. E. (2011). A's from Zzzz's? The causal effect of school start time on the academic achievement of adolescents. *American Economic Journal: Economic Policy*, *3*(3), 62-81. https://doi.org/10.1257/pol.3.3.62

Carskadon, M. A., Wolfson, A. R., Acebo, C., Tzischinsky, O., & Seifer, R. (1998). Adolescent sleep patterns, circadian timing, and sleepiness at a transition to early school days. *Sleep*, *21*(8), 871-881. https://doi.org/10.1093/sleep/21.8.871

Chan, N. Y., Zhang, J., Yu, M. W. M., Lam, S. P., Li, S. X., Kong, A. P. S., ... & Wing, Y. K. (2017). Impact of a modest delay in school start time in Hong Kong school adolescents. *Sleep Medicine*, *30*, 164-170. https://doi.org/10.1016/j.sleep.2016.09.018

Chokroverty, S. (2010). Overview of sleep & sleep disorders. *The Indian Journal of Medical Research*, *131*.

Crowley, S. J., Acebo, C., Fallone, G., Carskadon, M. A. (2006). Estimating dim light melatonin onset (DLMO) phase in adolescents using summer or school-year sleep/wake schedules. *Sleep*, *29*(12), 1632-1641. https://doi.org/10.1093/sleep/29.12.1632

Danner, F., & Phillips, B. (2008). Adolescent sleep, school start times, and teen motor vehicle crashes. *Journal of Clinical Sleep Medicine*, *4*(6), 3. https://doi.org/10.5664/jcsm.27345

Dewald, J. F., Meijer, A. M., Oort, F. J., Kerkhof, G. A., & Bögels, S. M. (2010). The influence of sleep quality, sleep duration and sleepiness on school performance in children and adolescents: A meta-analytic review. *Sleep Medicine Reviews*, *14*(3), 179-189. https://doi.org/10.1016/j.smrv.2009.10.004

Diette, T. M., & Raghav, M. (2017). Does early bird catch the worm or a lower GPA? Evidence from a liberal arts college. *Applied Economics*, *49*(33), 3341-3350. https://doi.org/10.1080/00036846.2016.1259750

Duarte, J. C. (2008). Privação do Sono, Rendimento Escolar e Equilíbrio Psico-Afectivo na Adolescência. 2008. Tese (Doutorado em Ciências de Saúde Mental) – Instituto de Ciências Biomédicas Abel Salazar, Universidade do Porto, Porto.

Evans, M. D. R., Kelley, P., & Kelley, J. (2017). Identifying the Best Times for Cognitive Functioning Using New Methods: Matching University Times to Undergraduate Chronotypes. *Frontiers in Human Neuroscience - Section Cognitive Neuroscience, 11*. https://doi.org/10.3389/fnhum.2017.00188

Felden, E. P. G., Filipin, D., Barbosa, D. G., Andrade, R. D., Meyer, C., & Louzada, F. M. (2016). Factors associated with short sleep duration in adolescents. *Revista Paulista de Pediatria*, *34*(1). https://doi.org/10.1016/j.rppede.2015.10.007

Gariépy, G., Janssen, I., Sentenac, M., & Elgar, F. J. (2017). School start time and sleep in Canadian adolescents. *Journal of Sleep Research*, *26*(2), 195-201. https://doi.org/10.1111/jsr.12475

Gibson E. S. *et al*. (2006). "Sleepiness" is serious in adolescence: Two surveys of 3235 Canadian students. *BMC Public Health, 6*, 116. https://doi.org/10.1186/1471-2458-6-116

Groen, J. A., & Pabilonia, S. W. (2019). Snooze or lose: High school start times and academic achievement. *Economics of Education Review*, 72, 204-218. https://doi.org/10.1016/j.econedurev.2019.05.011

Gulyani, S., Salas, R. E., & Gamaldo, C. E. (2012). Sleep medicine pharmacotherapeutics overview: Today, tomorrow, and the future (Part 1: Insomnia and circadian rhythm disorders). *Chest Journal, 142*(6), 1659-68. https://doi.org/10.1378/chest.12-0465

Guyton, M. D., & Hall, J. E. (2011). *Tratado de Fisiologia Médica.* 12ª ed., Elsevier Ltda, Rio de Janeiro.

Hansen, M., Janssen, I., Schiff, A., Zee, P. C., & Dubocovich, M. L. (2005). The impact of school daily schedule on adolescent sleep. *Pediatrics, 115*(6), 1555-1561. https://doi.org/10.1542/peds.2004-1649

Hinrichs, P. (2011). When the bell tolls: The effects of school starting times on academic apchievement. *Education Finance and Policy, 6*(4), 486-507. https://doi.org/10.1162/EDFP_a_00045

Kirby, M., Maggi, S., & D'Angiulli, A. (2011). School start times and the sleep–wake cycle of adolescents: A review and critical evaluation of available evidence. *Educational Researcher, 40*(2), 56-61. https://doi.org/10.3102/0013189X11402323

Lenard, M., Morrill, M. S., & Westall, J. (2020). High school start times and student achievement: Looking beyond test scores. *Economics of Education Review, 76,* 1-13. https://doi.org/10.1016/j.econedurev.2020.101975

Lufi, D.,Tzischinsky, O., & Hadar, S. (2011). Delaying school starting time by one hour: Some effects on attention levels in adolescents. *J Clin Sleep Med., 7*(2), 137-143. https://doi.org/10.5664/jcsm.28100

Lusher, L., & Yasenov, V. (2016). Double-shift schooling and student success: Quasi-experimental evidence from Europe. *Economics Letters, 139,* 36-39. https://doi.org/10.1016/j.econlet.2015.12.009

Lusher, L., & Yasenov, V. (2018). Gender performance gaps: Quasi-experimental evidence on the role of gender differences in sleep cycles. *Economic Inquiry*, *56*(1), 252-262. https://doi.org/10.1111/ecin.12483

Meltzer, L. J., Shaheed, K., & Ambler, D. (2016). Start later, sleep later: School start times and adolescent sleep in homeschool versus public/private school students. *Behavioral Sleep Medicine*, *14*(2), 140-154. https://doi.org/10.1080/15402002.2014.963584

Moreira *et al.* (2013). Comparação da qualidade do sono entre homens e mulheres ativos fisicamente. *Revista Eletrônica Saúde e Ciência*, *3*(2), 38-49.

Neves G. S. M. L., Giorelli, A. S., Floripo, P., & Gomes, M. M. (2013). Sleep disorders: overview. *Rev. Brasileira de Neurologia, 49*(2), 57-71.

Owens, J. A., Au, R., Carskadon, M., Millman, R., & Wolfson, A. (2014). School start times for adolescents. *American Academy of Pediatrics.* https://doi.org/10.1542/peds.

Pereira E. F., Moreno, C., & Louzada, F. M. (2014). Increased commuting to school time reduces sleep duration in adolescents. *Chronobiol International. The Journal of Biological and Medical Rhythm Research. 31*(1), 87-94. https://doi.org/10.3109/07420528.2013.826238

Pereira E. F., Teixeira, C. S., & Louzada, F. M. (2010). Sonolência diurna excessiva em adolescentes: Prevalência e fatores associados. *Rev. Paulista de Pediatria, 28,* 98-103. https://doi.org/10.1590/S0103-05822010000100015

Pope N. G. (2016). How the time of day affects productivity: Evidence from school schedules. *The Review of Economics and Statistics, XCVIII* (1), 1-11. https://doi.org/10.1162/REST_a_00525

Reynoso, A., & Rossi, M. A. (2019). Teenage risky behavior and parental supervision: the unintended consequences of multiple shifts school systems. *Economic Inquiry*, *57*(2), 774-791. https://doi.org/10.1111/ecin.12759

Sagyndykova, G. (2015). Academic performance in double-shift schooling. Department of Economics, Nazarbayev University, Astana, Kazakshtan. Retrieved from https://research.nu.edu.kz/ws/portalfiles/portal/15041326/DSSpaper_Galiya.pdf

Wahlstron, K. (2002). Changing times: Findings rrom the first longitudinal study of ;ater high school start times. *NASSP Bulletin*, *86*(633). https://doi.org/10.1177/019263650208663302

Wong, J. (2011). Does school start too early for student learning? Chapter 2 in Essays on the determinants of student choices and educational outcomes. Dissertation, Stanford University. Stanford, CA. Retrieved from https://stacks.stanford.edu/file/druid:wj919hv9027/Dissertation-augmented.pdf