The effect of delaying school start time on adolescents' time use and health: Evidence from a policy change in Korea

Dongkyu Yang[a] and Jaesung Choi[a]

[a] *Department of Economics, Sungkyunkwan University, Seoul, South Korea*

Abstract

This paper examines how delaying school start time to 9 o'clock affects time use and health of secondary school students in South Korea. To identify the causal impacts of delaying school start time, we employ a difference-in-differences methodology that exploits a unique natural experiment in South Korea using two nationally representative datasets. We find that the policy led students to sleep 16 minutes more on weekdays and 8 minutes less a day over the weekends, increasing sleep satisfaction among the affected students. Furthermore, the policy also contributed to increased growth and improved mental health. However, the effects of the policy were not uniform across subgroups. In terms of time use, students from the highest socioeconomic background increased sleep duration most. In contrast, students from the middle or lowest socioeconomic background increased electronic device usage and decreased study time. We provide suggestive evidence that these behavioral differences by socioeconomic background can be potentially related to the degree of parental monitoring and economic resources available.

Keywords: school start time; sleep time; health; difference-in-differences; South Korea

Introduction

Many studies report that adolescents experience sleep deficiency due to early school start time (Eaton et al. 2010; Gradisar et al. 2011; Saxvig et al. 2012). This deficiency could have significant influences on academic and health outcomes of adolescents (e.g., Stickgold and Walker 2007; Fogel and Smith 2011). Indeed, recent studies consistently show that starting school later causes students to sleep more and can have a significantly positive impact on academic performance (Chan et al. 2017; Morgenthaler et al. 2016; Carrell et al. 2011; Heissel and Norris 2018).

Because of the intense competition for entering prestigious universities, lack of sleep is especially severe among Korean adolescents. Many of these students stay at school for self-study or participate in private tutoring services until late at night. In such a competitive educational environment, the Gyeonggi Office of Education (GOE) in South Korea (hereafter Korea) delayed the school start time to 9 o'clock after the newly elected superintendent accepted a student's proposal posted on the GOE's website in June 2014. This policy was immediately introduced at the start of the new semester in September. On average, the policy has delayed school start time about 45 minutes for schools in Gyeonggi (GOE 2014). The introduction of the policy was so swift that students and parents had no choice but to comply. However, school start times in other provinces, such as Seoul, remained the same. Utilizing this policy change, we examined the effect of delaying school start time on adolescents' time use and their health outcomes.

To examine the impact of the policy change, we employed a difference-in-differences strategy by comparing students' time use and health outcomes in Gyeonggi with those attending schools in Seoul. For the empirical analysis, we relied on two nationally representative datasets. We first analyzed the Korea Youth Risk Behavior Web-based Survey (KYRBS) from 2011 to 2017 to see the impact of the policy change on sleeping behavior and health outcomes. We further analyzed data from the Korea Media Panel (KMP) to investigate how students allocated their additional time available after the policy change by focusing on the use of electronic devices.

At the time around policy introduction, public opinions were widely divided. Proponents of the policy claimed that delaying school start time would allow students to sleep more and to have a leisurely breakfast, which in turn would improve student health. While agreeing on the purpose of the policy, others worried that the late school start time would lead to poorer academic performance due to the shortening of time spent in school for self-study or extra classes. These opponents believed that the policy would increase the use of private supplementary education. Some people argued that if the delay in school start time yielded delays in school finishing time, then there should be more concerns on safety issues after sunset.

First, this study reviews whether worries and expectations about the policy are grounded. There are two other studies which investigate the effects of the Gyeonggi 9 o'clock attendance policy (Kim 2018; Shin 2018) on sleep time and academic outcomes. Both studies found that delaying school start time has increased sleep time of adolescents and also suggested evidence of improved outcomes on standardized tests. Consistent with Kim (2018) and Shin (2018), we found that the delay in the school start time led students to sleep 16.2 minutes more on weekdays.

Second, we investigated the influence of the policy on physical and mental health outcomes. After the introduction of the policy, the heights of students in Gyeonggi have increased by 0.17 cm per year more compared to their counterparts in Seoul. Because the effect on heights is cumulative, the gross gains for 7th graders after the introduction of the policy amounted to 0.72 cm over three years. Furthermore, the policy also improved the mental health of students in Gyeonggi. Sleep satisfaction increased by 0.1 standard deviations, and stress level decreased by 0.03 standard deviations.

Last, we further examined whether there are any differential impacts by students' socioeconomic background. Previous studies report heterogeneous time use pattern of adolescents by socioeconomic backgrounds (Wight et al. 2009; Badura et al. 2017). In the context of Korean education, Choi and Choi (2016) examined the impact of a 10 pm curfew policy on private tutoring institutions in Korea. This study found that students from lower socioeconomic backgrounds were more likely to increase their sleep time and internet usage for non-academic purposes compared to students from higher socioeconomic backgrounds. In this study, we also found that the impacts of the delaying school start time do not appear to be uniform across subgroups. After the policy change, students from the highest socioeconomic background have increased their sleep time by 18.2 minutes. In contrast, students from the lowest socioeconomic background increased their sleep time by 12.5 minutes. When we compare bedtime and wake-up time separately, the difference in sleep duration is mainly driven by the change in bedtime, a 6-minute delay for the highest and a 14-minute delay for the lowest.

To better understand the differential sleeping behavior by socioeconomic background, we also investigated the time spent on study and electronic devices. Students in the highest socioeconomic group decreased study time less than those from middle or lowest groups, widening the preexisting gap in study time. In addition, we found that students from lower socioeconomic backgrounds, in particular, increased time spent on computers and watching television compared to their counterparts from the highest socioeconomic background.

These disparities in sleep time, study time, and electronic device usage imply that the delaying school start time can result in unexpected consequences of widening academic performance gap by family background. We speculate that these behavioral differences by socioeconomic background may be potentially related to the degree of parental monitoring. Although we could not test this hypothesis explicitly due to the lack of information on parental behaviors, we found that there are differences in the increase in sleep time depending on whether there are either both parents, a single mother, or a single father in the household.

The rest of the paper proceeds as follows. In Section 2, we describe the context of the 9 o'clock attendance policy along with the Korean educational system. Section 3 illustrates the data and empirical strategy. Section 4 presents the main findings, and section 5 discusses the robustness of the results. Section 6 concludes by discussing potential mechanisms.

Institutional Background

Korean students face one of the harshest competitions in the world to enter prestigious colleges (Grubb et al. 2009). For example, high school students may attend school as early as 8 am and stay until 10 pm to prepare for the Korean SAT. Thus, there have been long-held criticisms about the demanding school schedule depriving time for sleep and breakfast, subsequently impacting on the health of adolescents.

In July 2014, liberal superintendents of education took office in both Seoul and Gyeonggi province, and these superintendents liberalized school start times to guarantee students' rest time, leaving the decision to the discretion of the principal. While schools in both regions resisted the adoption of 9 am school start time, the superintendent of Gyeonggi strongly pushed the introduction of the policy. In consequence, most of the schools in the Gyeonggi province changed their school start time in September 2014, at the beginning of the fall semester.

Before the policy, only 1% of middle schools and no high schools set their school start time at 9 am. However, in the fall semester of the same year, 571 (94.5%) middle schools out of 604, and 302 (67.0%) high schools out of 451 changed their start time to 9 am (GOE 2014). Furthermore, 99.1% of middle schools and 88.9% of high schools adopted the policy in spring 2015. In Seoul, however, the Seoul Metropolitan Office of Education did not prioritize these changes. In consequence, no schools adopted the policy in 2014, and only a few middle schools (3.6%) and no high schools adopted the policy in 2015. The sudden introduction of the 9 o'clock attendance policy in Gyeonggi minimizes confounding influences as the rapid implementation would not have provided enough time for students and parents to prepare or make any changes in advance.

Data and Methodology

Data and Descriptive Analysis

Korea Youth Risk Behavior Web-based Survey

First, we analyzed the Korea Youth Risk Behavior Web-based Survey (KYRBS) from 2011 to 2017 to assess the impact of the policy introduction on sleeping behavior and health outcomes. Every year, the Korea Centers for Disease Control and Prevention (KCDC) conducts a cross-sectional survey using web-based self-response questionnaires. To understand health behavior of Korean teenagers and produce health indicators for policy discussion, KYRBS has been held for a nationally representative sample of 65,000−70,000 secondary school students from grades 7 to 12. Among them, 15,000−20,000 students are from Seoul or Gyeonggi. Because KYRBS has been conducted between May and July, while the policy was first introduced in September 2014, the survey years of 2011 to 2014 can be classified as pre-treatment periods and survey years of 2015 to 2017 can be treated as post-treatment periods.

KYRBS is designed to report one's economic status as one of these five categories: (1) low, (2) lower-middle, (3) fair, (4) upper-middle, and (5) high. We classified students who reported their economic status as (1) low and (2) lower-middle to the lowest socioeconomic status group. Similarly, students who reported their economic status as (4) upper-middle and (5) high are classified as the highest status group. As a result, 33.5% of students are classified as the highest socioeconomic status group, 47.8% as middle status, and 18.8% as the lowest socioeconomic status group.

Regarding sleeping behavior, KYRBS asks the average time a student went to sleep and the time when he or she woke up last week. In Panel (A) of Appendix Figure 1, we present the proportion of students sleeping in 2014 and 2015 for Seoul (control group) and Gyeonggi (treatment group) from 8 pm to 10 am. For instance, the proportion of students sleeping is almost zero at 8 pm, and nearly all students are sleeping between 3 am to 6 am. As clearly distinguished between Seoul and Gyeonggi, there is no discernible difference between the two curves for Seoul in 2014 and 2015. In contrast, the curve for Gyeonggi in 2014 shifts to the right in 2015, which shows that more students slept later and also woke up later in 2015 than 2014 after policy introduction in Gyeonggi.

Table 1 presents descriptive statistics of dependent variables used in the analysis for Seoul and Gyeonggi, separately, before and after the policy. Samples with missing values in sleep time were excluded. Before the introduction of the policy, students in Gyeonggi slept 6.42 hours a day while students in Seoul slept 6.26 hours a day. Students in Gyeonggi slept 0.16 hours longer even before the introduction of the policy, mainly because of 0.20 hours earlier bedtimes. This difference may be due to more intensive use of private tutoring among students in Seoul. After the policy enactment, students in Gyeonggi increased their sleep time to 6.53 hours a day while students in Seoul decreased their sleep time to 6.11 hours, widening the difference of sleep time to 0.42 hours. As a result, the sleep time of students in Gyeonggi increased by 0.26 hours a day (15.6 minutes) relative to their counterparts in Seoul.

[Table 1 Here]

To better understand the changes in sleep time, we separately examined changes in bedtime and wake-time in Rows 2 and 3 of Table 1. Although students in Gyeonggi lagged their bedtime by 0.16 hours relative to Seoul, there is larger delay of 0.42 hours in wake-up time, which contributes to the overall increase in sleep time for students in Gyeonggi. In Row 4, we also present sleep time during the weekend and find that this decreased after the policy implementation. This changing pattern implies that increased amounts of sleep during weekdays can affect weekend sleep patterns, and students in Gyeonggi now have more balanced sleep schedules throughout a week.

Row 5 shows the frequency of breakfasts per week. In contrast to the increase in sleep time, the frequency of breakfasts changed little. This may be due to the fact that frequencies are already high even before the policy introduction (4.60 per week for Gyeonggi and 4.66 per week for Seoul). Rows 6 to 8 provide means for health-related variables. For physical health, we focused on height and Body Mass Index (BMI). Although students in Seoul were slightly taller in the pre-treatment period, the gap diminished by half (0.28 cm) after the policy introduction.

The survey also asks students to report items related to mental health on a 1 to 5 scale of agreement or disagreement with the statement. For the ease of interpretation, we reordered responses so that higher scores imply stronger agreement to the respective questionnaire. For example, 5 in sleep satisfaction means a student reports the highest satisfaction while 5 in stress level means a student reports the highest stress level. As shown in Rows 9 to 11, students in Gyeonggi have reported higher sleep satisfaction and subjective health, while they also reported a decrease in stress level.

Korea Media Panel

To examine adolescents' time use in detail, we further analyze the Korea Media Panel (KMP) data administered by the Korea Information Society Development Institute. The KMP supplies rich information about time spent on media by asking respondents to write a media diary, which describes daily media consumption every 15 minutes for three days. In addition, the KMP provides a wide range of demographic and socioeconomic characteristics. To understand how students allocate their additional time available after the delay of school starting time, we examined time use of electronic devices using the KMP. As the data provides information on the location of media consumption, we focused on the amount of time spent on electronic devices at home, particularly from 8 pm to bedtime.

In Panel (B) of Appendix Figure 1, we present the proportion of students using electronic devices before and after the policy for Seoul and Gyeonggi from 8 pm to 2 am. Similar to the change in sleep behavior, the proportion of students who used electronic devices does not change significantly in Seoul, whereas students in Gyeonggi clearly show a pattern of increasing use of electronic devices after the policy introduction. For example, 32.7% of students in Gyeonggi used electronic devices at 11 pm before the introduction of the 9 o'clock attendance policy while the proportion of students increased to 35.1% after the policy.

Estimation Strategy

$$\boldsymbol{Y_{ist} = \alpha + \beta X_{ist} + \delta d_{ist} + \gamma_s + \lambda_t + \varepsilon_{ist}} \quad \textbf{(1)}$$

We employ a difference-in-differences (DID) strategy to estimate the effects of the delayed school starting time. Here Y_{ist} represents dependent variables, such as sleep time, for student *i* in region *s* at year *t*. $\boldsymbol{d}_{ist}$ is a dummy variable indicating whether region *s* at year *t* is subject to the policy. Thus, $\boldsymbol{d}_{ist}$ has value of one if a student i attends schools in Gyeonggi province for years 2015−2017. γ_s represents region fixed effects, and year fixed effects λ_t are also included to control year-specific common changes for both regions. $\boldsymbol{X}_{ist}$ is a vector of individual, household, and school characteristics.

For individual characteristics, we take into account sex and age of students. For household characteristics, we consider family structure by distinguishing whether the students live with a father and mother, parental education (maximum of father's and mother's education), and household socioeconomic status. School characteristics include dummy variables to distinguish whether students attend general high schools or vocational high schools using middle school as a reference. Our final analytical sample included 146,248 observations in KYRBS and 4,643 observations in KMP.

Whether Seoul and Gyeonggi follow the same trend is a critical assumption in DID estimation. To check the robustness of our results, we conduct a falsification test by using leads and lags as done in Autor (2003). In addition, we also conduct additional analyses by using other six metropolitan cities except Seoul as an alternative control group.

Results

Change in Sleep Behavior

Figure 1 shows trends in sleep time of students from 2011 to 2017 using KYRBS. A vertical line between 2014 and 2015 represents the timing of the adoption of the 9 o'clock attendance policy in Gyeonggi province. Panels A to C show a common trend before the policy implementation (2011–2014). However, sleep schedule diverges after the policy introduction (Panel A). Bedtime among students in Gyeonggi was delayed compared to students in Seoul (Panel B), and wake-up time among students in Gyeonggi was even more delayed, outweighing the difference in bedtime (Panel C). As a result, total sleep time among students in Gyeonggi increased relative to students in Seoul.

[Figure 1 Here]

Table 2 presents estimation results using a difference-in-differences method. Columns 1 to 3 show estimates on the change in sleep time in three specifications. Column 1 presents the estimated result without any control. In Column 2, we include a set of individual, household, and school characteristics. In Column 3, we additionally include year fixed effects. Across all specifications, results on sleep time are all significant and of similar magnitudes. As shown in Columns 3 to 5, the delay in the school start time led students to sleep 16.2 minutes more on weekdays. This is mainly driven by a delay in wake-up time of 24.9 minutes whereas bedtime was delayed by 8.8 minutes.

The estimation results contradict one of the criticisms from those who opposed the introduction of the policy. Many opponents claimed that the total sleep hours among people are fixed so that the late school start time would not increase students' sleep hours (Baek et al. 2015). These opponents also argued that delaying school start time would only break the rhythm of daily life and produce students active at late night hours. However, our findings in Table 2 show that the lump-sum sleep time hypothesis is not grounded.

[Table 2 Here]

The baseline estimates are for 13-year-old boys in middle school. The coefficients in Column 3 show that girls sleep 30 minutes less than boys. In addition, as students get older, their sleep time decreases by 12.5 minutes a year. There is also a considerable difference in sleep time between middle school and high school students. Among high school students, those who attend vocational high schools slept 23 minutes less than middle school students. Students attending general high schools, who mostly prepare to enter colleges, slept 45 minutes less than middle school students. When we estimate six separate regressions for subgroups by sex and school type, the impacts of the policy range from 11 minutes to 22 minutes.

Impacts on Physical and Mental Health

We present estimation results for changes in physical health outcomes in Columns 1 to 3 of Table 3. Heights of students in Gyeonggi increase 0.17 cm more than their counterparts in Seoul. Although the magnitude would seem to be small at first, the estimate is the average effects for both middle and high school students and the effect on heights is cumulative. When we examine the change in height by school level, the impact is larger for middle school students, 0.25 cm for boys and 0.11 cm for girls. We did not find any meaningful change in weights, so students’ BMI decreased in Gyeonggi.

Students who were 7th graders in 2011 and 2012 were not exposed to the policy while attending middle school because they graduated middle school before the introduction of the policy in 2014. When we compare the cumulative increase in height between students in Gyeonggi and Seoul, the differences were not significant during the three years in middle school. However, when we examine cumulative change in heights for cohorts who entered middle school after the introduction of the policy, students in Gyeonggi grew 0.72 cm more than their counterparts in Seoul while attending middle school.

[Table 3 Here]

The policy also contributes to improvements in mental health outcomes. Columns 4 to 6 of Table 3 show changes in students’ reports regarding sleep satisfaction, subjective health status, and stress level. The level of sleep satisfaction of students in Gyeonggi increased by 0.087 (0.1 standard deviations) and subjective health status increased by 0.024 (0.03 standard deviations) due to the policy. In addition, students’ stress levels decreased by 0.028 (0.03 standard deviations) after the introduction of the 9 o’clock attendance policy.

Heterogeneous Effects of Delaying School Start Time by Socioeconomic Background

Heterogeneity in Sleep Time and Health Outcomes

We investigated whether the effects of the policy are similar among students by family backgrounds. Panels (A) to (C) of Figure 2 shows the increase in sleep time after the policy by socioeconomic backgrounds. We categorized students into three groups: upper, middle, and lower groups. In the figure, the center of each box represent a point estimate of the policy effects on sleep time (interaction term in the DID specification) along with whiskers representing 95% confidence interval. Although students in all groups increased their sleep time, students from the most affluent background increased their sleep time most. Students in the upper group increased sleep time by 18.2 minutes, while students from middle and lower groups increased their sleep time by 15.6 minutes and 12.5 minutes, respectively.

[Figure 2 Here]

The differences in delayed bedtime across the three groups drive most of the disparity in sleep time with little differences in wake-up time, which ranges from 1 to 3 minutes. Students from lower socioeconomic backgrounds delayed their bedtime more compared to students from higher socioeconomic backgrounds. Interestingly, students from higher socioeconomic status slept more even before the policy introduction (upper group: 6 hours and 25 minutes, middle group: 6 hours 21 minutes, lower: 6 hours 11minutes), resulting in greater divergence in sleep time by socioeconomic background.

Consistent with the changes in sleep time, physical and mental health of students also display differential effects by socioeconomic background. The magnitude of height growth was larger for students from higher socioeconomic backgrounds (Columns 1, 5 and 9 of Appendix Table 1). A similar pattern was also observed for mental health outcomes (Appendix Table 1). Although students from all groups report improved sleep satisfaction and subjective health, the magnitudes were disparate by socioeconomic backgrounds, as students from higher socioeconomic backgrounds reported larger gains. Furthermore, the decrease in stress level was significant only for students from the highest socioeconomic background.

Although we cannot directly test whether and to what extent improvements in mental health outcomes are attributable to increase in sleep time, we found a positive correlation between increase in sleep time and improvements in mental health outcomes. This finding suggests that increase in sleep time due to the policy change may be a driving force in the improvements in mental health outcomes.

Heterogeneity in Study Time and the Use of Electronic Devices

What would drive the disparities in sleep time by socioeconomic backgrounds? To address this question, we further examined time use of students in detail. First, we investigated the differences in study time using KYRBS. Since the students from the highest socioeconomic background increase sleep time most, one possibility is that these students may reduce their study hours compared to other groups. However, as shown in Panel (D) of Figure 2, the opposite is true. While students from the highest group did not significantly reduce their study time during weekdays, students from middle and lowest groups did (16.7 minutes and 23.1 minutes, respectively). Similar to the trend in sleep time, students from the lowest socioeconomic background showed the largest decrease in study time even though these students had the shortest study time before the policy. Thus, delaying school start time results in widening gaps in study time as well as sleep time by socioeconomic backgrounds.

The increase in sleep time and the decrease in study time both imply that students would have more time for other activities after the policy introduction in Gyeonggi. Following two possible changes could reduce time spent on studying at educational institutions. First, due to the delayed school start time, schools would reduce the total time of students being in school. Although exact information about school schedule is not available, guidelines for the policy explicitly recommend that schools not delay school finishing time as much as start time (GOE 2014). Given that amount of regular classes are regulated by Ministry of Education without any discreation at the school level, schools may have reduced time allocated to self-study sessions and extra classes. The second possibility involves an interplay between late school finish time and 10 pm curfew on private tutoring institutions. Even though school finish time is delayed, the policy did not accompany any policy change on curfew times on private tutoring institutions. Thus, without a change in time spent on regular classes in school, total time spent in educational institutions may decrease due to the decrease in the use of private supplementary education.

The change in sleep time and study time also could related with how students allocate their increased time outside educational institutions. In Panel (E) of Figure 2, we examined how students spent their increased free time after the policy. The figure presents the change in time use of electronic devices between 8 pm and bedtime by socioeconomic background using the KMP. Although the increase in electronic devices use was statistically insignificant and small (5.0 minutes) for students from the highest socioeconomic background, students from middle and the lowest backgrounds increased their time spent on electronic devices by 16.7 minutes and 24.6 minutes, respectively.

Time spent on watching television (54.0%), using computers (24.2%), and using smartphones (19.7%) take up 98% of the total time spent on electronic devices between 8 pm and bedtime. Compared to students from the highest group, students from the middle group spent more time using smartphones and watching television. Students from the lowest group spent more time using computers and watching television. In the debate around the introduction of the 9 o'clock attendance policy, opponents of the policy worried that the policy would lead to more students behaving as 'night owls' who would use electronic devices until late at night. Our finding confirms that these concerns are somewhat grounded. Furthermore, the policy's negative impacts are more concentrated among students from lower socioeconomic backgrounds.

Robustness Check

Leads and Lags

The critical assumption for the difference-in-differences strategy is that outcome in treatment and control groups would follow the same time trend in the absence of the treatment. To satisfy the assumption, there should be no other interventions that might confound the effect of the policy of interest. Although these assumptions are difficult to verify, we can conduct a falsification check by examining the dynamics of the policy effects.

$$\mathbf{Y}_{ist} = \boldsymbol{\alpha} + \boldsymbol{\beta}\mathbf{X}_{ist} + \sum_{k=-3}^{2}(\boldsymbol{\delta}_{2015+k}\boldsymbol{d}_{is,2015+k}) + \boldsymbol{\gamma}_s + \boldsymbol{\lambda}_t + \varepsilon_{ist} \quad \mathbf{(2)}$$

Following Autor (2003), we include three leads and two lags of the treatment besides the year of adoption as in equation (2). $\boldsymbol{d}_{is,2015+k}$ is a dummy variable indicating whether the sample is from region s in year 2015+k, and thus, $\boldsymbol{\delta}_{2015+k}$ represents the change in the dependent variable for students in Gyeonggi relative to students in Seoul in year 2015+k. Negative k indicates the observation comes from k years before the policy adoption, and positive k indicates k years after the policy adoption. We consider the same set of covariates as in Table 2.

[Figure 3 Here]

Panel (A) of Figure 3 presents point estimates of the leads and lags with their 95% confidence intervals. Under the assumption of the common trend before policy introduction, all coefficients for leads indicators should be close to zero and statistically insignificant. The coefficients on lead indicators for 3 years and 2 years are close to zero, showing that sleep time between Seoul and Gyeonggi were not markedly different before the introduction of the policy. Although the estimate on the lead indicator for 1 year is significant, its magnitude is quite small (3.2 minutes) compared to effects found for years after the policy introduction. The coefficient at the year of adoption shows that sleep time for students in Gyeonggi increased by 17.5 minutes. Next, coefficients for lag indicators show that the effects of the policy persisted for the next two years, ranging from 13.5 to 19.4 minutes.

In Panel (B) of Figure 3, we present effects of the policy on sleep time by socioeconomic backgrounds for students from the highest and lowest background groups. Although the coefficient for the lead indicator of 3 years for the lowest group and the coefficient for the lead indicator of 1 year for the highest group are significant, both magnitudes are relatively small with absolute values less than 5.5 minutes. After the policy adoption, students from the highest socioeconomic background group increased sleep time more than students from the lowest group, and the gap persists.

Alternative Control Group

Although we are not aware of any other policy changes specific to Seoul or Gyeonggi, we conduct an analysis by using other regions as an alternative control group as a robustness check of our main findings. Korea has 17 provincial-level entities: seven provinces, two special cities, and six metropolitan cities. The distribution of the Korean population is heavily concentrated at the Seoul metropolitan area (Seoul, Gyeonggi, and Incheon). In 2014, Gyeonggi province had a population of 12.0 million (23.6% of total Korean population), and Seoul had 9.98 million (19.7% of total Korean population). Because Gyeonggi province is heavily urbanized, we used six metropolitan cities (Busan, Daegu, Gwangju, Incheon, Ulsan, and Daejeon) as an alternative control group. These cities are similarly urbanized with a combined population of 13.0 million (25.6% of total Korean population).

Following Gyeonggi province, other metropolitan cities have introduced the 9 o'clock attendance policy. Nevertheless, none of them pushed ahead the policy as thoroughly as Gyeonggi. Although the proportion of schools that adopted 9 o'clock attendance varied across cities, we included all of them as a control group because there are no public records on the exact proportion of the schools that adopted the policy of delaying school start time. As a result, the difference between Gyeonggi and six metropolitan cities should be interpreted as the difference between a full compiler and partial compilers.

We present the estimation results for the change in sleep time using the main specification with regional fixed effects. We also conducted the same analysis by students' socioeconomic background and reported results in Appendix Table 2. After the introduction of the 9 o'clock attendance policy in Gyeonggi, students in Gyeonggi slept 10.6 minutes longer than their counterparts in six metropolitan cities. Again, the differential policy impacts among students from different backgrounds are also robust. Students from the highest socioeconomic background increased their sleep time by 11.2 minutes, while students from the lowest background increased their sleep time by 9.6 minutes.

Discussion and Conclusion

This study exploits a natural experiment in Korea, the 9 o'clock attendance policy in Gyeonggi, to examine the causal effects of delaying school start time on adolescents' sleep behavior, time use, and health outcomes. We also investigated the heterogeneous effects of the policy by socioeconomic backgrounds. We found that delaying school start time about 45 minutes led students to sleep 16.2 minutes more, and the effects were mainly derived by the delay in wake-up time outweighing the delay in bedtime. We also found that students in Gyeonggi decreased sleep hours during the weekend, which resulted in a more balanced sleep schedule throughout a week. The policy also contributes to physical and mental health outcomes. After the 9 o'clock attendance policy, students in Gyeonggi grew more in height than students in Seoul. Students in Gyeonggi were more satisfied with their sleep and overall health condition along with possessing a decrease in stress level. The increased sleep time due to the policy seems to be a major driving force for the changes as those who experienced greater increases in sleep time were more likely to enjoy larger benefits.

However, the impact of the policy was not uniform across subgroups by socioeconomic background. The increase in sleep time was largest among well-off students. In contrast, students from lower socioeconomic backgrounds were more likely to decrease study time and increase time spent on electronic devices. Specifically, students from the lowest socioeconomic background increased time spent on electronic devices by 24.6 minutes and decreased study time by 23.1 minutes. There were no significant effects on students from the highest background.

These behavioral differences by socioeconomic background may be related to the degree of parental monitoring and economic resources of a household, and these differences could widen the academic performance gap by family background. Although suggestive, we find heterogeneous effects of the policy on students' sleep time by the family type, which may reflect the degree of parental guidance and involvement in time allocation. Students who live with two parents increased their sleep time by 16.5 minutes after the introduction of the policy while students who live with a single mother or a single father increased their sleep time by 9.0 minutes and 12.9 minutes, respectively. The presence of parents, especially the presence of a mother, is found to be strongly related with students' time use.

Furthermore, economic resources of households can contribute to disparities in study time and electronic device usages because well-off households can spend more money on private tutoring services. For example, affluent parents can afford expensive private tutoring at home. Although there is a 10 pm curfew in Korea, monitoring private education at home is practically impossible, the fact that makes private education a viable supplement for reduced school time. As presented in Appendix Table 3, by employing a DID specification, we estimated the change in time spent on supplementary private education using the Korean Time Use Survey (KTUS). Columns 1 to 3 show that students from the highest socioeconomic background increased the time spent on supplementary private education by 21.6 minutes, whereas students from the lowest background increased their time use of supplementary private education by 3.8 minutes. Although the estimated coefficients are not statistically significant due to the small analytical samples available in KTUS, the results suggest the possibility of differential behavioral responses in time use due to the policy change.

Consequently, the policy enlarges the preexisting gap in study time and thus, potentially widens the academic performance gap. Kim (2018) and Shin (2018) show that the 9 o'clock attendance policy in Gyeonggi improved the overall academic performance of students. However, our results suggest that we need to be cautious in interpreting the overall positive effects of the policy on academic outcomes in that the policy can have differential impacts, even possibly negative, by socioeconomic background depending on how students respond to the introduction of the policy by adjusting time use. Thus, educational authorities should be more concerned about potential side effects and enact accompanying supplementary measures to prevent further stratification when delaying school start time.

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Table 1. Descriptive statistics and simple difference-in-differences, using KYRBS

	Before Policy			After Policy			Difference-in-Differences		
	(a) Gyeonggi	(b) Seoul	(A) Difference (a-b)	(c) Gyeonggi	(d) Seoul	(B) Difference (c-d)	DID (B-A)	SE	Obs
(1) Weekday Sleep Time (hours)	6.42	6.26	0.160	6.53	6.11	0.420	0.260***	(0.015)	142,861
(2) Weekday Bedtime (Time)	24.34	24.53	-0.195	24.67	24.70	-0.034	0.161***	(0.013)	142,861
(3) Weekday Wake Time (Time)	6.76	6.79	-0.035	7.20	6.81	0.386	0.421***	(0.007)	142,861
(4) Weekend Sleep Time[1] (hours)	8.57	8.38	0.198	8.52	8.46	0.063	-0.135***	(0.032)	99,487
(5) Number of breakfast per week	4.60	4.66	-0.052	4.38	4.39	-0.010	0.042	(0.029)	142,861
(6) height[2] (cm)	164.39	164.97	-0.579	165.16	165.46	-0.304	0.275***	(0.092)	139,656
(7) weight (kg)	55.78	56.34	-0.567	57.19	57.84	-0.656	-0.089***	(0.124)	139,656
(8) Body Mass Index (BMI)	20.52	20.59	-0.064	20.84	21.00	-0.159	-0.095***	(0.034)	139,656
(9) Sleep Satisfaction	2.82	2.87	-0.050	2.82	2.77	0.043	0.093***	(0.012)	142,861
(10) Subjective Health Status	3.80	3.85	-0.047	3.90	3.92	-0.021	0.026***	(0.009)	142,861
(11) Stress Level	3.33	3.34	-0.003	3.24	3.27	-0.032	-0.029***	(0.010)	142,861

Notes: Standard errors are presented in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.
1. Weekend sleep questionnaires are available from 2013 to 2017 while weekday sleep questionnairesares are surveyed in all period.
2. KCDC codifies students' heights and weights as missing if it exceeds 3 standard deviation of the sample. If one of two variables exceed the threshold, both values are codified as missing.

Table 2. Effect of delaying school starting time on adolescents' sleep pattern schedule

	Sleep Time			Bedtime	Wake Time
	(1)	(2)	(3)	(4)	(5)
Gyeonggi	9.606***	6.482***	6.521***	-8.949***	-2.428***
(Treatment Group)	(0.556)	(0.459)	(0.459)	(0.457)	(0.217)
Post	-9.037***	-7.457***	-1.681**	1.888**	0.206
(After Policy)	(0.672)	(0.556)	(0.788)	(0.781)	(0.385)
Gyeonggi X Post	15.615***	16.182***	16.153***	8.768***	24.921***
	(0.884)	(0.736)	(0.736)	(0.734)	(0.364)
Female		-30.159***	-30.136***	18.832***	-11.305***
		(0.357)	(0.357)	(0.356)	(0.176)
Age		-12.569***	-12.578***	12.527	-0.051
		(0.187)	(0.187)	(0.187)	(0.093)
Vocational High School		-23.223***	-23.063***	-9.452***	-32.516***
		(0.890)	(0.889)	(0.890)	(0.447)
General High School		-45.437***	-45.362***	16.811***	-28.551***
		(0.668)	(0.670)	(0.669)	(0.327)
Household Characteristics		O	O	O	O
Year FE			O	O	O
Constant	375.532***	445.285***	443.444***	1,424.313***	427.757***
Sample	142,861	142,387	142,387	142,387	142,387
R-squared	0.012	0.318	0.319	0.189	0.253

Notes: Robust standard errors are presented in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 3. Effect of delaying school starting time on adolescents' health

	Height (cm)	Weight (kg)	Body Mass Index	Sleep Satisfaction	Subjective Health Status	Stress Level
	(1)	(2)	(3)	(4)	(5)	(6)
Gyeonggi (Treatment Group)	-0.394^{***}	-0.424^{***}	-0.059^{***}	-0.055^{***}	-0.046^{***}	0.000
	(0.043)	(0.066)	(0.020)	(0.007)	(0.006)	(0.006)
Post (After Policy)	0.131^{*}	0.616^{***}	0.192^{***}	0.033^{***}	0.028^{***}	-0.024^{**}
	(0.072)	(0.114)	(0.035)	(0.013)	(0.010)	(0.011)
Gyeonggi X Post	0.172^{**}	-0.158	-0.093^{***}	0.087^{***}	0.024^{***}	-0.028^{***}
	(0.067)	(0.108)	(0.033)	(0.012)	(0.009)	(0.010)
Female	-9.968^{***}	-9.111^{***}	-0.756^{***}	-0.331^{***}	-0.262^{***}	0.322^{***}
	(0.033)	(0.053)	(0.016)	(0.006)	(0.004)	(0.005)
Single-Sex School	1.607^{***}	1.774^{***}	0.263^{***}	-0.041^{***}	-0.033^{***}	0.043^{***}
	(0.018)	(0.028)	(0.009)	(0.003)	(0.002)	(0.003)
Vocational High School	-0.244^{***}	0.967^{***}	0.392^{***}	-0.241^{***}	-0.057^{***}	-0.027^{**}
	(0.076)	(0.128)	(0.040)	(0.014)	(0.011)	(0.012)
General High School	0.134^{**}	1.150^{***}	0.348^{***}	-0.250^{***}	-0.043^{***}	0.009
	(0.058)	(0.096)	(0.030)	(0.011)	(0.008)	(0.009)
Household Characteristics	O	O	O	O	O	O
Year FE	O	O	O	O	O	O
Constant	166.79^{***}	57.31^{***}	20.43^{***}	3.20^{***}	4.12^{***}	2.98^{***}
Sample	139,656	139,656	139,656	142,387	142,387	142,387
R-squared	0.470	0.270	0.065	0.068	0.062	0.059

Notes: Robust standard errors are presented in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Figure 1. The effect of delaying school start time on adolescents' sleep pattern

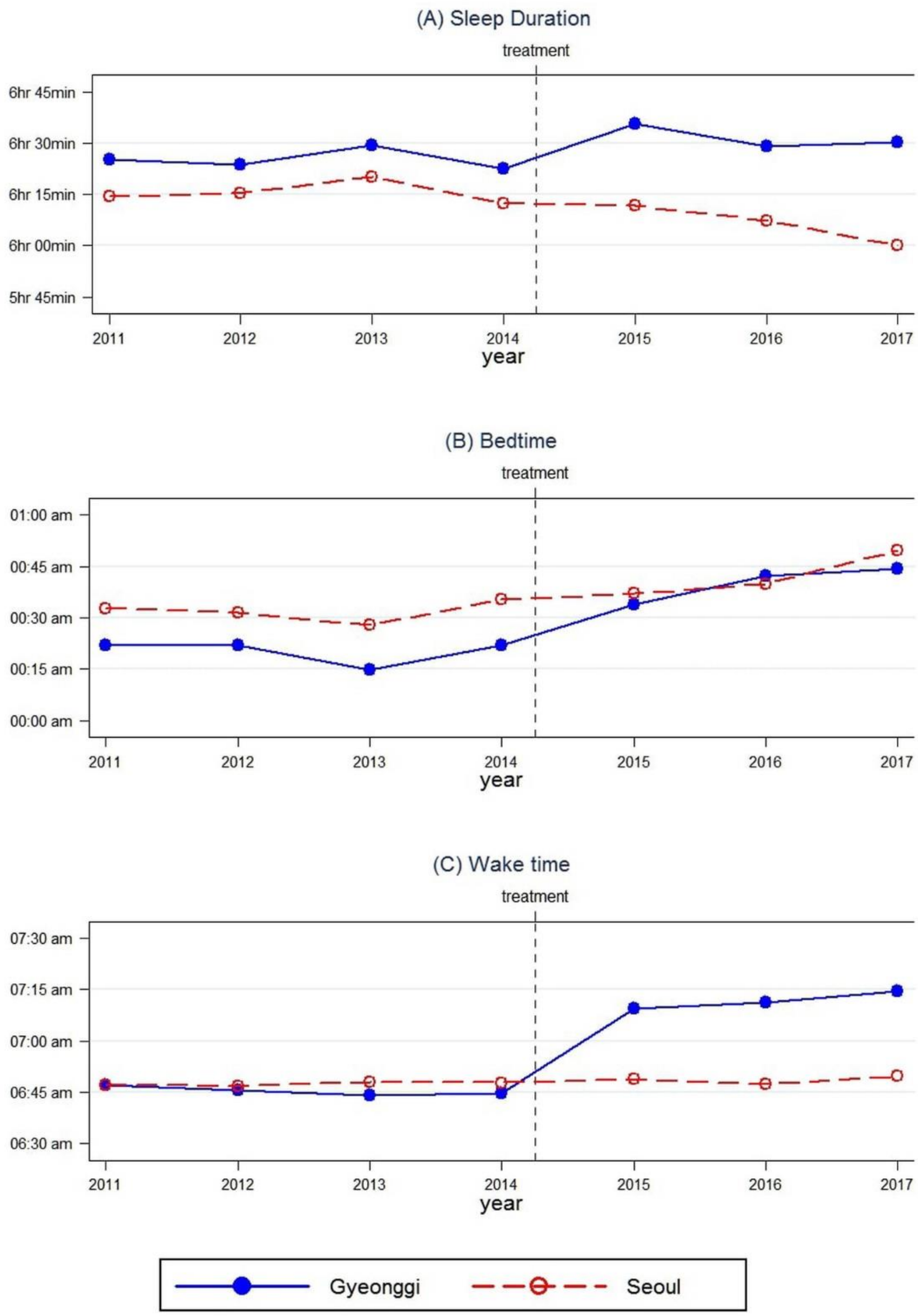


Figure 2. Heterogeneous effects of delaying school starting time on adolescents' sleep pattern and time use

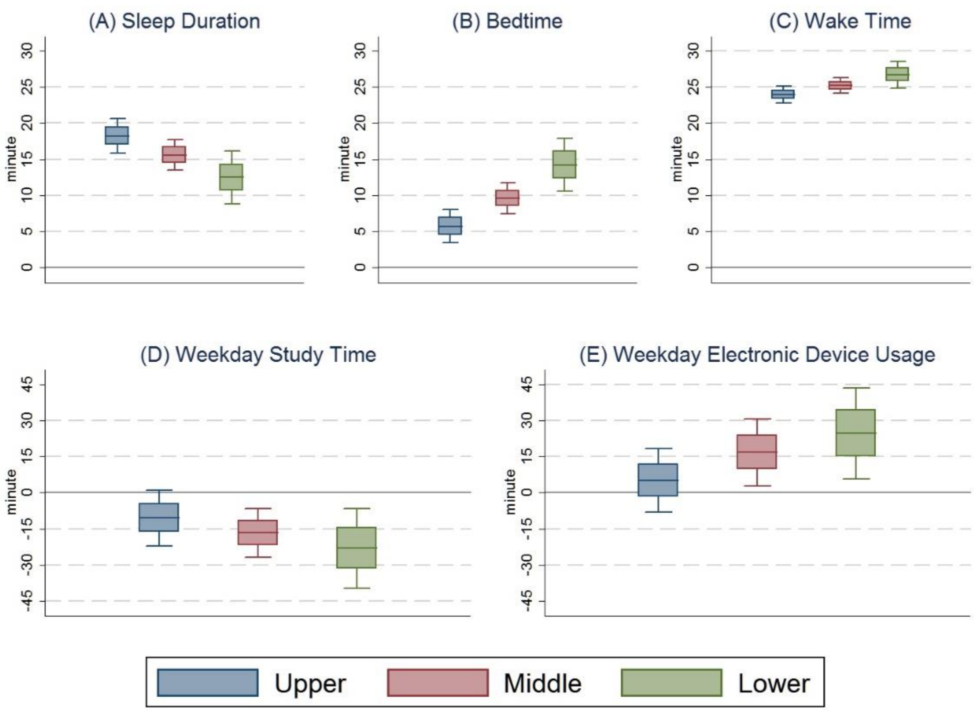
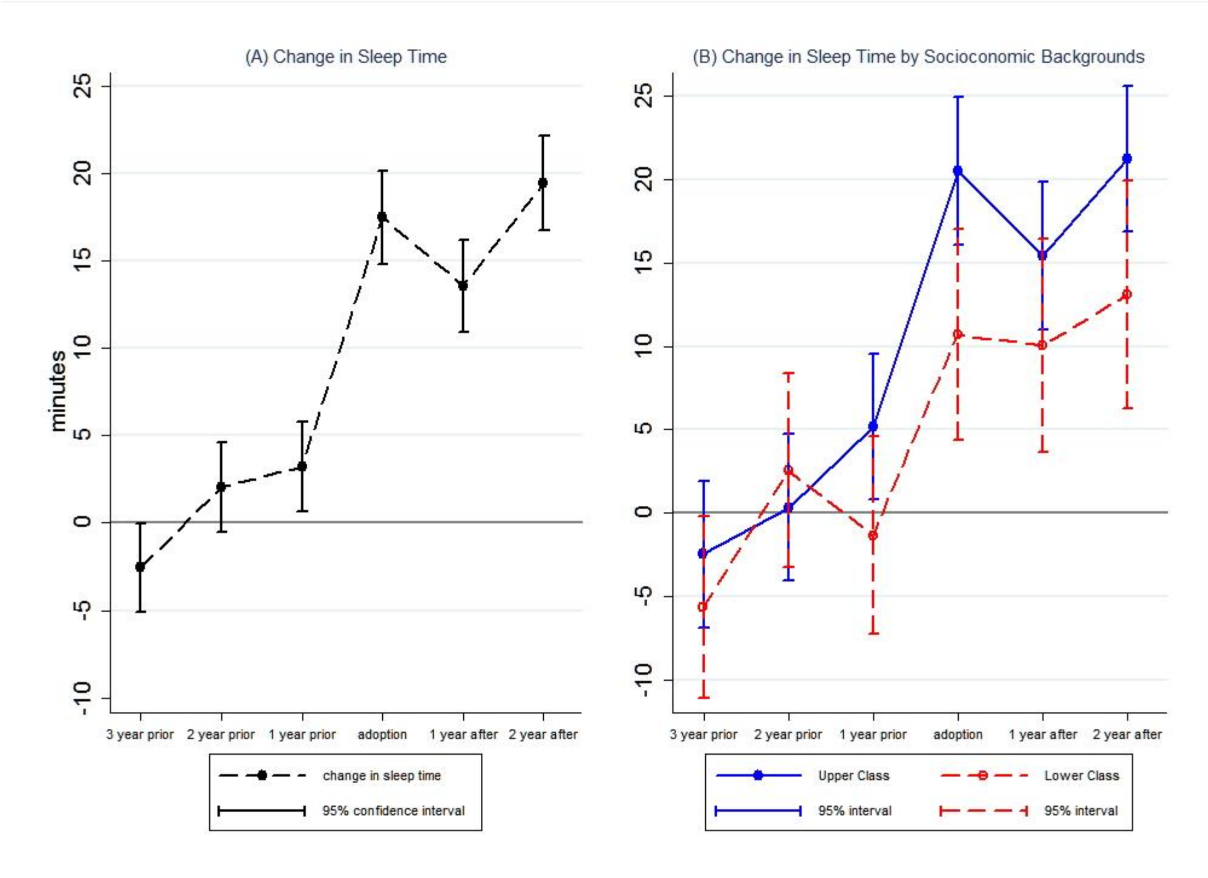


Figure 3. Estimated effect of te policy for years before, during, and after adoption



Appendix Table 1. Change in physical and mental health by the socioeconomic background of students

	Upper Class				Middle Class				Lower Class			
	Height (cm)	Sleep Satisfaction	Subjective Health Status	Stress Level	Height (cm)	Sleep Satisfaction	Subjective Health Status	Stress Level	Height (cm)	Sleep Satisfaction	Subjective Health Status	Stress Level
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Gyeonggi	-0.410***	-0.055***	-0.045***	0.008	-0.415***	-0.056***	-0.048***	-0.018**	-0.295***	-0.049***	-0.041***	0.023
(Treatment Group)	(0.076)	(0.013)	(0.010)	(0.011)	(0.062)	(0.011)	(0.008)	(0.009)	(0.092)	(0.016)	(0.013)	(0.014)
Post	0.221*	0.007	0.011	-0.009	0.155	0.035*	0.031**	-0.038**	-0.136	0.083***	0.060**	-0.034
(After Policy)	(0.117)	(0.021)	(0.015)	(0.018)	(0.107)	(0.018)	(0.014)	(0.016)	(0.176)	(0.031)	(0.026)	(0.026)
Gyeonggi X Post	0.204*	0.100***	0.032**	-0.050***	0.220**	0.084***	0.022*	-0.004	0.019	0.059**	0.003	-0.021
	(0.112)	(0.020)	(0.014)	(0.017)	(0.099)	(0.017)	(0.013)	(0.014)	(0.163)	(0.028)	(0.024)	(0.024)
Female	-9.453***	-0.337***	-0.254***	0.303***	-10.092***	-0.330***	-0.260***	0.329***	-10.702***	-0.316***	-0.281***	0.336***
	(0.055)	(0.010)	(0.007)	(0.008)	(0.049)	(0.008)	(0.006)	(0.007)	(0.077)	(0.013)	(0.011)	(0.011)
Age	1.918***	-0.060***	-0.044***	0.062***	1.514***	-0.033***	-0.027***	0.036***	1.197***	-0.018**	-0.024***	0.019***
	(0.030)	(0.005)	(0.004)	(0.004)	(0.026)	(0.004)	(0.003)	(0.004)	(0.042)	(0.007)	(0.006)	(0.006)
Vocational High	-0.905***	-0.272***	-0.079***	0.009	0.000	-0.240***	-0.049***	-0.022	0.601***	-0.238***	-0.060**	-0.044*
School	(0.158)	(0.029)	(0.022)	(0.025)	(0.109)	(0.020)	(0.015)	(0.017)	(0.154)	(0.028)	(0.023)	(0.024)
General High	-0.511***	-0.252***	-0.061***	0.013	0.259***	-0.258***	-0.036***	0.018	1.032***	-0.219***	-0.028	-0.029
School	(0.099)	(0.018)	(0.013)	(0.016)	(0.084)	(0.015)	(0.012)	(0.013)	(0.139)	(0.025)	(0.021)	(0.022)
Household Characteristics	O	O	O	O	O	O	O	O	O	O	O	O
Year FE	O	O	O	O	O	O	O	O	O	O	O	O
Constant	166.49***	3.32***	4.30***	2.87***	166.98***	3.18***	4.10***	2.99***	167.68***	2.93***	3.93***	3.31***
Sample	50,106	50,932	50,932	50,932	64,014	65,164	65,164	65,164	25,536	26,291	26,291	26,291
R-squared	0.455	0.067	0.046	0.042	0.477	0.058	0.034	0.042	0.488	0.042	0.030	0.035

Notes: Robust standard errors are presented in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Appendix Table 2. The effect of delaying school start time on adolescents' sleep pattern using an alternative control group

	Sleep Time	Sleep Time		
		Upper	Middle	Lower
	(1)	(2)	(3)	(4)
Gyeonggi	0.393	-1.083	0.713	1.843
(Treatment Group)	(0.550)	(0.990)	(0.784)	(1.236)
Post	2.845***	2.037**	2.804***	4.461***
(After Policy)	(0.591)	(0.991)	(0.848)	(1.494)
Gyeonggi X Post	10.624***	11.201***	10.714***	9.631***
	(0.618)	(1.034)	(0.889)	(1.567)
Female	-26.928***	-28.627***	-26.821***	-23.875***
	(0.294)	(0.502)	(0.421)	(0.709)
Age	-12.077***	-12.866***	-12.008***	-10.666***
	(0.155)	(0.263)	(0.222)	(0.377)
Vocational High School	-19.019***	-13.472***	-19.240***	-22.807***
	(0.721)	(1.484)	(1.034)	(1.502)
General High School	-51.345***	-51.215***	-51.461***	-51.103***
	(0.554)	(0.944)	(0.790)	(1.360)
Household Characteristics	O	O	O	O
Year FE	O	O	O	O
Constant	449.482***	449.529***	449.392***	440.524***
Sample	201,077	68,713	95,671	36,693
R-squared	0.331	0.353	0.334	0.267

Notes: Robust standard errors are presented in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Appendix Table 3. Change in the time spent on private lectures by the socioeconomic background

	Time Spent on Private Lectures		
	Upper	Middle	Lower
	(1)	(2)	(3)
Gyeonggi	-19.770	-23.714	-10.577
(Treatment Group)	(25.104)	(16.514)	(31.140)
Post	-7.531	-3.174	-17.262
(After Policy)	(22.721)	(15.676)	(25.649)
Gyeonggi X Post	21.557	24.823	3.827
	(29.151)	(19.608)	(34.135)
Constant	135.00***	99.21***	67.31***
Sample	190	318	174
R-squared	0.004	0.014	0.009

Notes: Robust standard errors are presented in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Appendix Figure 1. Change in time-use patterns of adolescents