No need to worry: The short lived nature of relative age effects among Korean elementary school children

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Abstract

Although students generally start their elementary school education at a given legal age, there are considerable age differences between classmates. Within a class of timely enrolled children, these age gaps can be up to eleven months – a significant amount of time especially for the youngest cohorts. Our study contributes to the debate in educational economics and related social science fields to what extent these relative age gaps influence academic outcomes. We examine the existence, magnitude, and duration of relative age effects in South Korea for various school subjects. Our results show that relative age effects exist among Korean elementary school students and that these effects are more pronounced in science-related subjects than in language subjects. We also find that female students tend to be less affected by relative age effects than their male peers. Importantly, however, we show that relative age effects generally decline after fourth grade and disappear completely by the start of secondary education.

Keywords: Seasonal birth, Academic outcomes, Relative age effect

JEL Classification: I20, I21, J13

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1 Introduction

An extensive literature shows that relative age gaps among young elementary school students significantly affect academic as well as social outcomes (see, for example, Puhani & Weber (2006) for Germany; Kawaguchi (2011) for Japan; Robertson (2011) for Chicago; Peña (2020) for Mexico and Zhang et al. (2017) for China). The study by Sprietsma (2008) covers 16 countries from the PISA 2003 database. In addition, there are studies that examine the effects later in life, for example on employment, educational attainment and hourly wages in adulthood (Dobkin & Ferreira, 2010; Black et al., 2011; Grenet, 2011; Fredriksson & Öckert, 2013; Nam, 2014). The aforementioned studies have produced mixed results. Dobkin & Ferreira (2010) and Nam (2014) find that the relative age effect on educational attainment at the time of entering adulthood is very small or non-existent. In contrast, Black et al. (2011), Grenet (2011), and Fredriksson & Öckert (2013) find that relative age effects last until adulthood. Black et al. (2011) state that relative age affects earnings up to 11.6% for females and 9.9% for males at the early stage of careers but the effect disappears by the age of 30. Grenet (2011) shows relatively older tend to be more academically qualified and more likely to be employed than the relatively young.

The relevance of relative age effects at the start of schooling is easy to understand when one considers that a given age difference of, say, six months represents a large proportion of the lifetime and experience of that age group. Long-lasting relative age effects that extend into adulthood, however, are more difficult to understand. One possible mechanism may be that students who are relatively older than their peers tend to perform better in the early years of school and that this initial academic success reinforces a virtuous cycle that leads to a lasting advantage.

In South Korea, the impact of the relative age effect on academic performance has long been a concern for parents whose children were born in the later months of their academic cohort (Hong et al., 2010; Lee, 2011; Yun, 2017). Our main objective is to scientifically investigate relative age effects on Korean elementary school students using data from the KCYPS dataset. We are not only interested in the mere existence of relative age effects, but also in their magnitude and duration, specific to each school subject. In doing so, we hope to provide important information for policy makers and current and future parents. Our results show that relative age effects exist among young elementary school students in most academic subjects. In the scientific subjects (mathematics, natural sciences and social sciences) these effects are generally more pronounced than in the language subjects (Korean and English). Remarkably, the relative age effect becomes insignificant after fourth grade in all but one subject; only in social sciences does it retain its influence until sixth grade.

A key contribution of our study is the subject-specific analysis of relative age effects (i.e., mathematics, social science, natural science, Korean, and English). Since such analyses are rare in the related literature (with a few exceptions such as Kawaguchi, 2011; Robertson, 2011; and Nam, 2014), our study provides valuable insights into how relative age effects vary across school subjects. Importantly, our research provides evidence of a temporary nature of relative age effects in Korea. In general, relative age effects persist until fourth grade and decline thereafter, except in the social sciences, where they persist until the end of elementary school. This temporary nature is an important finding and paves the way for future investigations of the long-term effects of age on educational outcomes.

2 Data

Our study uses the Korean Children and Youth Panel Survey (KCYPS)[1] of the National Youth Policy Institute (NYPI). Based on the size and population characteristics of seventeen first-tier administrative divisions, the NYPI chose the schools to be surveyed using proportional stratified sampling. After that, the NYPI randomly chose students based on the information on class size. The panel structure of the dataset allows us to follow the same cohort of students from their entry into first grade in 2010 (first wave of the KCYPS) until 2016, when they entered seventh grade and thus middle school (seventh wave of the KCYPS). A total of 2,342 students were surveyed for the first wave, while the NYPI reported a total of 2,002 students for the seventh and final wave. The majority, but not all, of the first-

[1] This research uses anonymized data collected by National Youth Policy Institute of South Korea which is publicly available for research purposes. The Korean privacy law and the Helsinki Declaration on human subjects testing are hence fully respected and our research is exempted from approval requirements by local ethical committees.

graders surveyed were children born in 2003. About three out of a hundred students was born either in 2002 (17 students) or in 2004 (58 students, of which 53 were born in January or February 2004). However, most children born in 2002 and 2004 are not included in the dataset, as it only covers those who started school in 2010, but not the two cohorts before and after. Table 1 shows the number of observations by year and month of birth after pooling the data from students in grades 2 to 6.

Table 1. Birth Year and Month

	Month												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
2002		*4*			*5*				*19*	*15*	*9*	*22*	74
2003	799	916	920	1,019	785	783	808	862	936	885	876	791	10,380
2004	171	83	*10*	*5*			*5*			*5*	*5*		284

Note: The table shows the years and months of birth after pooling the data of students in grades 2 to 6. Our main explanatory variable relative age is calculated based on the birth year and month. Table entries in italics refer to students born in 2002 or between March and December 2004. These observations are excluded from our regression analysis. However, some robustness tests also include students born in January and February 2004.

Our main explanatory variable relative age is calculated based on birth year and month. Table 1 shows the distribution of birth years and months in the first wave of the KCYPS dataset. Students born in 2002 and 2004 are excluded from the main regressions because they represent students who postponed or advanced their entry into school for personal or health reasons. Moreover, due to a policy change[2], students born in January and February 2003 are excluded from our main regressions because they had the opportunity to choose which academic cohort to join. If they chose to join the regular cohort, they may have been better prepared for elementary school than their classmates because they effectively had one more year, which may lead to endogeneity issues in the estimation of relative age coefficients. In our empirical analysis we measure relative age as follows: Students born in December 2003 are assigned the number 1 as their relative age. Those born

[2] Until 2007, Korean students born between March 1st and the end of February the following year were grouped into the same academic year. In 2007, the Korean government modified the birth months of academic cohorts so that they now coincide with calendar years. During the transitional period, parents of students born in January and February of 2003 could apply for an early school entry or choose to join the regular cohort. A similar choice has been and still is in place for students with special needs. Parents of students with physical and mental disabilities who wish to study at a regular school can register their children with a one year delay.

in November 2003 are assigned the number 2 and so on down to those born in March 2003, who are assigned the number 10. This follows the procedure in Nam (2014) where students' age by month is the main control variable. Because our study uses only 2003 born students, our relative age variable captures the same effect. The following three tables present the summary statistics for the outcome and control variables after combining data from classes 2 to 6. Note that only those observations that are used in at least one of our regressions are included. More specifically, the table entries are based on observations of children born between January 2003 and February 2004.

The KCYPS dataset includes information on student performance in mathematics, social sciences, natural science, Korean, and English, measured by categorical outcome variables ranging from very good (5) to very poor (1). Since English education begins from grade three, learning outcomes are only reported from the third grade onwards. For all other subjects observations start from grade two. Table 2 summarizes the learning results in mathematics (Math), social science (SoSci)[3], natural science (NaSci), Korean and English after pooling from the second to the sixth grade.

Table 2. Descriptive Statistics on the Outcome Variables

Variable	Mean (SD)	Percentage	5	4	3	2	1	Observations
Math	3.7928 (0.9769)	75.86 (19.54)	2,887	3,795	2,989	788	175	10,634
SoSci	3.7297 (0.9422)	74.59 (18.84)	2,451	3,934	3,310	796	141	10,632
NaSci	3.8804 (0.8722)	77.61 (17.44)	2,817	4,320	2,966	456	70	10,629
Korean	3.9444 (0.8134)	78.89 (16.27)	2,809	4,791	2,731	240	63	10,634
English	3.9062 (1.0502)	78.12 (21.00)	3,040	2,579	1,918	676	186	8,399

Note: Descriptive statistics after pooling data from students in grades 2 to 6 (for English data from students in grades 3 to 6 was pooled). 5 denotes very good; 4, good; 3, average; 2, poor; 1, very poor. Standard deviations are in parentheses.

The KCYPS dataset also has detailed family background information such as mother's education, father's education, and annual family income in Korean Won (KRW). The descriptive statistics for family background variables are shown in Table 3.

[3] We used the "Ethics" course outcome for 2nd grade students as they officially learn "Social Science" course from the 3rd grade.

Table 3. Descriptive Statistics on Family Background

Variable	Observations	Mean (SD)	Median	Definition
MoEdc	10,131	2.8891 (0.9373)	3	Mother's Education
FaEdc	10,049	3.0912 (1.0266)	3	Father's Education
Income	10,236	4826.337 (2533.389)	4500	Annual Household Income in 10,000 KRW

Note: Descriptive statistics after pooling data from students in grades 2 to 6. Parents' education is categorized as follows: 1 = Middle School or Less; 2 = High School; 3 = Community College; 4 = University; 5 = Graduate School. Standard deviations are in parentheses.

The dataset also offers information on personal characteristics such as tutoring time, assignment time, health and sex. Table 4 summarizes the descriptive statistics on these personal characteristics. Note that private tutoring time exceeds the time for take-home assignments by a factor of three to four. This is a common finding in Korea. Elementary school students study on average 123 minutes daily after attending school: the largest portion comes from private tutoring (Statistics Korea, 2014).

Table 4. Descriptive Statistics on Personal Characteristics

Variable	Observations	Mean (SD)	Median	Definition
TutorT	10,559	123.0314 (76.4921)	120	Average Tutoring Time per Day (in minutes)
AssignT	10,546	40.4754 (28.7680)	30	Average Assignment Time per Day (in minutes)
Health	10,597	1.6723 (0.5411)	2	Personal Health
Sex	10,634	1.4860 (0.4998)	1	Sex

Note: Descriptive statistics after pooling data from students in grades 2 to 6. Health is categorized as follows: 1 = very healthy; 2 = healthy; 3 = unhealthy; 4 = very unhealthy. Sex is categorized as follows: 1 = male; 2 = female. Standard deviations are in parentheses.

3 Empirical Strategy

Most empirical studies that test relative age or seasonal effects use ordinary least squares, instrumental variable, or regression discontinuity methods. For instance, Lawlor et al. (2006), Dhuey & Lipscomb (2008), Kawaguchi (2011), Sprietsma (2008), and Robertson (2011) use ordinary least squares estimations to measure the relative age effect; Datar (2006), Puhani & Weber (2006), Smith (2010), and Nam (2014) use instrumental variable regressions. Studies that have used the regression discontinuity design include Dobkin & Ferreira (2010), Fredriksson & Öckert (2013), Crawford et al. (2014). Instrumental variable and regression discontinuity methods are typically used with cross sectional data where the observed age in months and the relative age from zero to eleven are not in a linear relationship. However, the data that this study uses is a yearly panel from first graders in 2010. In other words, the observed age in months and the relative age are linear dependent and hence give the same variation. For example, students born in March are nine months older than students born in December. Then the variation captured by the observed age in months and the relative age cannot be different: for both variables, students born in March are nine months older than those born in December. Thus, we mainly use pooled ordinary least squares after controlling the two fixed effects (grade and school district fixed effects), ordinary least squares for grade-specific analyses, and ordered probit models instead of an instrumental variable or a regression discontinuity approach.

In the first step, we combine data from second through sixth grades and use the pooled ordinary least squares approach to examine whether relative age effects exist. The performance measures Math, NaSci, SoSci, Korean, and English are our outcome variables. Control variables include TutorT, Health, AssignT, MoEdc, FaEdc, Income, Sex, and school districts. It is well-known that family background characteristics such as parental education levels and household income have a major impact on students' academic performance (Davis-Kean, 2005; Duncan et al., 2011; Dahl & Lochner, 2012). Therefore, we control for mother's and father's education as well as household income in our regressions. Moreover, private tutoring is very wide-spread among Korean students (see also Table 3). According to Statistics Korea (2018), more than 80 percent of elementary school students receive additional private tutoring. It is therefore essential to control for private tutoring. Health is also included as a control variable since a student's physical condition can influence her or his academic performance. The pooled ordinary least squares regression equation is as follows:

$$Outcome_{i,s,t} = \beta_0 + \beta_1 RelatAge_{i,s,t} + \theta^T X_{i,s,t} + \pi^T Z_{i,s,t} + \mu_t + \delta_s + \varepsilon_{i,s,t} \quad (1)$$

where ε is assumed to have the usual ideal properties. Outcome represents the academic performance of student i in a subject (Math, SoSci, NaSci, Korean, and English; i.e. we run a total of five regressions). RelatAge is the variable of interest and varies between one (for students born in December) and ten (for those born in March). X represents family background variables such as FaEdc, MoEdc, Income, and also the school district. Z is the vector for personal characteristics such as TutorT, AssignT, Health, and Sex. μ denotes year (grade) fixed effects and δ denotes school district fixed effects.

In the next step, we run separate ordinary least squares regressions using the same model without pooling the data by grades such that we obtain grade-specific results. This way we hope to learn more about the duration of relative age effects:

$$Outcome_{i,s} = \beta_0 + \beta_1 RelatAge_{i,s,} + \theta^T X_{i,s,} + \pi^T Z_{i,s,} + \delta_s + \varepsilon_{i,s} \qquad (2)$$

In total 24 ordinary least squares regressions are performed (second to sixth grade times five subjects minus one because English education starts with the third grade).

Furthermore, we investigate whether male or female students are more affected by relative age effects and, last but not least, we conduct robustness checks. To answer the question of which sex is more affected by relative age effects, we simply repeat our regression analyses separately for the two sexes. To check the robustness of our results, we first use ordered probit regressions, taking advantage of the fact that the dependent variable is categorical and takes values from 1 to 5. Another set of robustness checks is conducted using the outcome variables from the seventh wave of the KCYPS, which corresponds to the period when the student cohort moved into seventh grade and thus into middle school. Finally, we address at least partially the problem of panel attrition. To this end, we use longitudinal and cross-sectional weights to adjust and perform weighted least squares regressions.

4 Results

Table 5 presents the results of our pooled ordinary least squares regression analysis. Each column refers to a separate regression for the respective outcome variable.

Table 5. Relative Age Effects by Subject (Pooled Ordinary Least Squares)

		Math	SoSci	NaSci	Korean	English
RelatAge		0.01758***	0.01616***	0.00981**	0.01155***	0.00470
		(0.00545)	(0.00488)	(0.00434)	(0.00423)	(0.00653)
P>|t|		0.001	0.001	0.024	0.006	0.472
TutorT		0.00152***	0.00054***	0.00050***	0.00041***	0.00162***
		(0.00017)	(0.00015)	(0.00014)	(0.00014)	(0.00020)
P>|t|		0.000	0.000	0.001	0.004	0.000
Health		-0.17150***	-0.17054***	-0.17515***	-0.16186***	-0.22264***
		(0.02364)	(0.02212)	(0.01973)	(0.01893)	(0.02743)
P>|t|		0.000	0.000	0.000	0.000	0.000
AssignT		-0.00025	0.00034	0.00033	0.00025	0.00008
		(0.00039)	(0.00038)	(0.00036)	(0.00033)	(0.00044)
P>|t|		0.522	0.379	0.358	0.451	0.861
MoEdc						
	2	0.65585***	0.32127***	0.18989	0.28081***	0.43023*
		(0.13393)	(0.12131)	(0.15456)	(0.07752)	(0.24728)
P>|t|		0.000	0.008	0.219	0.000	0.082
	3	0.70313***	0.40783***	0.23776	0.37693***	0.61821**
		(0.13716)	(0.12433)	(0.15654)	(0.08127)	(0.25292)
P>|t|		0.000	0.001	0.129	0.000	0.015
	4	0.74040***	0.49253***	0.29469*	0.37954***	0.58888**
		(0.14010)	(0.12576)	(0.15787)	(0.08365)	(0.25476)
P>|t|		0.000	0.000	0.062	0.000	0.021
	5	0.80326***	0.56714***	0.41788**	0.48032***	0.70910***
		(0.15951)	(0.14612)	(0.17459)	(0.10972)	(0.26823)
P>|t|		0.000	0.000	0.017	0.000	0.008
FaEdc						
	2	0.11414	-0.10698	0.07193	0.03339	0.21320
		(0.16322)	(0.09652)	(0.11378)	(0.09844)	(0.24202)
P>|t|		0.484	0.268	0.527	0.734	0.378
	3	0.15949	-0.06008	0.11476	0.09235	0.29188
		(0.16582)	(0.10179)	(0.11653)	(0.10252)	(0.24638)
P>|t|		0.336	0.555	0.325	0.368	0.236
	4	0.21460	0.01308	0.15958	0.11047	0.41285*
		(0.16603)	(0.10239)	(0.11772)	(0.10298)	(0.24542)
P>|t|		0.196	0.898	0.175	0.284	0.093
	5	0.28200	0.10116	0.25638**	0.20295*	0.46412*
		(0.17852)	(0.11380)	(0.12816)	(0.11393)	(0.25353)
P>|t|		0.114	0.374	0.046	0.075	0.067
Income		0.00001	0.00001	0.00000	0.00001	0.00003***
		(0.00001)	(0.00001)	(0.00001)	(0.00001)	(0.00001)
P>|t|		0.111	0.241	0.775	0.396	0.000
Sex		-0.23738***	-0.00590	-0.05409**	0.20304***	0.13295***
		(0.03131)	(0.02764)	(0.02516)	(0.02484)	(0.03730)
P>|t|		0.000	0.831	0.032	0.000	0.000
Fixed Effects		Grade and school district fixed effects controlled				
Observations		7812	7,810	7,807	7,812	6,139
Clusters (ID)		1769	1,769	1,769	1,769	1,681

Note: *,**,*** denote statistical significance at the 10%, 5% and 1% levels, respectively. Standard errors are clustered at the individual level and reported in parentheses. Appendix Table A1 presents the Relative Age Effects when clustering at the school and school district levels.

As can be seen, there are relative age effects with high statistical significance in mathematics, social sciences, natural sciences, and Korean. This means that children born in earlier months tend to perform better in these subjects in elementary school. In particular, the relative age effect is more pronounced in science subjects such as mathematics and social sciences than in Korean. Interestingly, the effect is statistically insignificant in English. Note that we obtain statistically comparable results when we change the clustering level from the individual to the school or school district level (see Appendix Table A1).

Having demonstrated the existence of relative age effects, measuring their duration is crucial. Therefore, we ran additional regressions separately for each grade level, i.e., without pooling the data (see equation (2)). Table 6 shows the estimated coefficients of the respective relative age effects as well as the corresponding test statistics by grade level and school subject.

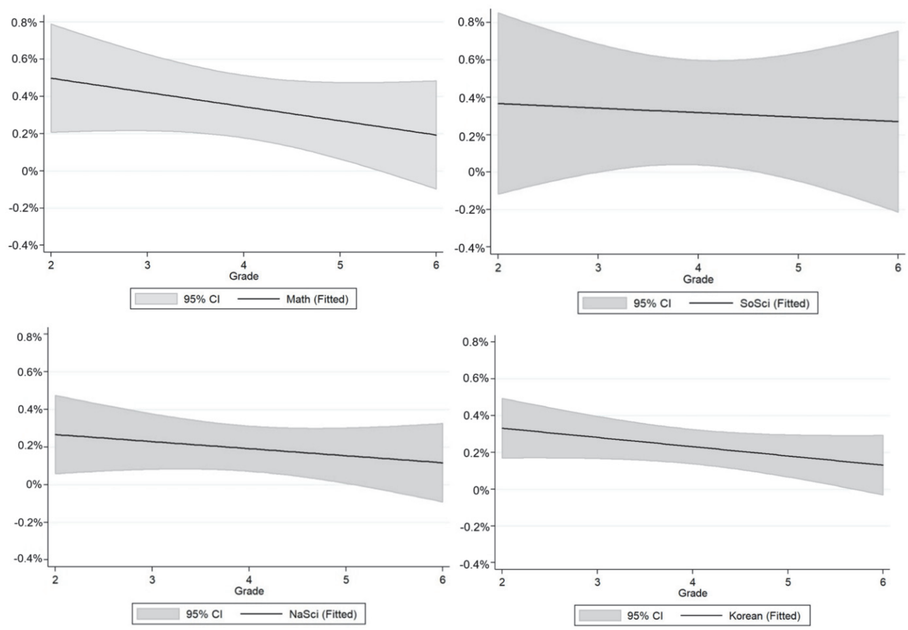
Table 6. Relative Age Effects by Grade and Subject (Ordinary Least Squares)

Grade	Math	SoSci	NaSci	Korean	English
2	0.02329***	0.01098	0.00973	0.01350*	
	(0.00841)	(0.00747)	(0.00725)	(0.00754)	
P>|t|	0.006	0.142	0.180	0.074	
Observations	1,668	1,668	1,668	1,668	
3	0.01972**	0.02644***	0.01291*	0.01624**	0.01673*
	(0.00851)	(0.00840)	(0.00776)	(0.00734)	(0.00882)
P>|t|	0.021	0.002	0.096	0.027	0.058
Observations	1,568	1,568	1,566	1,568	1,568
4	0.02542***	0.02190***	0.01523**	0.01533**	0.00300
	(0.00786)	(0.00789)	(0.00753)	(0.00689)	(0.00903)
P>|t|	0.001	0.006	0.043	0.026	0.740
Observations	1,523	1,522	1,521	1,523	1,520
5	0.00769	0.00439	0.00658	0.00746	-0.00278
	(0.00848)	(0.00861)	(0.00746)	(0.00688)	(0.00913)
P>|t|	0.365	0.610	0.378	0.279	0.761
Observations	1,528	1,527	1,528	1,528	1,526
6	0.01026	0.01599*	0.00351	0.00531	0.00441
	(0.00865)	(0.00819)	(0.00765)	(0.00684)	(0.00902)
P>|t|	0.236	0.051	0.646	0.438	0.625
Observations	1,525	1,525	1,524	1,525	1,525

Note: The same control variables as in the pooled ordinary least squares regression are used. *,**,*** denote statistical significance at the 10%, 5% and 1% levels, respectively. Standard errors are clustered at the individual level and reported in parentheses. Appendix Table A1 presents the Relative Age Effects when clustering at the school and school district levels.

The table contains the results of a total of 24 separate least squares regressions. As can be seen, the relative age effect disappears from 5th grade onwards for mathematics, natural science, Korean, and English. For students in 5th and 6th grades, the relative age effect is not only statistically insignificant but also of small magnitude. These patterns in the results remain robust when considering different levels of clustering for the standard errors (see Table A1 in the Appendix). In summary, we find that the relative age effect becomes smaller as students get older. Figure 1 illustrates these findings graphically. It shows the fitted values of the relative age effects for all subjects except English. All four graphs demonstrate both the downward trend and the limited duration of the respective relative age effect. Although a causal interpretation of estimation results is not always justified, the fact that there is no correlation between relative age and educational outcomes after the 5th grade suggests that the relative age effect disappears as students get older. Vanishingly small estimated coefficients, which are also not statistically significant, are therefore sufficient to show that there is no causal relationship between academic performance and relative age.

Figure 1. Declining Relative Age Effect



Next, we present the results of our sex-specific analyses. To find out which sex is more affected by relative age effects, we ran the pooled ordinary least squares and grade-specific regressions separately for male and female students (see Tables A2 and A3 in the appendix). Here, too, we find that only minimal relative age effects occur for both male and female students after the fourth grade. Until then, however, male students are more affected by the relative age effect than their female classmates.

For our first robustness check, we use seventh grade data from the same cohort of students. As students entered middle school, the KCYPS dataset transitioned to more precisely measured academic outcome variables based on school test scores. These variables range from 1 to 8 where '1' is assigned to students who scored lower than 65 percent and '8' is assigned to students who scored higher than 96 percent. Moreover, just like the elementary schools, all Korean middle schools teach the same academic curriculum set by the national government. This ensures higher comparability and accuracy in measuring academic outcomes, so that we can additionally support our estimates by using this improved data from the 7th grade. As shown in Table 7 below, the estimated coefficients regarding the relative age effect remain statistically insignificant in grade 7.

Table 7. Robustness Check: Using Seventh Grade Outcomes

Grade 7	Math	SoSci	NaSci	Korean	English
Grade 7	-0.0011	0.02332	0.02329	0.01590	0.0035
	(0.02230)	(0.02047)	(0.02075)	(0.01898)	(0.02108)
P>|t|	0.961	0.255	0.262	0.402	0.868
Observations	1,470	1,447	1,469	1,469	1,470

Note: The same control variables as in the pooled ordinary least squares regression (cf. Table 5) are used. *,**,*** denote statistical significance at the 10%, 5% and 1% levels, respectively. Standard errors are clustered at the individual level and reported in parentheses.

For our second robustness check, we continue to use the seventh grade data, but this time we also include observations from students born in January and February 2003 and 2004. As shown in Table 8 below, the inclusion of students who chose to enter school early does not result in any significant changes compared to the previous table, with the exception of social sciences.

Table 8. Robustness Check: Relative Age Effects in Seventh Grade (incl. January and February Borns)

Grade 7	Math	SoSci	NaSci	Korean	English
RelatYoung	0.21361	-0.75844**	-0.29551	-0.37548	-0.36065
	(0.40242)	(0.36900)	(0.37254)	(0.34114)	(0.38207)
P>|t|	0.596	0.040	0.428	0.271	0.346
Observations	1,778	1,751	1,777	1,776	1,778

Note: In these regressions, we replace the relative age variable with a binary variable (RelatYoung) that takes the value one if a student was enrolled early (i.e., children born in January and February 2004). Note that we include all students born between January 2003 and February 2004, i.e., we consider students born within a 14-month period. Otherwise, the same control variables as in the pooled ordinary least squares regression (cf. Table 5) are used. *,**,*** denote statistical significance at the 10%, 5% and 1% levels, respectively. Standard errors are clustered at the individual level and reported in parentheses.

For our third robustness check, we use the ordered probit regression approach. Since our dependent variables – academic outcomes – are ordinal in nature, the ordered probit regression model is very well suited to the present data structure. In estimating this model, we used the same control variables as in our main regressions. Table 9 shows the estimated coefficients of the relative age effects from a total of 29 ordered probit regressions, separately for grade level and school subject.

Table 9. Robustness Check: Relative Age Effects by Grade and Subject (Ordered Probit)

	Math	SoSci	NaSci	Korean	English
Pooled	0.02078***	0.01913***	0.01294**	0.01568***	0.00557
	(0.00637)	(0.00583)	(0.00562)	(0.00590)	(0.00722)
P>|t|	0.001	0.001	0.021	0.008	0.441
Clusters (ID)	1,769	1,769	1,769	1,769	1,681
Observations	7,812	7,810	7,807	7,812	6,139
Grade 2	0.02738***	0.01548	0.01254	0.01763*	
	(0.00949)	(0.00958)	(0.00961)	(0.00947)	
P>|t|	0.004	0.106	0.192	0.063	
Observations	1,668	1,668	1,668	1,668	
Grade 3	0.02362**	0.03090***	0.01708*	0.02107**	0.01975**
	(0.00974)	(0.00965)	(0.00988)	(0.00987)	(0.00996)
P>|t|	0.015	0.001	0.084	0.033	0.047
Observations	1,568	1,568	1,566	1,568	1,568
Grade 4	0.03404***	0.02913***	0.02185**	0.02313**	0.00535
	(0.01006)	(0.00998)	(0.01008)	(0.01024)	(0.01018)
P>|t|	0.001	0.004	0.030	0.024	0.599
Observations	1,523	1,522	1,521	1,523	1,520
Grade 5	0.00921	0.00395	0.00923	0.01049	-0.00468

	Math	SoSci	NaSci	Korean	English
	(0.00995)	(0.00991)	(0.01009)	(0.01028)	(0.01012)
P>|t|	0.354	0.690	0.360	0.308	0.644
Observations	1,528	1,527	1,528	1,528	1,526
Grade 6	0.01116	0.01951**	0.00491	0.00802	0.00518
	(0.01008)	(0.01004)	(0.01011)	(0.01035)	(0.01017)
P>|t|	0.268	0.052	0.627	0.438	0.610
Observations	1,525	1,525	1,524	1,525	1,525

Note: The same control variables as in the pooled ordinary least squares regression (cf. Table 5) are used. *,**,*** denote statistical significance at the 10%, 5% and 1% levels, respectively. Standard errors are clustered at the individual level and reported in parentheses. Appendix Table A4 presents the Relative Age Effects when clustering at the school and school district levels.

As can be seen, the ordered probit regression results are consistent with the results from our ordinary least squares regressions (cf. Tables 5 and 6). The relative age effect is statistically significant in mathematics, social science, and Korean up to fourth grade, and the duration of the effect in social science is longer than in other subjects. Moreover, the magnitude of the relative age effect is comparatively smaller among fifth and sixth grade students.

For our last robustness check, we conduct weighted least squares regressions to account for increasing panel attrition over the course of the survey. To be precise, we use the longitudinal and cross-sectional weights provided by the KCYPS. The results of these weighted least squares regressions are presented in Tables A5 and A6 in the appendix. As can be seen from the tables, the magnitude of the estimated coefficients and their statistical significance remain generally consistent despite the weighting of the observations. This should mitigate any concerns about the possible non-randomness of the panel attrition.

5 Discussion

Although relative age effects tend to decrease from the 5th grade onwards, our regression results suggest that they undeniably play an important role in elementary school. Various influencing factors and mechanisms may shape, strengthen and/or prolong relative age effects. Essentially, the phenomenon may be due to a combination of cultural influences, curriculum structures, societal expectations and individual cognitive development. The interaction of these factors ultimately leads to comparatively older students achieving better results in the first years of study, although the extent of this effect depends on the respective school subject.

In the social sciences, we generally observe the strongest relative age effect. This is likely due to older students' greater empathy skills, which are required to understand and analyze the topics covered in the subject, such as social structures, history and political concepts (Crawford et al., 2010). In a nutshell, older students are more familiar with important social events, commemorations, and related activities, giving them a broader awareness and an advantage in understanding social science topics. Robertson's (2011) findings support this argument by showing that older students tend to have better social skills, which benefits their performance in social studies classes. Moreover, assuming that the relative age effect in social sciences runs parallel to the development of students' social skills, it would be expected to last longer in this subject. As a result, the relative age effect in the social sciences may persist longer. Furthermore, the connection with students' social skills may be even more pronounced in the Korean context, as the Korean education system places great emphasis on the constant repetition of learned concepts and largely ignores students' personality development.

The relative age effect is also strong in mathematics, most likely due to the cumulative and structured nature of this school subject, which quickly becomes apparent when looking at the Korean (or any other) mathematics curriculum. Mastery of one concept is often critical to grasping the next. Students with a better understanding of an early learning content therefore have an advantage in elaborating, grasping, and understanding the next concept which may lead to an amplification or prolongation of an existing relative age effect. Additionally, mathematics requires a lot of logical thinking and problem-solving skills, skills that develop with age. Therefore, relatively older students, with their more advanced cognitive abilities, are better prepared to process the complexity of mathematical concepts (Bedard & Dhuey, 2006; Fredriksson & Öckert, 2014). A similar, albeit somewhat weaker, explanation could also apply to the natural sciences.

We also observe a relative age effect in Korean, even as early as first grade. Korean culture places great emphasis on children mastering the Korean language at a very young age (Lee & Larson, 2000). The Korean education system also places high demands on literacy skills and requires proficiency in reading, writing, and comprehension (e.g., Sorenson, 1994). To this end, mastery of elements such as honorifics, complex grammar, and an expanded vocabulary is crucial. The emphasis on Korean language proficiency is so widespread and present that it shapes children's education even before elementary school, including preschool. It is therefore not surprising that in this school subject, the relatively older students benefit most from their head start.

In English, the relative age effect is less pronounced. Since English is a foreign language in Korea, it is rarely spoken outside the classroom. And with children having very little exposure to the English language in everyday life, the process of learning English is more standardized and less dependent on age-related cognitive development, which most likely attenuates the relative age effect. In fact, English instruction in Korea often focuses on memorizing vocabulary and grammar rather than on cognitive skills (Moodie & Nam, 2015). As a result, relatively older students are less likely to have a significant advantage over their younger peers in this subject. In addition, it should be noted that the expenditure on private tutoring in English is the highest compared to other subjects (Statistics Korea, 2019).[4] Consequently, learning success in English depends more on the socioeconomic background of the family than in other subjects, which weakens the influence of relative age effects.

Our results also show that male students tend to be more affected by relative age effects compared to their female peers. This difference is most likely due to the fact that girls generally exhibit faster cognitive and emotional development, which leads to earlier maturity and gives them advantages in both social and academic contexts. In fact, previous research confirms that girls often develop earlier and are better prepared for the demands of school, which in turn may mitigate the influence of the relative age effect within their grade level (Asato et al., 2010; OECD, 2018., Suutela et al., 2022). Our results also point in the same direction: due to the developmental differences between boys and girls, the relative age effect is less pronounced among female students, as the early maturation of girls tends to weaken its influence.

Based on the relative age effect found among early elementary school students (grades 1 to 4), the following policy recommendations are proposed

[4] The high willingness of many Korean families to pay for English language skills is also reflected in the fact that they often send their children to study in English-speaking countries for one or two years (Statistics Korea, 2018).

to eliminate inequalities. Flexible curriculum adaptations should provide differentiated mathematics and natural science instruction tailored to students' developmental levels. Programs to promote social skills development are recommended to help younger students access abstract social science concepts. Additional Korean language support is needed to fill gaps in understanding. Our analysis in general and the policy recommendations derived from it in particular may also be applicable to countries outside South Korea where school curricula are standardized and academic achievement is a top priority for both students and parents.

Finally we briefly address the limitations of our study. First and foremost, it would be helpful to have access to complete information on the 2002 or 2004 cohorts, as we could then apply more robust identification strategies, such as using school entry cut-off months as instrumental variables or regression discontinuity designs. Second, it would be desirable to use actual test scores rather than categories because this would more accurately capture the full range of academic outcomes. Third, despite the application of weighted least squares regressions using both longitudinal and cross-sectional weights, the attrition problem could not be fully resolved (see Appendix Tables A5 and A6). Nonetheless, our findings are consistent and robust to various modifications. They regularly show that relative age effects disappear from the 5th grade onwards.

6 Conclusion

This study makes three main contributions to the literature on relative age effects. First, it demonstrates the existence of the relative age effect in Korean elementary education through the analysis of five key subjects: mathematics, social science, natural science, Korean, and English. Relative age effects are observed in all subjects except English. A key feature of our study is the school-subject-specific analysis of relative age effects, which has been relatively little explored in the literature, with only a few notable exceptions (Kawaguchi, 2011; Robertson, 2011; Nam, 2014). Our study provides valuable insights into how these effects vary across school subjects. Second, we measure the duration of relative age effects. Our estimates are based on a pooled (i.e. cross-grade) model with two-sided fixed effects and a grade-specific fixed-effects model. Both models are analyzed using the least squares method and the ordered probit estimation procedure. Our results consistently show that the relative age effect persists until fourth grade, except in social science, where it continues until sixth grade. We argue, among other things, that comparatively older students are likely to have better developed social skills, which can be crucial for understanding social science topics. The temporary nature of relative age effects in Korea that we find may also provide us with some initial insight into the long-term influences that relative age effects have on education. Third, we find that the magnitude and statistical significance of relative age effects are larger for science subjects (mathematics, social science, and natural science) compared to language subjects (Korean and English). We believe that these findings are consistent with the assumption that language acquisition occurs more naturally, whereas learning mathematical and scientific content requires greater cognitive ability. Our school-subject-specific analysis of relative age effects and differences in their persistence therefore provides valuable insights both for educational policy and for future research on this topic.

An important implication of our results concerns any possible endogeneity issues related to seasonal birth. Based on our results we think that endogeneity issues can be rightfully discarded when conducting empirical investigations that look into the academic performance of middle and high school students. The same must then be true for subsequent outcome measures such as tertiary education and labor market outcomes. In this respect our study is consistent with the findings in Dobkin & Ferreira (2010) and Nam (2014) but contradicts Black et al. (2011), Grenet (2011), and Fredriksson & Öckert (2013). The importance of this implication is not restricted to educational research. Policy makers and parents alike need to understand that too strong a focus on putative adverse effects of seasonal births in fact diverts attention from the most important question of all: given the heterogeneous student body of today how can the learning conditions be set in such a way that as fair and equal opportunities as possible are guaranteed.

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Appendix

Table A1. Relative Age Effects by Grade and Subject with Different Levels of Clustering

	Math	SoSci	NaSci	Korean	English
Pooled	0.01758	0.01616	0.00981	0.01155	0.00470
	[0.00584]***	[0.00490]***	[0.00462]**	[0.00460]**	[0.00669]
	{0.00638}***	{0.00498}***	{0.00469}**	{0.00454}**	{0.00691}
Clusters [School]	474	474	474	474	455
Clusters {School District}	136	136	136	136	135
Observations	7,812	7,810	7,807	7,812	6,139
Grade 2	0.02329	0.01098	0.00973	0.01350	
	[0.00848]***	[0.00784]	[0.00797]	[0.00703]*	
	{0.00825}***	{0.00796}	{0.00802}	{0.00730}*	
Clusters [School]	181	181	181	181	
Clusters {School District}	100	100	100	100	
Observations	1,668	1,668	1,668	1,668	
Grade 3	0.01972	0.02644	0.01291	0.01624	0.01673
	[0.00879]**	[0.00925]***	[0.00811]	[0.00772]**	[0.00977]*
	{0.00906}**	{0.00990}***	{0.00841}	{0.00768}**	{0.01066}
Clusters [School]	240	240	240	240	240
Clusters {School District}	106	106	106	106	106
Observations	1,568	1,568	1,566	1,568	1,568
Grade 4	0.02542	0.02190	0.01523	0.01533	0.00300
	[0.00889]***	[0.00867]**	[0.00759]**	[0.00740]**	[0.00927]
	{0.00929}***	{0.00922}**	{0.00821}*	{0.00852}*	{0.00922}
Clusters [School]	275	275	275	275	275
Clusters {School District}	117	117	117	117	117
Observations	1,523	1,522	1,521	1,523	1,520
Grade 5	0.00769	0.00439	0.00658	0.00746	-0.00278
	[0.01020]	[0.00894]	[0.00808]	[0.00789]	[0.00920]
	{0.01099}	{0.00855}	{0.00799}	{0.00793}	{0.00900}
Clusters [School]	319	318	319	319	318
Clusters {School District}	119	119	119	119	119
Observations	1,528	1,527	1,528	1,528	1,526
Grade 6	0.01026	0.01599	0.00351	0.00531	0.00441
	[0.00982]	[0.00813]*	[0.00758]	[0.00686]	[0.00892]
	{0.00924}	{0.00868}*	{0.00757}	{0.00683}	{0.00899}
Clusters [School]	339	339	339	339	339
Clusters {School District}	123	123	123	123	123
Observations	1,525	1,525	1,524	1,525	1,525

Note: The same control variables as in the pooled ordinary least squares regression (cf. Table 5) are used. Standard errors are either clustered at the school level and reported in [brackets] or at the school district level and reported in {braces}. *,**,*** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Table A2. Relative Age Effects by Grade and Subject of Male Students

	Math	SoSci	NaSci	Korean	English
Pooled	0.01991***	0.01650**	0.01422**	0.01404**	0.00980
	(0.00756)	(0.00686)	(0.00629)	(0.00596)	(0.00934)
P>|t|	0.009	0.016	0.024	0.019	0.294
Clusters (ID)	923	923	923	923	879
Observations	4,067	4,065	4,065	4,067	3,197
Grade 2	0.01348	0.01823	0.02015*	0.00760	
	(0.01172)	(0.01115)	(0.01066)	(0.01104)	
P>|t|	0.251	0.102	0.059	0.491	
Observations	867	867	867	867	
Grade 3	0.02502**	0.02412**	0.01752	0.02293**	0.02136*
	(0.01203)	(0.01230)	(0.01109)	(0.01068)	(0.01282)
P>|t|	0.038	0.050	0.115	0.032	0.096
Observations	821	821	820	821	821
Grade 4	0.03233***	0.02572**	0.02261**	0.01288	0.00719
	(0.01070)	(0.01154)	(0.01098)	(0.01016)	(0.01337)
P>|t|	0.003	0.026	0.040	0.205	0.591
Observations	796	795	795	796	794
Grade 5	0.01855	-0.00624	0.00504	0.01673*	0.00594
	(0.01253)	(0.01234)	(0.01064)	(0.00984)	(0.01335)
P>|t|	0.139	0.613	0.635	0.090	0.656
Observations	789	788	789	789	788
Grade 6	0.00852	0.01441	-0.00074	0.00882	0.00661
	(0.01212)	(0.01156)	(0.01091)	(0.01000)	(0.01309)
P>|t|	0.482	0.213	0.946	0.378	0.614
Observations	794	794	794	794	794

Note: The regression analysis employs the same control variables as in the previous model, with the exception of the sex dummy variable (see Table 5). Standard errors are clustered at the individual level and reported in parentheses. *,**,*** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Table A3. Relative Age Effects by Grade and Subject of Female Students

	Math	SoSci	NaSci	Korean	English
Pooled	0.01421*	0.01521**	0.00594	0.00992	0.00459
	(0.00794)	(0.00702)	(0.00626)	(0.00610)	(0.00939)
P>|t|	0.074	0.031	0.343	0.104	0.625
Clusters (ID)	846	846	846	846	802
Observations	3,745	3,745	3,742	3,745	2,942
Grade 2	0.02927**	0.00424	-0.00268	0.01828*	
	(0.01287)	(0.01040)	(0.01033)	(0.01072)	
P>|t|	0.023	0.684	0.795	0.089	
Observations	801	801	801	801	
Grade 3	0.01237	0.02836**	0.00999	0.01167	0.01634
	(0.01284)	(0.01216)	(0.01162)	(0.01065)	(0.01284)
P>|t|	0.336	0.020	0.390	0.274	0.204
Observations	747	747	746	747	747
Grade 4	0.01715	0.02135*	0.00983	0.02063**	0.00413
	(0.01233)	(0.01133)	(0.01102)	(0.00990)	(0.01290)
P>|t|	0.165	0.060	0.373	0.038	0.749
Observations	727	727	726	727	726
Grade 5	-0.00705	0.01009	0.00944	-0.00295	-0.00663
	(0.01238)	(0.01307)	(0.01156)	(0.01035)	(0.01344)
P>|t|	0.569	0.441	0.415	0.776	0.622
Observations	739	739	739	739	738
Grade 6	0.01907	0.01401	0.00949	-0.00101	0.00907
	(0.01314)	(0.01234)	(0.01143)	(0.00999)	(0.01320)
P>|t|	0.147	0.257	0.407	0.920	0.493
Observations	731	731	730	731	731

Note: The regression analysis employs the same control variables as in the previous model, with the exception of the sex dummy variable (see Table 5). Standard errors are clustered at the individual level and reported in parentheses. *,**,*** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Table A4. Relative Age Effects by Grade and Subject with Different Levels of Clustering (Ordered Probit)

	Math	SoSci	NaSci	Korean	English
Pooled	0.02078	0.01913	0.01294	0.01568	0.00557
	[0.00686]***	[0.00587]***	[0.00603]**	[0.00644]**	[0.00736]
	{0.00745}***	{0.00596}***	{0.00610}**	{0.00636}**	{0.00756}
Clusters [School]	474	474	474	474	455
Clusters {School District}	136	136	136	136	135
Grade 2	0.02738	0.01548	0.01254	0.01763	
	[0.00957]***	[0.01005]	[0.01054]	[0.00887]**	
	{0.00928}***	{0.01031}	{0.01066}	{0.00920}*	
Clusters [School]	181	181	181	181	
Clusters {School District}	100	100	100	100	
Grade 3	0.02362	0.03090	0.01708	0.02107	0.01975
	[0.01025]**	[0.01056]***	[0.01018]*	[0.01032]**	[0.01091]*
	{0.01063}**	{0.01121}***	{0.01064}	{0.01036}**	{0.01179}*
Clusters [School]	240	240	240	240	240
Clusters {School District}	106	106	106	106	106
Grade 4	0.03404	0.02913	0.02185	0.02313	0.00535
	[0.01136]***	[0.01094]***	[0.01022]**	[0.01102]**	[0.01030]
	{0.01182}***	{0.01167}**	{0.01104}**	{0.01261}*	{0.01030}
Clusters [School]	275	275	275	275	275
Clusters {School District}	117	117	117	117	117
Grade 5	0.00921	0.00395	0.00923	0.01049	-0.00468
	[0.01192]	[0.01030]	[0.01096]	[0.01167]	[0.01033]
	{0.01282}	{0.00978}	{0.01079}	{0.01176}	{0.00997}
Clusters [School]	319	318	319	319	318
Clusters {School District}	119	119	119	119	119
Grade 6	0.01116	0.01951	0.00491	0.00802	0.00518
	[0.01142]	[0.00999]*	[0.01007]	[0.01037]	[0.01006]
	{0.01062}	{0.01053}*	{0.01003}	{0.01035}	{0.00999}
Clusters [School]	339	339	339	339	339
Clusters {School District}	123	123	123	123	123

Note: The same control variables as in the pooled ordinary least squares regression (cf. Table 5) are used. The number of observations varies between 7,812 and 6,139 for the pooled regressions and between 1,520 and 1,668 for the grade-specific regressions. Standard errors are either clustered at the school level and reported in [brackets] or at the school district level and reported in {braces}. *,**,*** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Table A5. Relative Age Effects by Grade and Subject (Weighted Least Squares I)

	Math	SoSci	NaSci	Korean	English
Pooled	0.01523**	0.01313**	0.00671	0.01059**	-0.00166
	(0.00615)	(0.00529)	(0.00492)	(0.00476)	(0.00727)
P>|t|	0.013	0.013	0.172	0.026	0.819
Clusters (ID)	1,741	1,741	1,741	1,741	1,647
Observations	7,642	7,640	7,637	7,642	5,971
Grade 2	0.02429***	0.01075	0.01204*	0.01840**	
	(0.00848)	(0.00743)	(0.00715)	(0.00760)	
P>|t|	0.004	0.148	0.093	0.016	
Observations	1,668	1,668	1,668	1,668	
Grade 3	0.01506*	0.02048**	0.00688	0.01491**	0.00647
	(0.00852)	(0.00831)	(0.00781)	(0.00732)	(0.00880)
P>|t|	0.077	0.014	0.378	0.042	0.462
Observations	1,543	1,543	1,541	1,543	1,543
Grade 4	0.01711**	0.01561*	0.00822	0.01152	-0.00505
	(0.00792)	(0.00808)	(0.00769)	(0.00702)	(0.00918)
P>|t|	0.031	0.054	0.285	0.101	0.582
Observations	1,500	1,499	1,498	1,500	1,498
Grade 5	0.00757	0.00693	0.00490	0.00886	-0.00497
	(0.00870)	(0.00864)	(0.00757)	(0.00694)	(0.00916)
P>|t|	0.384	0.422	0.517	0.202	0.588
Observations	1,475	1,474	1,475	1,475	1,474
Grade 6	0.00936	0.01373*	0.00135	-0.00055	-0.00059
	(0.00880)	(0.00832)	(0.00794)	(0.00693)	(0.00922)
P>|t|	0.287	0.099	0.865	0.936	0.949
Observations	1,456	1,456	1,455	1,456	1,456

Note: The same control variables as in the pooled ordinary least squares regression (cf. Table 5) are used. Furthermore, longitudinal weights are used for weighted least squares. Standard errors are clustered at the individual level and reported in parentheses. *,**,*** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Table A6. Relative Age Effects by Grade and Subject (Weighted Least Squares II)

	Math	SoSci	NaSci	Korean	English
Pooled	0.01489**	0.01356***	0.00715	0.01115**	-0.00400
	(0.00609)	(0.00525)	(0.00485)	(0.00472)	(0.00727)
P>|t|	0.015	0.010	0.141	0.018	0.582
Clusters (ID)	1,769	1,769	1,769	1,769	1,681
Observations	7,812	7,810	7,807	7,812	6,139
Grade 2	0.02409***	0.01069	0.01189*	0.01838**	
	(0.00848)	(0.00743)	(0.00715)	(0.00760)	
P>|t|	0.005	0.151	0.097	0.016	
Observations	1,668	1,668	1,668	1,668	
Grade 3	0.01629*	0.02065**	0.00836	0.01663**	0.00411
	(0.00848)	(0.00823)	(0.00776)	(0.00726)	(0.00871)
P>|t|	0.055	0.012	0.282	0.022	0.637
Observations	1,568	1,568	1,566	1,568	1,568
Grade 4	0.01709**	0.01803**	0.01089	0.01280*	-0.00584
	(0.00782)	(0.00799)	(0.00758)	(0.00694)	(0.00910)
P>|t|	0.029	0.024	0.151	0.065	0.521
Observations	1,523	1,522	1,521	1,523	1,520
Grade 5	0.00567	0.00379	0.00395	0.00876	-0.00889
	(0.00851)	(0.00850)	(0.00747)	(0.00685)	(0.00914)
P>|t|	0.505	0.656	0.597	0.201	0.331
Observation	1,528	1,527	1,528	1,528	1,526
Grade 6	0.00777	0.01598*	0.00147	0.00003	-0.00099
	(0.00867)	(0.00817)	(0.00778)	(0.00684)	(0.00913)
P>|t|	0.370	0.051	0.850	0.996	0.914
Observations	1,525	1,525	1,524	1,525	1,525

Note: The same control variables as in the pooled ordinary least squares regression (cf. Table 5) are used. Furthermore, cross-sectional weights are used for weighted least squares. Standard errors are clustered at the individual level and reported in parentheses. *,**,*** denote statistical significance at the 10%, 5% and 1% levels, respectively.