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Peer effects in primary school: Evidence from age variation*

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Abstract
We investigate the role of age composition within classroom on student achievement. Exploring strict enrolment rules in Norwegian schools and absence of grade repetition, we investigate the hypothesis that classmates age affect individual student achievement. Using rich administrative data from the 4'th grade national tests in mathematics and reading in 2004, we find that male students being in classrooms with relatively old peers achieves better in mathematics than other male students. The effect is much weaker for female students and absent in reading.

Keywords: Peer effects, age composition, achievement
JEL: I21, J13

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1. Introduction

This paper investigates the empirical relevance of age peer effects in primary schools. The existence of, and direction of peer effects in school, are important topics in the public debate on school policies and in the theoretical literature on the behaviour of schools and parents. Critics of school choice programs often argue that these programs have negative distributional consequences since more segregation means that low ability and low income students would lose the positive effect from being in school with more able peers in a restricted system. Several influential equilibrium models of the educational market are based on the assumption that parents and students take into account peer effects on education outcomes when they make housing and schooling decisions [Epple and Romano (1998), Nechyba (2000)]. Lazear (2001) consider classroom instruction as a congested public good due to peer group effects and derives predictions on optimal class size and school integration policies based on this assumption.

Despite a quite large literature, the empirical evidence on peer effects has not been very conclusive. The main reason for this is that empirical investigations of peer effects face severe methodological problems examined in the seminal paper by Manski (1993). A main problem is to distinguish between the true peer effects on educational outcomes and the effect of people actively choosing schools and neighbourhoods to take advantage of peer effects[1]. The ideal way to study peer effects would be to conduct an experiment whereby two otherwise equal students were randomly sent to two schools with different peer composition and observe the difference in their school achievement. While this is rarely possible in practice, our approach is to explore variations in peer group composition that comes close to such an experimental approach. We explore natural variation in the age composition within a grade across schools and classes to provide evidence on peer influence. Empirical evidence from several countries suggest that a student's age conditional on schooling quantity has a positive and substantial effect on his/her school achievement[2]. Thus, a 9 year old student being placed

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[1] Henderson et al. (1978) and Summers and Wolfe (1977) are leading examples from the early literature. Studies in the early literature typically regressed individual student achievement against individual student characteristics and mean class achievement to capture peer influence and typically found large positive peer effects. However, these estimates could be seriously biased because of student sorting and school resource allocation behaviour

[2] This is documented in Bedard and Dhuhey (2005), Datar (2005), Fredriksson and Oeckert (2004), Leuven et. al. (2003) and Strøm (2004).

in a class with older classmates will be exposed to classmates who are higher achievers than a similar student being placed in a class with relatively younger students. The question we raise is whether the former student will achieve better than the latter student due to learning spill over or better learning environment.

To investigate the role of such age peer group effects we explore the strict enrolment rules in Norwegian schools saying that all students born in a certain calendar year shall start school at the same time (august) and have exactly equal amounts of schooling. While having the same amount of schooling, the actual age variation within class is nearly one year between the youngest and the oldest student. In early grades this age difference relative to absolute age will be quite substantial. If birth events during the year are random, and parents do not choose school based on the age distribution within a calendar year, differences in age distribution within grade across schools would be close to random. We explore this variation to investigate the hypothesis that the age of one’s classmates affects individual achievement using complete register data from the 4.th grade national tests in mathematics and reading in Norwegian public schools conducted in 2004.

Other papers have used experimental approach to study peer group effects in education. Randomly assigned roommates in college have been used to study the impact of peers on several college student outcomes [Sacerdote (2000) and Zimmerman (2002)]. While these studies are interesting in their own right, they shed little light on the operation of peer group effects in typical policy relevant environments as schools and classrooms in compulsory education. More closely related to our paper is Hoxby (2000) who uses idiosyncratic changes in gender and race composition across grades and schools as measures of exogenous peer group variation and find that peer effects matter for students in public Texas schools[3].

The impact of the age of one’s peers in the classroom is an issue that have received little attention in the empirical literature so far[4]. Nevertheless, the question of age mixing in classes

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[3] Other recent papers investigating includes Hanushek et al. (2003) who find a strong positive effect of lagged peer group achievement on individual student achievement after using a battery of fixed effects. Figlio (2003) studies the impact of peer student misbehaviour on individual student achievement using the number of boys with names typically given to girls as instrumental variables for peer misbehaviour and finds strong peer effects on achievement using data from Florida.

[4] Motivated by evidence from sports science, Fredriksson and Oeckert (2004) investigates the hypothesis that both the absolute and the relative (given by the individual’s rank in the age distribution in school) affect achievement for 9’th graders in Swedish schools. They find evidence for positive relative age effects only in sports. Also related to our approach is a recent paper by Argys and Rees (2004) who analyse the role of age peer

within grades and whether students from different grades should be placed together at least in certain subjects is clearly of interest for policymakers and have also received attention in the theoretical literature on optimal class size and school integration policies represented by Lazear (2000). By using exogenous variation in peer age, our paper provides empirical evidence on the potential gains and losses from student mixing policies.

The paper is organized as follows:
Section 2 presents a simple model of education production to explain the main hypothesis and our empirical strategy. Section 3 gives some descriptive statistics, while Section 4 presents our main empirical results. Section 5 concludes.

2. Theoretical framework and empirical strategy

In this section we present a stylised model of the production process in class with age peer group effects and use this model to discuss the challenges facing empirical research on age peer group effects. To simplify, consider a class with two students, denoted 1 and 2[5]. Let student achievement be generated by a linear model as in (1) and (2):

(1) $A_1 = a_0 + a_1 AGE_1 + a_2 AGE_2 + a_3 A_2 + X_1 \alpha + u_1$

(2) $A_2 = b_0 + b_1 AGE_2 + b_2 AGE_1 + b_3 A_1 + X_2 \beta + u_2$

where A_i denotes student i's achievement, AGE_i, denotes the student's age. A_j and AGE_j denotes the achievement and age of his classmate respectively. X_1 and X_2 are vectors representing other factors affecting achievement of student 1 and student 2 and may contain both individual characteristics and class specific elements common for both students. u_i, i=1, 2 are random errors.

This simple model implies that the student's own age (AGE_i) have a direct effect a_1 (b_1) on his achievement. Several arguments suggest that his own age affect his achievement

group effects on risky behaviour by youths. Because they observe that risky behaviour increases with children's age, they hypothesize that due to contagion effects individuals younger compared to their peers will be be more likely to start risky behaviour than individuals that are older compared to their peers. They use variation in state level school start up dates and birth dates to test the hypothesis.

[5] Generalizing to more than 2 students gives the same qualitative results.

positively. More mature students may be better able to learn complex material and they are likely to be less disruptive. But one student's age may also affect the other student's achievement. We distinguish between two basic mechanisms: First, a direct effect denoted by a_2 (b_2). This effect can be positive if older students who are less disruptive not only do better themselves, but their behaviour mean that the other students in class have a less disruptive environment and produce more achievement other things equal, similar to that suggested by Lazear (2001). The teacher may even react to a classroom with only young students by reducing achievement expectations and thereby reduced effort from the students. Second, the fact that the older student has higher achievement can by itself have a positive effect on his classmates through direct learning spill over. The learning spill over effect is denoted by the coefficient a_3 (b_3) in front of the classmate's achievement.

Consider next the age effects in the reduced form achievement equations (c_1, c_2, d_1, d_2 are reduced form effects for the other determinants of achievement):

$$(3)\ A_1 = \frac{a_0 + a_3 b_0}{1 - a_3 b_3} + \frac{a_1 + a_3 b_2}{1 - a_3 b_3} AGE_1 + \frac{a_2 + a_3 b_1}{1 - a_3 b_3} AGE_2 + X_1 c_1 + X_2 c_2 + v_1$$

$$(4)\ A_2 = \frac{b_0 + a_0 b_3}{1 - a_3 b_3} + \frac{b_2 + b_3 a_1}{1 - a_3 b_3} AGE_1 + \frac{b_1 + b_3 a_2}{1 - a_3 b_3} AGE_2 + X_1 d_1 + X_1 d_2 + v_2$$

It turns out that the age effects in the structural equations cannot be inferred from knowledge of the reduced parameters in (3) and (4). But, we can, given $|a_3 b_3| < 1$, infer whether a general peer age effect exists or not. Take student 1's achivement equation as an example. The parameter in front of AGE_2 will be zero only if $a_2 = 0$ and/or $a_3 = 0$, i.e. if there is no direct peer age effect or no learning spillover effect.

The inference of general peer age effects builds on the assumption that the random errors in the reduced form achievement equations are uncorrelated with the age composition. We now argue that the strict enrolment rules in Norway, and non-existence of class repeating practices, imply that age composition of the class comes close to random.

First, school enrolment date or year is not subject to parental choice. All students in Norway are obliged to start school in August in the calendar year they turn 6 years old. Exemptions to this rule are rare, and have to be approved by the local school authorities after an application process where health and psychological specialists are involved. It turns out that between 98 and 99% of each cohort starts school in the year they are expected to according to the rule. Second, while grade repetition is a quite normal event in many other countries, this almost never happens within the Norwegian compulsory school system. Further, there is no formal tracking throughout compulsory school (1-10.th grade) and the private schools enrol only a minor fraction of the students.

Given these strict regulations of school enrolment, we now discuss in more depth whether the age distribution across classes is exogenous. First, in line with Angrist and Krueger (1991), assume at the outset that birth distribution across the calendar year is random. A further assumption is that parents do not make location decisions based on the variation in age composition within cohorts across neighbourhoods. Parents may well use information regarding the variation in socio-economic characteristics, parental resources, the number of children in each cohort and even gender composition across neighbourhoods when making decisions on where to locate. However, we find it much less likely that the variation across neighbourhoods in the distribution of birthdays within a cohort is used in this decision. Such information is much harder to obtain than information on other neighbourhood characteristics which is often available from public sources. In this respect, our approach comes close to that of Hoxby (2000) who use changes in race and gender compositions across grades to infer possible gender and race peer effects.

Having argued that school choice is not likely to be affected by age composition across neighbourhoods within cohorts, an important objection to our strategy is that the age distribution across classes within school may be non-random. For instance, some schools may place late-born children in one class and early born children in another class, making the age composition across classes within school endogenous. A related problem occurs when teacher allocation policy in school is determined by student age variation across classes. Our solution to this problem is to conduct the analysis at the grade level. However, a problem with a grade level strategy is that we do not investigate the peer effect in the units where they are most likely to occur which is typically in the class. Thus, to come closer to the ideal situation, we also limit the sample to schools where the number of children in a grade is lower than the maximum class size allowed. Implicitly, we assume that a school will not operate with two classes at a grade when the maximum class size rule is not binding.

With the sample of schools defined as above, endogenous allocation of teachers across classes within grade is not an issue. In this situation, teacher allocation will be correlated with student age variation across classes and schools only if the allocation of teachers across grades is determined by age composition between cohorts. For instance, if the school systematically allocates high quality teachers to cohorts with many late born students, there will be a bias towards finding a negative effect of peer age on individual student achievement. We cannot fully rule out these kinds of bias, but current teacher allocation policies in Norwegian schools suggest that it is of little importance. Current policy in schools is that the teacher starts with a class in first grade and follows this class throughout 7.th grade in lower secondary school. When this practice is implemented in a school with one class per grade and no teacher quits, this implies that the available teacher for the first graders starting a given year is the teacher finishing the 7-graders the year before. Thus current teacher allocation will be strongly determined by historical decisions and such schools will have small possibilities to distribute teachers according to age composition across grades.

Another threat to our strategy occurs if age composition of a class influences other school resources distributed to this class. According to Norwegian school law, classes with students classified as special needs students are given additional educational resources in the form of more teachers and assistants. For instance, if late born children are more likely to be classified as special education students the effect of age composition may partly represent the effect of extra resources. If extra resources improve achievement, this would tend to bias towards zero any negative peer effect from having relatively younger peers in class. We cannot fully account for this possibility with the data available, and in this respect, the estimates on the age peer effect should be viewed as conservative. Our strategy is further to investigate whether our results are sensitive to the inclusion of variables representing special education resources.

3. Descriptive statistics

Our data consists of individual scores on national test in mathematics and reading given to 4.th graders in all public schools and a fraction of private schools in Norway 2004. These test results for individual students are linked to register information on student family background: parents' education, parents' income, minority status, number of siblings, birth order within the family and student age (in months). Further, the data include a school identifier which enables us to include information on school characteristics and resources. In the following we describe the tests used, present the distribution of test scores across birth quarters along with an analysis of the relationship between students' birth dates and socioeconomic and family characteristics.

The purpose of the mathematics test in 4.th grade was to retrieve information on the students achievement in 1)communication, 2) representation, use of symbols and formalism, 3) mathematical reasoning, 4) mathematical modelling and applications, 5) problem solving. Test scores for each category were reported, but in this analysis we use the aggregate test scores which are also recommended by the test administrators.

The reading test in 4.th grade contained three parts: One part consisted of identifying words and the two other parts used two texts to test reading comprehension. We use the aggregate test scores from these elements.

To facilitate comparison across the two tests we have normalized the scores in each test to a variable with mean 0 and standard deviation 1 based on the total population of students.

Consistent with the strict formal rules on student enrolment in Norway with students enrolling in school in august the year they turn 6 years old, 98.6 percent of the total population of 4th graders in 2004 were born in 1994. In the following we will use two sub-samples. Sub-sample A consists of all students in schools were all 4.th graders are born in 1994. The number of schools in this sample is 1873. Sub-sample B consists of students in schools were all children are born in 1994, and the number of students in 4.th grade is less than 28, which is the maximum size of a class. Furthermore, the rules present until the school year 2003-2004 implied that extremely small schools could mix grades to obtain a class size of sufficient size. To account for this, the schools reporting that grades are mixed in some or all grade levels are dropped from this sub-sample. The number of schools in this sample is 439. Column (1) in Table 1, column (1) gives descriptive statistics of the test score distribution for mathematics, in total and across birth quarters for the whole population of 4.th grade students born in 1994. Column (2) and (3) presents the same information for sub-samples A and B. Columns (3), (4) and (5) do the same for reading. In Appendix 1 descriptive statistics for the control variables are given, for sub-sample A and sub-sample B respectively. There are notable differences in, for example, educational levels of the parents and share of children with immigrant status across subsample A and B. The reason for this is that relatively more of the schools within bigger cities where both educational levels as well as share of immigrants tend to be higher are excluded in subsample B.

Table 1. Distribution of test scores across quarter of birth and samples.

	Mathematics			Reading		
	Total sample born 1994 (1)	Sub-sample A (2)	Sub-sample B (3)	Total sample born 1994 (4)	Sub-sample A (5)	Sub-sample B (6)
All students	0.0135 (0.985)	-0.0044 (0.984)	-0.0346 (0.973)	0.0103 (0.993)	-0.0006 (0.989)	-0.0384 (0.972)
Born 1st quarter	0.1291 (0.970)	0.1059 (0.980)	0.0932 (0.963)	0.1290 (1.013)	0.1126 (1.008)	0.0737 (0.990)
Born 2nd quarter	0.0600 (0.968)	0.0326 (0.969)	-0.0106 (0.974)	0.0461 (0.991)	0.0276 (0.986)	-0.0220 (0.997)
Born 3rd quarter	-0.0329 (0.997)	-0.0344 (0.984)	-0.0592 (0.965)	-0.0335 (0.978)	-0.0337 (0.976)	-0.0671 (0.946)
Born 4th quarter	-0.1120 (0.989)	-0.1311 (0.988)	-0.1771 (0.974)	-0.1091 (0.973)	-0.1173 (0.971)	-0.1502 (0.936)

We first note that there is a clear pattern in performance across birth quarter. In all samples, the difference in achievement in both mathematics and reading between a student born in 1. quarter (oldest) and a student born in the 4.quarter (youngest) is around 23% of a standard deviation. The achievement level is however quite different across sub-samples, with the sub-sample based on schools with fewer students in 4.th grade than the maximum class size rule (sample B) has lower achievement. This is not surprising since the average parent education level is lower in this sub-sample.

A possible threat to our identification strategy is the possibility that birth season is correlated with observable or unobservable determinants of student performance. Before turning to the analysis of age peer effects, we therefore consider the relationship between student age and student family background in sub-sample A and B which we use in the subsequent analysis. Table 2 shows the results from a regression between birth month and several family characteristics including father's and mother's income, father's and mother's education, family size etc. First, we note that the explanatory power of the regression is very low which is a first indication that birth season is close to random. However, there is some indication that 1.generation immigrants are born later in the year than native children and that children with large number of siblings, being oldest in family and born in families with mothers having intermediate education is somewhat more likely to be born early in the year (significant only in subsample A).

If immigrant students perform poorer than natives as often found in other studies, this may generate a positive bias in our estimates of age effects. On the other hand, if student achievement is positively correlated with parent's education and negatively correlated with family size as indicated in earlier empirical research, this suggests that the revealed positive relationship between students' achievement and age (conditional on schooling time) in Table 1 above may be downward biased.

Our conclusion from this first look at the test score and birth season data is that late born children in 4.th grade performs substantially lower than their older classmates. This is in line with previous findings in Leuven et al. (2004), Datar (2005), Bedard and Dhuey (2005), Strøm (2004) and Fredriksson and Oeckert (2005). However, the results also suggest that we cannot fully rule out the possibility that birth season is correlated with observed determinants of achievement although these determinants only explains a tiny fraction of the variation in birth dates. Our strategy is therefore to include a battery of family background variables in our achievement equations and also check if the results are sensitive to the inclusion of observed school characteristics. The important question which we focus on in this paper is whether this apparent performance difference also means that students placed in classes with younger classmates perform lower than other children.

Table 2. Relationship between birth season and socioeconomic and family characteristics. Dependent variable: Birth month.

Independent variable	Sub-sample A N = 35,083	Sub-sample B N = 7,757
Log income of father	0.0268 (0.030)	0.0079 (0.069)
Log income of mother	0.0032 (0.036)	-0.0030 (0.082)
Father's education, i. intermediate educ. i. higher education	 -0.0523 (0.064) -0.0955 (0.073)	 0.0114 (0.134) -0.2261 (0.158)
Mother's education, i. intermediate education i. higher education	 0.1219 (0.071)* 0.0501 (0.078)	 0.1210 (0.145) -0.0255 (0.164)
Immigrant status, i. 1st gen. immigrant i. 2nd gen. immigrant i. born in Norway with one foreign parent, or born abroad with Norwegian parents	 -0.4838 (0.161)*** -0.0959 (0.102) -0.0026 (0.069)	 -0.3792 (0.375) 0.4697 (0.283)* 0.0891 (0.159)
Number of siblings	0.0505 (0.022)**	0.0354 (0.047)
Birth order among siblings (1 being youngest)	0.0505 (0.026)*	0.0064 (0.056)
Living with both parents	-.0744 (0.045)	-0.0198 (0.097)
R^2	0.0010	0.0022

4. Empirical results

This section presents the results from estimation of reduced form achievement equations based on individual test score data. In addition to standard family background variables, our key explanatory variable for the i'th student is the age of his classmates. As our measure of peer age for the i'th student we use the average age (in months) for the 4.th grade students in school when the i'th student is excluded. To get a clean age measure, we initially only include schools where all 4.th grade students were born in 1994 (the normal age). We first present the results from models where all such schools are included in the sample (Subsample A). We then present results from a restrictive sample including only schools where the number of 4.th graders are below the maximum class size rule (Subsample B).

Results: Subsample A

Table 3 column (1) shows the effect of own age (measured in months) and the effect of classmates' age (measured in months) on performance in mathematics when standard family background variables are included in the model. As expected from the descriptive statistics presented above, the student's own age show up as a strong determinant of achievement. According to the results, a student born in January (the oldest) achieves close to 0.3 standard deviations better than a student born in December (the youngest). As to the effect of class-mates age it is estimated to be positive and numerically about half the own age effect. However, the high standard errors imply that the null hypothesis of zero peer age effect cannot be rejected at conventional significance levels. The results in column (3) show the results for reading. The same pattern arises, with the point estimate being positive, but with high standard errors.

Columns (2) and (4) in Table 3 show the estimated effects when a number of school level variables are added to the model. The motivation for this is first that allocation of school resources may depend on student characteristics. For example, it may be the case that students born late in the year is more likely to be classified as special education students. Since such students will receive more resources, this may bias downward the effect of classmates' age if achievement is positively correlated with resources. Further, the estimated relationship between birth month and family background variables above suggested that omitted school characteristics to some extent may be (weakly) correlated with peer age. 1.generation immigrants were somewhat more likely to be born late in the year than native children. On the other hand students with children speaking foreign language at home have the right to additional language instruction and therefore schools with such students are given additional resources. To capture the combined effect of omitted variables and possible compensating resources, we add to the model the following school level variables: The number of students in 4.th grade, the share of students in 4.th grade receiving additional instruction in Norwegian language, the share of students in 1-4.th grade being classified as special needs students and the share of boys in 4.th grade. The results in column (2) and (4) show that adding these variables to the model does not matter much, and does not change the effect of classmates age in any significant way[6].

Table 3. Estimated achievement equation: Sub-sample A. Robust standard errors adjusted for clustering at the school level in parenthesis. ***, ** and * indicates significance at 1%, 5% and 10% level, respectively.

Independent variable	Mathematics		Reading	
	(1)	(2)	(3)	(4)
Own age	0.026***	0.026***	0.026***	0.026***
Classmates age	0.016 (0.011)	0.013 (0.011)	0.010 (0.011)	0.011 (0.011)
Family characteristics included[7]	Yes	Yes	Yes	Yes
School characteristics included[8]	No	Yes	No	Yes
Observations	34,852	34,852	34,629	34,629
R^2	0.074	0.075	0.079	0.081

[6] We also estimated models with the share of 1.generation immigrants in grade, the share of highly educated parents in grade and the level of teacher hours per student in 4.th grade as additional school characteristics and the results were unchanged.

[7] Family characteristics are: Gender, father's and mother's income, father's and mother's education, number of siblings, birth order among siblings, immigrant status and whether the student lives with both or only one of his/her parents.

[8] School characteristics are: number of children in class, proportion of children in class with special education in Norwegian, amount of special resources in school, and proportion of boys in class.

Results: Subsample B

A problem with the grade level strategy as used above is that we do not perform the analysis at the level where peer influence is most likely to occur, i.e. in the classroom. A further problem is that a school with say 35 students in 4.th grade, and two classes, may choose to compose the classes with respect to student age in a way that maximize peer group effects. If this is the case, it would be difficult to identify the causal effect of peer age on achievement. This leads us to search for circumstances where such age mixing behaviour is minimized. Our strategy is to explore the fact the maximum class-size rules that were present in Norway until the schoolyear 2003-2004. The maximum class size were 28 students and if followed strictly, this implies that schools with the number of students equal to or less than 28 students have one class of 4.th graders.

Columns (1) and (3) in Table 4 show the results for mathematics and reading when we include standard family background variables in addition to own age and peer age and columns (2) and (4) show the corresponding results when school characteristics are added to the model. While the effect of own age is quite stable around 0.3 compared to the results in Table 3, the estimated effect of peer age changes. We first note that the peer age effect differs substantially between mathematics and reading. While the estimated effect on reading achievement is again low and not significantly different from zero at all conventional levels, the effect on mathematics achievement is substantial in numerical terms, while statistically significant only at the 10% level.

Taken at face value, the estimated coefficients mean that one month increase in peer age increases mathematics achievement by 0.04 standard deviations, while one month increase in own age increases achievement by around 0.03 standard deviations. Thus, other variables held constant, going from a class with classmates born in December to a class with classmates born in January increases math achievement by more than one third of a standard deviation. However, this overstates the numerical peer age effect compared to the own age effect, since the actual variation in peer age variable in the sample is much lower than the variation in own age. To get a better judgement, we can compare the effect from a one standard deviation increase in both age variables. The results in Table 4 then means that one standard deviation increase in peer age and own age increases test scores by 0.03 and 0.1 standard deviations respectively. This means that the own age effect is more than 3 times larger in numerical terms than the peer effect.

Table 4. Estimated achievement equation: Sub-sample B. Robust standard errors adjusted for clustering at the school level in parenthesis. ***, ** and * indicates significance at 1%, 5% and 10% level, respectively.

Independent variable	Mathematics		Reading	
	(1)	(2)	(3)	(4)
Own age	0.032***	0.032***	0.027***	0.027***
Classmates age	0.040* (0.023)	0.039* (0.023)	0.009 (0.025)	0.008 (0.026)
Family characteristics included	Yes	Yes	Yes	Yes
School characteristics included	No	Yes	No	Yes
Observations	7713	7713	7739	7739
R^2	0.066	0.069	0.073	0.076

Results: Sample B - Gender differences

So far we have assumed that both the own and peer age effect is equal across different student groups. This may be a too restrictive assumption, and Table 5 shows the results from estimating separate models for girls and boys and reveals an interesting pattern. First, we note that the own age effect in reading is quite similar across genders and consistent with our previous finding there is no evidence of peer age effects in reading. Second, the effect of own age on mathematics achievement is somewhat higher for girls than for boys. On the other hand, the peer age effect is much lower for girls than for boys and not significantly different from zero. According to this result, the male students seem to benefit more from being in a class with older students than girls do. To illustrate the numerical effects, a one standard deviation increase in peer and own age increases mathematics achievement for male students by around 0.04 and 0.10 standard deviations, respectively.

Table 5. Estimated achievement equation across gender. Robust standard errors adjusted for clustering at the school level in parenthesis. ***, ** and * indicates significance at 1%, 5% and 10% level, respectively.

	Mathematics		Reading	
Independent variable	(3) Boys	(4) Girls	(3) Boys	(4) Girls
Own age	0.028***	0.035*	0.026***	0.029***
Classmates age	0.047* (0.028)	0.030 (0.024)	0.005 (0.030)	0.010 (0.028)
Family characteristics included	Yes	Yes	Yes	Yes
School characteristics included	Yes	Yes	Yes	Yes
Observations	3,946	3,766	3,956	3,781
R^2	0.063	0.076	0.061	0.060

Results: Sample B - Old versus young students

An important question is whether both young and old students benefit from being placed in classes with older peers or whether the benefit only applies to the younger students. To examine this question, we run separate models for those students born in January and February (the oldest) and the students born in November and December (the youngest). Column (1) and (2) in Table 6 presents the results for achievement in mathematics under the assumption that the parameters are equal for girls and boys. The point estimate of peer age effect for the late born children is substantially higher than for the early born where the coefficient is also imprecisely estimated. This suggests that late born children are those who gain most by being in a class with older peers. This impression is even stronger when turning to the results for boys only. Using the estimated parameter in column (4) we find that one standard deviation increase in peer age increases the math achievement of male late born students by 0.06 standard deviations. The results for females are much less clear as is to be expected since the earlier results showed no significant peer age effects for girls.

Turning to the results for reading presented in Table 7, they confirm our earlier conclusion that reading achievement is unaffected by peer age. The effects are far from being significantly different from zero at conventional levels.

In conclusion, our estimated models seems to indicate that late born children, and especially late born males gain from being placed in a class with older peers. On the other hand, the gain for the oldest children from being placed in a class with similarly aged peers is much lower.

Table 6. Estimated achievement equations for late-born and early born students. Mathematics. Robust standard errors adjusted for clustering at the school level in parenthesis. ***, ** and * indicates significance at 1%, 5% and 10% level, respectively.

	Both genders		Males		Females	
Independent variable	Born January-february	Born November-December	Born January-february	Born November-December	Born January-february	Born November-December
	(1)	(2)	(3)	(4)	(5)	(6)
Classmates age	0.049 (0.045)	0.075* (0.041)	0.009 (0.055)	0.148*** (0.054)	0.092 (0.058)	0.011 (0.054)
Family characteristics included	Yes	Yes	Yes	Yes	Yes	Yes
School characteristics included	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,260	1,182	659	592	601	590
R^2	0.050	0.060	0.058	0.091	0.066	0.081

Table 7. Estimated achievement equations for late-born and early born students. Reading. Robust standard errors adjusted for clustering at the school level in parenthesis. ***, ** and * indicates significance at 1%, 5% and 10% level, respectively.

	Both genders		Males		Females	
Independent variable	Born January-february	Born November-December	Born January-february	Born November-December	Born January-february	Born November-December
	(1)	(2)	(3)	(4)	(5)	(6)
Classmates age	0.026 (0.043)	0.0000 (0.040)	0.020 (0.052)	0.042 (0.053)	0.033 (0.057)	-.033 (0.051)
Family characteristics included	Yes	Yes	Yes	Yes	Yes	Yes
School characteristics included	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,261	1,185	660	593	601	592
R^2	0.041	0.044	0.052	0.063	0.051	0.049

Results: Sample B – students with high and low educated parents

Our final issue is to investigate whether the peer age effect differs according to parents education. We define students from families with high educated parents as having at least a father or mother with high education. Students defined as having low educated parents have both father and mother with intermediate or low education.

The results from estimated achievement equations in mathematics for these subsamples are shown in the first two columns in Table 8. We first note that the own age effect in mathematics is larger for students with low educated parents, while the effect of peer age is of the same magnitude as above, but imprecisely estimated. However, splitting these subsamples between boys and girls shows that boys with low educated parents have a precisely estimated and numerically substantial peer group effect while the effect for boys with high educated parents is low and insignificant. For girls, the opposite picture emerges, but the results here are less clear due to imprecisely estimated effects. The results for reading achievement is shown in Table 9 and reveals once again the absence of age peer group effects in reading.

Table 8. Estimated achievement equations for students with high or low educated parents. Mathematics. Robust standard errors adjusted for clustering at the school level in parenthesis. ***, ** and * indicates significance at 1%, 5% and 10% level, respectively.

	Both genders		Males		Females	
Independent Variable	High educated parents	Low educated parents	High educated parents	Low educated parents	High educated parents	Low educated parents
Own age	0.022***	0.036***	0.012	0.036***	0.033***	0.036***
Classmates' age	0.044 (0.031)	0.038 (0.025)	0.027 (0.036)	0.063** (0.032)	0.060 (0.037)	0.010 (0.027)
Family characteristics included	Yes	Yes	Yes	Yes	Yes	Yes
School characteristics included	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.049	0.034	0.042	0.033	0.065	0.034
N	2,788	4,924	1,414	2,532	1,374	2,392

Table 9. Estimated achievement equations for students with high or low educated parents. Reading. Robust standard errors adjusted for clustering at the school level in parenthesis. ***, ** and * indicates significance at 1%, 5% and 10% level, respectively.

	Both genders		Males		Females	
Independent Variable	High educated parents	Low educated parents	High educated parents	Low educated parents	High educated parents	Low educated parents
Own age	0.027***	0.026***	0.023***	0.026***	0.030***	0.026***
Classmates' age	0.026 (0.032)	-.003 (0.027)	0.011 (0.038)	0.001 (0.031)	0.041 (0.037)	-.010 (0.031)
Family characteristics included	Yes	Yes	Yes	Yes	Yes	Yes
School characteristics included	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.061	0.035	0.043	0.018	0.051	0.019
N	2,801	4,936	1,418	2,538	1,383	2,398

5. Concluding comments.

The question raised in this paper was: Does the age of a child's peers affect the child's cognitive achievement? To answer this question, we explored the fact that strict enrolment rules in Norway with a strict cutoff date combined with the absence of grade repetition generates natural variation in peer age across schools. Using age level information and complete register data from the 4.th grade national tests in mathematics and reading in Norwegian public schools conducted in 2004 we find some evidence that being in a class with older peers increases achievement in mathematics, but not in reading. Further, this peer age effect found in mathematics seems to be most prevalent among the youngest male students in a cohort and males with low educated parents.

It is important to note that our estimated peer age effects should be interpreted as a reduced form effect. This means that we cannot decide whether the effect is caused by learning spillover from higher achieving older peers or whether the older peers generates a more productive learning environment. Nevertheless, the results in the paper indicates that peer group effects is of importance in education production, but that the effects varies both across gender and school subjects.

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Table A1. Descriptive statistics (APPENDIX)

	All students born 1994	Sub-sample A	Sub-sample B
	Mean (Std. dev.)	Mean (Std. dev.)	Mean (Std. dev.)
Student characteristics:			
Age, in months	117.6 (3.39)	117.6 (3.38)	117.6 (3.39)
Father high education	30 %	27 %	22 %
Father medium education	61 %	63 %	69 %
Mother high education	34 %	32 %	27 %
Mother medium Education	58 %	60 %	64 %
Father's income, Yearly	300,906 (858,853)	285,855 (450,903)	265,865 (221,086)
Mother's income, yearly	209,074 (317,853)	205,289 (230,931)	199,629 (257,785)
Living with both parents	73 %	73 %	73 %
Number of siblings	1.5 (0.99)	1.5 (0.98)	1.5 (1.00)
Immigrant status: 1st gen. immigrant 2nd gen. immigrant Born in Norway or abroad w. at least one Norwegian parent	 2.4 % 4.0 % 8.4 %	 2.1 % 3.4 % 7.9 %	 1.2 % 1.9 % 6.4%
School and grade characteristics:			
Average age in grade	117.7 (0.76)	117.6 (0.79)	117.6 (0.81)
Number of students in 4.th grade	39.5 (20.3)	34.6 (20.0)	19.8 (4.68)
Share of special education resources (1-4.th grade)	0.10 (0.079)	0.10 (0.078)	0.11 (0.08)
Share of boys in grade	0.51 (0.106)	0.51 (0.115)	0.51 (0.118)
Share of students with special teaching in Norwegian	0.063 (0.105)	0.054 (0.097)	0.042 (0.092)