A joint Initiative of Ludwig-Maximilians-Universität and Ifo Institute for Economic Research

Program on Education Policy and Governance

CESifo / PEPG Conference on

Schooling and Human Capital Formation in the Global Economy

CESifo Conference Centre, Munich
3 - 4 September 2004

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Student achievement and birthday effects *

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Abstract
The paper explores the strict school enrolment rules to estimate the effect of age at school entry on school achievement for 15-16 year old students in Norway using achievement tests in reading from OECD-PISA. Since enrolment date is common and compulsory for all students born in a particular calendar year, it is possible to identify the pure effect of enrolment age holding the length of schooling constant. The results indicate that the youngest children (born in December) face a significant disadvantage in reading compared to their older classmates. These results suggest that more flexible enrolment rules should be considered to equalize the opportunities of the children.

JEL codes:I21, I28, J34
Keywords: Enrolment age, student test scores

Paper prepared for presentation at the CESifo-Harvard University/PEPG Conference on “Schooling and Human Capital in the Global Economy: Revisiting the Equity-Efficiency Quandary,” CESifo Conference Center, Munich, September 3-4, 2004. Present version, July 2004.

* Comments from Hans Bonesrønning, Torberg Falch, Oddbjørn Raaum and participants at the 2004 Annual Meeting of Norwegian Economists, Trondheim are gratefully acknowledged.

1. Introduction

While several studies show that student characteristics and family background are important factors shaping students performance in school, economists have paid little attention to the relationship between educational outcomes and the age at which students are enrolled in schools. Cognitive theories give ambiguous predictions on this issue. On the one hand, some theories suggest that young children are more receptive for learning than older ones, while other theories takes the position that children have to reach a certain age in order to learn more complex material [Mayer and Knutson (1999)]. This suggests that the relationship between student achievement and age at enrolment depends on the curriculum faced by the children when they are exposed to schooling. Further, the effect of enrolment age can be highly non-linear, i.e. children may benefit from starting at age 7 compared to age 8, while they may lose from starting at age 5 compared to age 6. Finally, although enrolment age may be important for the child's learning in the first grades, the effects may fade as the children become older. Ultimately, the relationship between achievement and school enrolment age is an empirical one that deserves attention.

The issue is important when policymakers make decisions on school entry rules, i.e. whether children should start school at age 5, 6 or 7. Further, the degree of flexibility in the school entry rules is a policy question. On the one hand, low cost is an argument for inflexible rules. A rule saying that all children born in a calendar year shall enter school at the same time is easy to run and implies small administrative costs compared to a system where the parents have some choice of the school enrolment time, potentially combined with individual testing procedures. On the other hand, if there is a relationship between children's age and the ability to learn, strict rules may hurt children born in specific parts of the year. Thus, if reform towards more enrolment flexibility is to be considered such negative effects from strict rules should be identified and quantified. This paper addresses the question whether students gain or lose by being exposed to schooling at a younger age than their classmates, holding the quantity of schooling constant.

Empirical studies have not yet produced clear evidence on the issue. Some studies by specialists in pedagogy and psychology find that the youngest children in a grade seem to perform less well than their older classmates in several dimensions; lower test scores, higher propensity to repeat a grade and more likely to qualify for special education[1]. Others find that younger children do equally well as their younger class mates. A recent study by Mayer and Knutson (1999) from the US, using more sophisticated statistical methods, suggest that the younger students have even higher test scores than their older classmates controlling for schooling quantity. Most of these studies investigate the effects in the first grades. A particular issue in this paper is to study the age effect on achievement when students are about to leave compulsory schooling, since this achievement is likely to directly affect their future career in the labour and education market.

While most of the studies are done by none-economists, two economic papers have studied the link between age at enrolment and performance in the education and labour market. First, Leuven et al. (2003) use variation in potential enrolment age together with the incidence of holidays to estimate the effect of potential time in school on achievement for young Dutch children. Variation of birthdays relative to the summer holiday introduces an exogenous variation in potential time in school. They find that conditional on age, potential time in school increases achievement only for disadvantaged students. Their findings imply that the age effect and time in school effect cancel out for non-disadvantaged students.

Second, Angrist and Krueger (1991) used quarter of birth as an instrument for length of schooling in human capital earnings equations. Since US compulsory school laws imply that students have to remain in school until their 16.th or 17.th birthday (varies across states) and the school year starts in the third quarter, students born early in the year will have more schooling than students born in the third quarter. The identifying assumption is that quarter of birth does not affect earnings or productivity directly, only through the variation in length of schooling. Thus, an investigation of possible direct effects of age at enrolment on student performance is worthwhile in order to evaluate the general validity of the Angrist and Krueger approach.

An important challenge when addressing the age effect empirically is to isolate the effect of enrolment age from the effect of schooling quantity. This problem arises if children exposed to schooling at a young age also receive more schooling (measured as months of schooling) than children enrolled at an older age. Another, and related challenge is the possibility that

[1] A brief survey can be found in Mayer and Knutson (1999).

some parents may choose the enrolment date strategically in order to optimise their child's opportunities. For instance, if children are required to start school no later than the year they turn 7 years old, but parents are allowed to enrol their child earlier from the year they turn 6, the age distribution within a grade will partly reflect the decision of parents to enrol their child earlier or later. Thus, if school motivated parents have a higher propensity to delay school entry for children born late in the year, a simple regression of individual test scores in a given grade on student age measured in months could easily generate a biased estimate of the age effect.

The present paper contributes to the existing literature on school entry age effects by exploring the strict enrolment rules in Norway to identify and estimate the effect of age on achievement for 15-16 year old students tested in 2000 in connection with the OECD-PISA 2000 program. Norwegian children are exposed to very strict enrolment rules as the school law requires every child born in a certain calendar year to start school at the same point in time. An important element in the education policy in Norway has been to integrate children with different backgrounds and ability. Most important for the question at hand is that the possibility to except from the school entry rule by starting earlier or later is severely limited. As argued below, in practise, very few students get exception from the rules. Further, students almost never retain a grade or get promoted faster than the normal rule. Thus, a grade consists of children born in the same calendar year, with the students born in January nearly one year older than their youngest classmates. The basic identification assumption is that the strict enrolment rules and the absence of grade repetition allow me to treat the variation in birth dates across students in a given grade as exogenous. By estimating reduced form education production functions extended by students' age, I find that 15-16 year old students born late in the calendar year achieve significantly lower test scores in reading compared to their oldest classmates. This result is quite robust across several econometric specifications including fixed school effects and different sub-samples.

The paper is organized as follows: Section 2 presents a simple model to discuss enrolment age effects. Section 3 summarizes the existing literature on age effects. Section 4 describes the institutional details and the identification strategy. Section 5 presents the data and empirical results, while section 6 concludes.

2. Conceptual framework

In order to organize the discussion of potential effects of school entry age I use a simple model of education production inspired by the approach in Todd and Wolpin (2003). I concentrate on the role of the school in this process, while the behaviour of parents is not explicitly modelled. To proceed, consider two periods in the student's life: The preschool period and the school period. Consider a student entering school at a given point in time, 0, and then being exposed to formal schooling in a given time interval before being tested at time T. Let A_0 denote initial endowment of cognitive and non-cognitive resources affecting future achievement just before the student enter school, and A_T achievement at the testing time. Let Q_0 denote the student's age at time 0 (age at enrolment) and Z_0 family and individual characteristics affecting his individual endowment. Let S denote school resources allocated to the student during his school time, while Z is the family characteristics during school time. I now introduce the following behavioural relationships.

(1) $A_0 = f(Q_0, Z_0)$

(2) $S = S(A_0)$

(3) $A_T = g(A_0, S, Q_0, Z)$

Equation (1) implies that the student's initial endowments depend on students' age at enrolment, along with individual and family characteristics. Although it is most reasonable to assume that $\frac{\partial f}{\partial Q_0} > 0$, i.e. higher age imply higher endowment of initial resources (higher initial achievement), one could imagine family and home conditions under which the student actually lose from being exposed to the home environment fore a longer time.

Equation (2) formalizes the idea that schools redistribute their resources between different students based on initial student endowment. Thus, if school resources are distributed in a compensatory manner, students with low initial endowment may be given more attention from the teacher or allocated extra teachers or assistants. Equation (3) implies that the student's achievement at time T depends on initial endowments, school resources and the age at which he is exposed for the school environment. Inserting (1) and (2) into (3), I obtain the following expression for the total effect of increasing enrolment age on achievement at time T.

(4) $\frac{\partial A_T}{\partial Q_0} = \frac{\partial g}{\partial A_0}\frac{\partial f}{\partial Q_0} + \frac{\partial g}{\partial S}\frac{\partial S}{\partial A_0}\frac{\partial f}{\partial Q_0} + \frac{\partial g}{\partial Q_0}$

According to (4) the total effect of age at enrolment on achievement operates through three main channels. The first term in (4) reflects that an increase in enrolment age affects initial endowments. Since the achievement effect of higher endowment is positive and initial endowment is positively related to age at enrolment, the first term is positive. It is reasonable to believe that the effect of age at enrolment through this effect is most pronounced in the first grades, i.e. for low T. The second term represents the effect of enrolment age on the distribution of school resources. If school resources are distributed across students in a compensatory manner, this term is negative. The last term represents the direct effect on achievement from being exposed for formal schooling at an older age. To illustrate, if a teacher reads the same text to two otherwise equal students, one exactly 9 years old and the other nearly 8 years old, the effect on achievement for the two students may differ. Some cognitive theories suggest that young children are more receptive for learning than older ones, while others take the position that children have to reach a certain age in order to learn more complex material. Thus, the sign of the third effect is ambiguous and it would obviously depend on the curriculum faced by the students.

The most satisfactory approach would be to identify the separate contribution from each of these channels. However this is a very demanding task. For instance, identification of the pure school learning effect (the third term in equation (4)), requires conditioning on initial endowments immediately prior to school entry and on school resources allocated to individual students during their whole school career. Since this requires unrealistic amounts of data, the ambition in this paper is to estimate the total effect of exogenous variation in school entry age on achievement, conditional on school quantity (measured in school years or months). This question should be of interest to policymakers when deciding whether to change the compulsory enrolment age or to make the enrolment rules more flexible. The empirical challenge discussed below is to ensure that the school entry age variation is exogenous and possible to separate from variation in length of schooling.

3. Existing literature.

The existing literature on education outcomes and school enrolment age is quite diverse. Some educational studies have typically found that the oldest children in a cohort perform better than their younger classmates, but that the effects are relatively small and tend to decrease as the children reach higher grades [Crosser (1991), Sharp et. al. (1994)]. An interesting study by Cahan and Cohen (1989) used data on achievement for 5 and 6-graders in Jerusalem schools to estimate the separate impacts of one year of additional schooling and one year of age on cognitive development. Their point of departure is that students born close to the cut off enrolment date are approximately similar in age, but those born just before the cut off date have one year additional schooling compared to those born just after the cut off date. The achievement difference between these children then gives an estimate on the effect of an additional year of schooling holding age constant. The age effect was estimated by comparing within grade achievement between those born early and late in the academic year. A problem in their study is that school admission was delayed or accelerated compared to the normal cut off date for a significant part of the children and this was most frequent for children born close to the cut off date. To cope with this problem, they excluded from the within grade analysis the children who were under-aged or over-aged and those born close to the cut off date. While they estimate a positive effect of age on within grade achievement, they conclude that one year of additional schooling gives three times more achievement than one year of age.

Morrison et al. (1997) tried to isolate the pure school learning age effect from the initial endowment effects. They used cut off school entry age to compare the achievement growth of first grade children born just after the cut off date with the achievement growth of children born just before the cut off date. In addition, to obtain a pre-post research design, they used kindergarten children just too young to join the first grade as a control group to assess how much a child at the same age would have learnt when not being in first grade. They used a total sample of 539 children from 26 schools in one city in Canada. The results showed that the youngest and oldest children in first grade had similar growth in achievement and that the youngest first graders did significantly better than the control group. Thus, they argue that early enrolment will likely have a positive effect on student performance in early grades. However, their results do not provide evidence on the long time effect from early schooling.

Another interesting recent study by Mayer and Knutson (1999) extends the literature on achievement effects by using data from US schools and exploring differences in enrolment age and procedures across states to obtain identification of the causal effect of age. Their results show that children exposed for schooling at a younger age scores *higher* on cognitive tests compared to older ones conditional on schooling length. This latter result may suggest that lower school enrolment age is a promising policy tool.

Other researchers have investigated the effect of school entry age on other aspects of student behaviour. Shephard and Smith (1986) found that children who were young relative to their classmates, i.e. born just before the school entry cut-off date, had a higher risk of grade repetition. Another strand of literature studies the relationship between age in school and the incidence of psychological disorders. Based on a large sample of children from UK, Goodman et. al. (2003) presents evidence that the youngest children in a school year is more prevalent to psychological disadvantage than older children

An important drawback of many of the studies of the age effect on several aspects of student performance is that they do not take into account that the possibility of strategic enrolment decisions by the parents along with grade repetition decisions made the schools may cause serious bias in the estimated effects. Another weakness of many studies is the usually small samples used by the researchers.

As to research done by economists, a recent interesting paper by Leuven et al. investigate the relationship between early test scores and time in school using exogenous variation in the potential schooling time generated by enrolment rules in the Dutch school system. Dutch children are required to start school at the beginning of the school year they turn 5 years old[2]. However, the children may actually start school from their 4.th birthday on. The children choosing this option, spends the time in the first grade, and than starts grade one again from the beginning of the school year. Children having their 4.th birthday before the summer holiday has a lower number of potential school months than children having their 4.birthday after the holiday, conditional on age. This creates an exogenous variation in potential school time conditional on age, and the authors find that increased potential school time increase second grade test scores for the disadvantaged students only. On the one hand, starting school earlier increases school length, which has a positive effect on test scores. On the other hand, being exposed for schooling at a younger age has a negative effect on achievement. Their findings indicate that the net effect on achievement is positive only for disadvantaged

[2] The school year in the Netherlands lasts from October 1 to September 30.

students. It is however an open question to which extent these results carry over to achievement in higher grades.

Another type of research, initiated by Angrist and Krueger (1991), have used birth quarter as an instrument for education attainment in human capital earnings equations. Since US students in the time period analysed were obliged to stay in school until a certain age that varied across states, students born in different quarters of the year would have different compulsory length of schooling. Interestingly, the identification assumption behind the Angrist and Krueger study was that age at enrolment did not affect worker productivity directly; only indirectly through the length of compulsory schooling. This assumption would not be valid if enrolment age affects student achievement for given quantity of schooling, a question raised by Bound and Jaeger (2000) in their critic of the Angrist and Krueger approach.

To sum up, although researchers from several disciplines have investigated the relationship between age at school entry and school and labour market performance, the evidence is so far not conclusive. One particular problem with much existing research on the issue is the failure to identify the total school entry age effect conditional on school quantity, particular in circumstances when school entry age is to some extent a choice variable for the parents. A second weakness is that most of the evidence is based on children in early grades. Thus the size of the age effects on student's achievement at the end of compulsory school is still an open question.

4. Institutions, empirical strategy and data.

4.1. Institutional context and empirical strategy.

The empirical challenge is to estimate the effect of exogenous variation in students' age on student achievement conditional on school length. Most countries use specific cut off dates such that children born within a certain time interval, i.e. a calendar year, starts school at the same time. A simple strategy to identify age effects would then be to compare achievement for children born at different dates in the calendar year using the assumption that birth dates are randomly distributed within the year. At least two main obstacles may exist to this simple procedure. First, many countries give parents some choice regarding enrolment date. As an illustration, in the Netherlands, all children is required to enrol in the beginning of the academic year they turn five years old, but they have the option to enrol from their 4. birthday

[Leuven et. al. (2003)]. Second, in many countries students' advancement from one grade to another is conditional on a minimum achievement level. Both these possibilities will imply that the age variation within a grade is not exogenous and that the length of schooling across students within a grade is not constant. Thus, variation in achievement levels across student ages within a grade would then reflect both variations in age, variations in school length and potential variations in parents' propensity to delay or accelerate school start for their children.

I will argue that three features of the schooling system in Norway make it possible to rely on a simple empirical strategy to identify the age effect. First, the school enrolment date or year is not subject to parental choice. According to the school law the students in the sample had to enrol in school in the year they became 7 years old and had to join compulsory school for 9 years.[3] Exemptions from this rule required a formal application from the parents, and the application had to be approved by health and school specialists, while the final decision were taken by the local government. Accordingly, very few children were exempted from the rule. Second, while grade retention is quite normal in the US and several other countries around the world, this almost never happen within the Norwegian compulsory school system. This is consistent with the strong integration and equalizing policy that all students within a cohort should be treated equal, and be given education in their ordinary classes. Thus, all students who have been exposed to the Norwegian school system during their whole school career have identical length of schooling. Third, private schools cover a negligible fraction of the students, implying that the only realistic choice for the parents is the public school system regulated by the school law. The public schools use a national curriculum and are subject to national rules on maximum class sizes, criteria for special education and teacher certification. Finally, all students start school in mid August and the school year lasts until mid June.

These institutional features imply that the enrolment date for the children born in a certain calendar year is in reality not a choice variable for the parents, and that nearly all students tested in a given grade have been exposed for exactly the same number of school years and months. Further, as the cut-off date is January 1, a student born in January entered school nearly 1 year older than a student born in December. The institutional setting described above suggests that the age variation within a grade is only due to differences in birth date. To ensure that we only include students exposed to the Norwegian public school system

[3] From 1997, the school entry age was changed to 6 years, while the number of school years increased from 9 to 10.

throughout their whole school career, we include only students born in Norway. The fact that 99.5% of the remaining students in public schools born in 1984 in the Norwegian PISA study reported that they were in grade 10 documents that the institutional arrangements regarding enrolment and grade were actually enforced. Thus, the Norwegian setting provides a nice opportunity to identify effects from age at school entry on student performance. The simplest way to do this is to compare average test scores for students born in different quarters within a year. However, this will not be a satisfactory strategy if birth season differs systematically between individuals with different backgrounds. For instance, if highly educated parents for some reason have a higher propensity to have children born in the first quarter of the year than others, simply comparing average test scores could erroneously indicate that children born early in the year have higher test scores. Accordingly, I choose to embed the analysis of age of enrolment effects in the education production function tradition, see Hanushek (2003) and Todd and Wolpin (2003) for an extensive review. This literature emphasizes the role of both individual background variables and school resource variables as the main determinants of education achievement.

4.2. Data description

Empirical research on enrolment age effects on student achievement requires access to achievement data combined with detailed information on student age and grade. The data used in this paper consists of the Norwegian part of the international PISA 2000 data from testing 15-16 year olds in reading, which in addition to test scores includes of a huge amount of information on individual background factors including birth month and year. The tests were completed between March 27 and April 15, 2000. Since I only have information on test scores at one point in time, the test scores reflect the cumulative effect of school, individual and family effects during the entire life and school time up to the test date. The reading test consisted of three parts: One part focused on retrieving information, another part focused on interpreting text and the third part focused on reflection and evaluation. Within each of these parts, the students answered several questions. To obtain a reading test score index, the PISA study used Item Response Theory (IRT) to calculate weighted averages of the correct answers to all questions with the difficulty of the questions as weights[4]. In a final step the individual test scores were standardized across OECD countries with mean 500 and standard error equal

[4] More details on this procedure can be found on the PISA web site, http://www.pisa.oecd.org/index.htm. Fertig and Smith (2002), Wolter and Vellacott (2002) and Fertig (2003) are recent examples on studies using the PISA data to estimate education production functions.

to 100. The methodology used to obtain the test scores in the PISA study is very similar to that used in the international study of student performance in mathematics and science (TIMMS)[5].

To ensure that the students included in the analysis have all been exposed to the Norwegian school system in their whole school career, I exclude students born in other countries. Moreover, I exclude from the analysis the few students reporting grades other than grade 10 and students in non-public schools.

5. Empirical results.

5.1. Descriptive evidence

I first present in Table 1 the raw mean test scores for students born in different quarters of the year 1984. The picture is quite clear: Students born in the first quarter have a mean score about 17 points above those born in the fourth quarter. This is a first indication that the youngest students face a real disadvantage relative to their older classmates. Figure 1 presents a further illustration of the relationship between test scores and age with birth month on the horizontal axes and mean test score on the vertical axes. Measuring birth date at the monthly frequency reveals much the same broad picture: older students have a higher test score than younger ones. However, such raw data differences can be driven by composition effects due to systematic relationships between birth season and family background variables affecting student achievement. Thus, it is important to control for other family and school specific factors that may affect student performance. Another reason for estimating the age effect conditional on other factors determining achievement is to gauge the quantitative effect of age variation.

5.2. Reduced form education production functions.

In this section I present the results from estimation of reduced form education production functions extended by variables representing student age. While the PISA data set contains numerous variables describing the students attitudes towards school, homework, time use and so on, these variables are likely to be outcome variables and thus should not be included as determinants of achievement. One possible threat to my empirical strategy is the possibility that birth season is correlated with observable or unobservable determinants of student

[5] Woessmann (2003) contains a detailed discussion of the TIMMS data. Hanushek and Luque (2002) is another recent example of the use of these data in estimation of education production functions.

performance. Consequently, I choose to include reasonably objective student background and family variables traditionally used in education production functions: Gender, father and mother's education and labour market attachment, and educational resources at home are standard variables. Following this tradition I include a gender dummy variable, dummy variables indicating whether mother (father) has higher education and dummy variables indicating whether mother (father) has a fulltime job. To account for educational resources at home I include dummy variables indicating whether the family has between 10 and 50 books, between 50 and 100 books, between 100 and 250 books and above 250 books at home. Families with less than 10 books serve as the reference group.

Further, a number of studies including Behrman and Taubman (1986), Plug and Wijverberg (2003), Wolter and Vellacot (2002) and Bonesrønning (2003) find that birth order and family size have significant effects on student achievement. Older siblings are found to achieve higher test scores and to have a higher propensity to attain college, than younger ones presumably because the oldest siblings and the children in small families receive more education resources at home. If birth season tends to differ systematically between say the first and second child, it would be important to control for these variables, and accordingly I include the students number of siblings and dummy variables indicating whether the student is single child, first born and middle born with youngest child being the reference category. Moreover, I also include a variable indicating whether the student speaks another language than Norwegian. This is a potential important variable in determining reading test scores. A final variable included to capture family background is a dummy variable indicating whether the student lives with both parents.

Another determinant of student performance is school resources. Since the coefficient of interest is an individual characteristic, we can control for resources affecting all students in the school equally in a very general way by including school specific effects. This is potentially important if birth season vary geographically.

The first column in Table 2 shows the result from a simple specification with the student age measured in months and with only student and family characteristics included. The effect of student age is significantly positive and implies that a student born in January scores about 17 points higher than a student born in December, close to the gap found in the raw data. The second column in Table 2 extends the specification with school fixed effects and the results are almost unchanged. To account for possible non-linearities in the age effect, the third and fourth columns report the results from specifications with birth quarters. Again, the picture is remarkably stable, and implies that a student born in the first quarter scores about 14 points above students born in the fourth quarter of 1984. To gauge the quantitative relevance of the effect I compare the age effect with other standard determinants of student achievement. First, the effect of being born in the first quarter of the year is approximately similar in magnitude to the effect of having a father with high education. Second, the magnitude of the effect is close to half of the gender achievement gap since girls are found to have a reading score about 30 points higher than boys. Thus, based on these findings it is tempting to conclude that the rigid enrolment rules in Norway implies that students born late in the year face a significant disadvantage compared to their older classmates.

So far I have shown that the conclusion is robust with respect to the inclusion of several observed family characteristics and observed and unobserved school variables. It is still a possibility that part of the effect may be driven by unobserved family characteristics. If some potential parents believe in a negative effect on student performance from starting school at a young age, they may manipulate the time of birth in order to optimise their child's age at school enrolment. In particular, if unmeasured parental variables determining the propensity to fine-tune birth time with respect to school enrolment age is positively correlated with student performance, the above estimates may be biased upwards. However, the extent to which birth-date can be fine tuned is physically limited. One strategy to account for this would be to restrict the sample to only include students born very close to the cut-off date. Ideally, if I could include only students born, say the last week of December and those born the first week of January, being the youngest or oldest in class is reasonably a random event. Unfortunately, I cannot get that far since I only have data on birth month. Even if exact birth date data were available, reliable results from such a strategy would probably require a much larger total sample of students tested in each country than in the PISA study. A second best alternative is to restrict the sample to only those born in January and December and include a dummy variable indicating whether the student is born in January. The results from this specification are shown in the fifth column of Table 2. While the sample is quite small (425 students), the model reveals a numerically *higher* effect of student age than the above specification. According to the results from this restricted sample, a student born in January have close to 22 points higher reading score than a student born in December, other factors constant. Although, this strategy is less than perfect in removing non-randomness in student birth dates, it supports the earlier results that the youngest students face an important disadvantage due to the strict enrolment system.

5.3. Sub-sample results

Having shown that variation of student age within a grade, conditional on schooling quantity is generally important, it is of interest to investigate whether the effect differs between student groups. For instance, if the physical and mental development of boys are generally slower than for girls, being born late in the year may be more negative for boys than for girls. The two first columns in Table 3 show the estimation results when the sample is split between male and female students. The effect of student age (in months) is much the same across genders, while the effect of other family and personal characteristics differs quite substantial.

Another question is that the effect of being exposed to schooling at an earlier age may differ between students with different home resources. One possibility is that children with small educational resources at home in the preschool period may actually gain from being exposed to school at a young age. The results in Leuven et al. (2003) seem to indicate that the net effect on early test scores from more potential school time is positive for children with low parental resources. Unfortunately, I only have information on home resources at the test date, and thus cannot isolate the effect of home resources during the preschool period from the effect of home resources during the whole school career. Nevertheless, to provide some evidence on the distributional effects, I estimate the model on the sample of students with and without higher education. The results from this exercise are presented in the third and fourth columns in Table 3. There is some evidence that the age effect is stronger for students with high educated parents than for students with parents without higher education, but the difference is not dramatic. The same pattern arise if I split the sample according to the number of books at home as shown in the fifth and sixth columns in Table 3 where the model is estimated on the sample of students reporting less than 100 books at home and another sample of students reporting having more than 250 books at home. Thus, it is tempting to conclude that there is some weak evidence that the disadvantage from being born late in the calendar year is highest for children with relatively large home and parental resources.

5. Conclusion

This paper has investigated the relationship between students' achievement at the end of compulsory school, and the age at which students are exposed to formal schooling, holding schooling time constant. Using the Norwegian institutional arrangements with strict enrolment rules the variation in enrolment age generated by birthday variation is reasonably exogenous. The results show that younger students have a significant disadvantage relative to their older classmates. I find that the oldest students, born in January just after the school entry cut off date score nearly 1/5 of a standard deviation higher than the youngest students born in December, just before the cut off date. This age effect is approximately equal to the estimated effect from having father with high education. Further, I find that the age effects are fairly similar across students with different family backgrounds, although some weak evidence indicated that children with high educated parents suffered the most from being born late in the calendar year. While I cannot offer a structural interpretation of the results, it does indicate that there is a potential gain from using more flexible school entry rules.

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Table 1. Mean achievement across birth quarters. Students born 1984, 10.grade.

Birth quarter	Mean test score in reading	Number of students
1. Quarter	515.0	960
2. Quarter	512.4	1012
3. Quarter	504.2	893
4. Quarter	498.8	797

Figure 1. Average test score by birth month

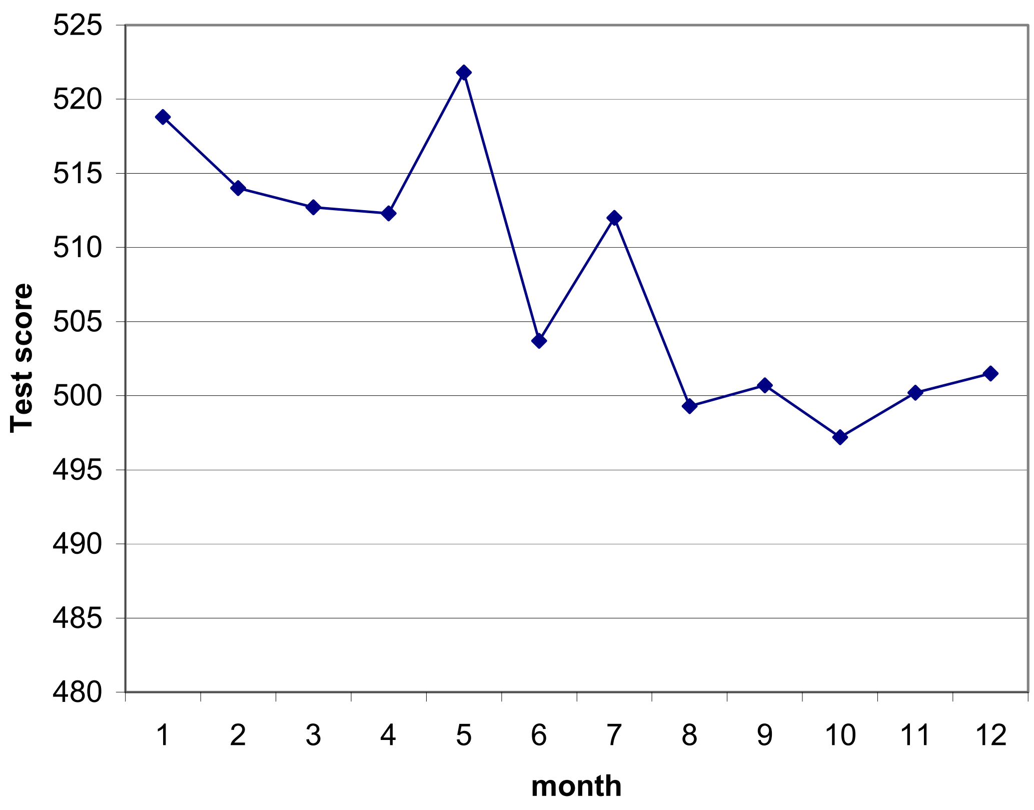

Table 2.Education production functions estimates. Reading. Adjusted for clustering. Robust standard errors in parenthesis. ** (*) denotes significant at 5% (10%) level.

Explanatory variables	All students	All students	All students	All students	Students born in January and December
Age (in months)	1.614 (0.476)**	1.652 (0.506)**			
Born 1.quarter			13.770 (4.208)**	14.443 (4.958)**	
Born 2.quarter			9.598 (4.860)**	10.077 (4.905)**	
Born 3.quarter			4.080 (4.468)	3.872 (5.069)	
Born January					21.749 (7.895)**
Female	33.459 (3.709)**	32.082 (3.412)**	33.499 (3.707)**	32.145 (3.413)**	22.792 (9.289)**
Home language	52.141 (11.446)**	50.337 (10.439)**	52.248 (11.463)**	50.364 (10.445)**	53.706 (35.442)**
Fulltime mother	6.777 (3.977)*	6.065 (3.555)*	6.871 (3.950)*	6.126 (3.556)*	11.135 (10.058)
Fulltime father	7.825 (6.156)	7.631 (5.31)	7.675 (6.144)	7.492 (5.321)	12.826 (12.194)
Mother high education	-0.366 (4.595)	-4.115 (4.103)	-0.571 (4.589)	-4.337 (4.096)	-0.528 (11.279)
Father high education	13.407 (4.026)**	10.647 (4.054)**	13.666 (4.030)**	10.887 (4.053)**	2.918 (10.831)
Living with both parents	14.531 (4.043)**	15.172 (4.092)**	14.372 (4.048)**	14.979 (4.096)**	7.593 (10.069)
Number of siblings	-4.323 (1.906)**	-2.453 (1.771)	-4.316 (1.916)**	-2.440 (1.773)	-9.179 (4.378)**
Single child	6.458 (9.674)	6.827 (8.952)	6.448 (9.691)	6.789 (8.965)	2.414 (27.048)
Oldest child	17.298 (4.469)**	17.335 (4.084)**	17.513 (4.471)**	17.547 (4.084)**	19.038 (10.787)*
Middle child	8.285 (4.692)*	6.658 (5.055)	8.389 (4.666)*	6.709 (5.062)	13.882 (13.913)
Books at home:					
11-50	30.918 (10.417)**	25.553 (8.831)**	31.047 (10.484)**	25.559 (8.836)**	63.729 (22.263)**
51-100	39.119 (10.409)**	33.885 (8.491)**	39.145 (10.447)**	33.852 (8.496)**	44.290 (21.313)**
101-250	65.161 (9.850)**	58.283 (8.325)**	65.120 (9.887)**	58.165 (8.327)**	71.068 (20.005)**
More than 250	80.399 (9.726)**	71.864 (8.181)**	80.545 (9.742)**	71.939 (8.184)**	87.413 (20.612)
School fixed effects	No	Yes	No	Yes	No
R^2	0.146	0.239	0.146	0.239	0.124
Observations	2795	2795	2795	2795	426

Table 3. Table 2.Education production functions estimates. Reading. Adjusted for clustering. Robust standard errors in parenthesis. ** (*) denotes significant at 5% (10%) level.

Explanatory variables	Females	Males	Both parents high education	None of parents high education	More than 250 books at home	Less than 100 books At home
Age (in months)	1.710 (0.657)**	1.556 (0.778)**	2.022 (0.884)**	1.595 (0.617)**	1.961 (0.823)**	1.462 (0.841)*
Female			39.136 (6.383)**	32.320 (5.324)**	44.435 (5.608)**	25.850 (5.549)**
Home language	27.821 (12.906)**	72.085 (19.754)**	27.337 (18.215)**	82.558 (23.092)**	52.587 (21.704)**	49.403 (17.755)**
Fulltime mother	10.025 (4.672)**	3.105 (5.742)	9.362 (7.051)	2.592 (5.394)	0.624 (6.297)	9.813 (5.894)
Fulltime father	15.559 (6.136)**	-2.327 (9.919)	1.801 (13.339)	5.467 (6.883)	14.082 (10.923)	-6.813 (7.619)
Mother high education	5.339 (5.493)	-5.842 (6.612)			12.116 (5.992)**	-8.495 (7.525)
Father high education	8.541 (5.161)*	18.795 (6.045)**			15.647 (6.647)**	10.932 (6.982)
Living with both parents	13.688 (5.235)**	16.158 (6.241)	16.908 (7.723)**	14.872 (6.360)**	5.199 (6.075)	10.750 (6.193)*
Number of siblings	-2.143 (2.556)	-5.547 (2.839)**	-7.171 (3.942)*	-4.648 (2.665)	-2.960 (3.237)	-8.357 (2.697)**
Single child	14.234 (12.257)	1.967 (13.249)	11.586 (20.627)	-2.094 (12.856)	15.179 (18.295)	-28.384 (14.113)
Oldest child	19.017 (5.393)**	14.467 (6.015)**	11.714 (7.504)	22.028 (6.812)**	22.235 (6.505)**	11.549 (7.144)
Middle child	7.098 (6.601)	7.131 (6.286)	10.453 (9.176)	11.287 (6.873)*	9.221 (8.651)	6.759 (7.017)
Books at home:						
11-50	15.457 (12.676)	43.141 (14.215)**	41.215 (25.532)**	26.659 (11.923)**		32.01 (10.261)**
51-100	29.999 (12.821)**	46.246 (15.243)**	73.925 (24.453)**	31.596 (11.327)**		40.979 (10.370)**
101-250	55.917 (12.821)**	73.248 (13.401)**	88.835 (22.747)**	57.035 (11.830)**		
More than 250	78.675 (11.911)**	79.980 (13.668)**	116.313 (23.611)**	63.583 (11.391)**		
School fixed effects	No	No	No	No	No	No
R^2	0.152	0.103	0.159	0.149	0.091	0.096
Observations	1400	1394	899	1225	1091	1032