The Long-Lasting Effects of School Entry Age: Evidence from Italian Students

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Using data for 9, 13 and 15-year-old students from three different datasets (PIRLS-2006, TIMSS-2007 and PISA-2009), we investigate whether the age at school entry affects children school performance at the fourth, eighth and tenth grade levels. Since student's age in a grade may be endogenous, we use an Instrumental Variable estimation strategy exploiting the exogenous variations in the month of birth coupled with the entry school cut-off date. We find that younger children score substantially lower than older peers at the fourth, the eighth and the tenth grade. The advantage of older students does not dissipate as they grow older. We do not find any significant effect of the relative age of a child with respect to the classmates' age. Finally, we show that secondary school students are more likely to be tracked in more academic schools rather than in vocational schools if they are born in the early months of the year.

Keywords: school entry age, educational production function, student achievement, choice of track; instrumental variables, Italy, PIRLS; TIMSS; PISA.

JEL classifications: I21, I28, J13; J24.

1. Introduction

What is the optimal age for children to begin school? Do the effects of age on achievement, if any, tend to persist as children grow older? Are there consequences of school entry age when individuals enter in the labor market? To answer these questions, a growing economic literature is investigating the effects of school entrance age on student achievement and on individual labor market performance.

In modern educational systems, due to a single annual cut-off date, all children born in a given cohort enter at school at the same time. For example, in Italy children turning six by the 31st December have to start school in September of the relevant year. This implies that in

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the same class some pupils – born in the early months of the year – are significantly older than other pupils born in the later months.

Younger pupils, who have not yet reached a sufficient level of maturity, may have more difficulties in learning and concentration and may accumulate less skills for any period of time spent at school. The problem is particularly relevant if the initial disadvantages of younger children are not cancelled along time and if, as Heckman (2000) points out, "early learning begets later learning and early success breeds later success just as early failure breeds later failure".

The organization of the educational system may exacerbate the problem of younger entrants if there exists tracking and students are separated into different groups or are assigned to academic or vocational tracks according to their initial educational achievement. In such a system, initial lower performance can translate in long-term consequences affecting adult labor market outcomes.

We investigate the effects of the month of birth on school performance of Italian students using three different, well-known, datasets analyzing the achievement of students in different subjects and at different stages of their scholastic career. Firstly, we study pupils' performance in Reading Literacy at the fourth grade using the 2006 PIRLS-Progress in International Reading Literacy Study. Secondly, we focus on Mathematics and Science knowledge for children at the fourth grade (approximately 9-year-olds) and eighth grade (13-year-olds) using the 2007 TIMSS-Trends in International Mathematics and Science Study. Finally, we deal with 15-year-old students, in their upper secondary school, using the 2009 PISA - Programme for International Student Assessment, reporting the type of secondary school chosen and students' performance in the fields of Mathematics, Science and Reading Comprehension.

The use of these datasets allows us to verify if there is an effect of the month of birth on school performance for 9-year-old students and if the effect of age remains stable or tends to decline as students progress along their career until students are 15 years old.

Since in Italy, as in many other countries, parents have some discretion on when their child starts school and teachers may decide if a pupil has to be retained in a grade, the student's age in a grade is not exogenously determined and may be correlated to observable and unobservable factors affecting school performance. Therefore, OLS estimators may yield biased results. Following the existing literature, we adopt an Instrumental Variable (IV) estimation strategy using as an instrument for the student's actual age the "expected age", that is, the age a student should have on the basis of his/her month of birth and of the established cut-off date.

We firstly show that younger children obtain significantly lower performance than older ones at the fourth grade. Starting school 11 months older causes an increase ranging from 0.20 to 0.40 standard deviations in a child's performance in reading comprehension, mathematics and science. More importantly, we show that the effects of age remain nearly unchanged for students in the eighth grade, when they are 13 years old. Moreover, we find that student's performance is little influenced by his/her age relative to the age of peers in a class: the age of classmates does not appear to affect a child's achievement neither at the fourth nor at the eighth grade.

In the second part of the paper, to investigate whether the age effect persists until adolescence, we use the PISA dataset measuring educational performance in Mathematics, Science and Reading for 15-year-old students. These students are typically in their upper secondary school and have already chosen a vocational, technical or academic track. We analyze if 15-year-old students' performance and their choice of the upper secondary school track is affected by their month of birth. We find that the performance of students born in the final months of the year is significantly lower than that of students born in the early months. Interestingly, the probability of choosing the Lyceum, the most academic oriented track, turns out to be significantly lower for younger entrants. This choice typically has direct consequences on the subsequent decision to enroll in a University and, probably, has also impact on future labor market performance.

Educational economists have recently analyzed for a number of countries the effects of school entry age on scholastic achievement and on individual labor market performance.[1] A first stream of the empirical literature focuses on the relationship between school entrance age and pupils' achievement. These studies use variations in birth date and school entry cut-off dates as an exogenous source of variations in entrance age in order to study the outcomes of children that are in the same grade but have different birth dates (Elder and Lubotsky, 2009; Datar, 2006). Findings from these studies suggest that younger kindergarten entrants face a disadvantage over older entrants which tends to fade away as children progress through

[1] Some previous studies in the educational psychology literature have found that children who have delayed entry at school show a lower performance than the same age peers and that children who are younger relative to their classmates have a higher risk of grade retention (Graue and DiPerna; 2000; Stipek, 2002, for a review). However, these studies typically do not take into account endogeneity problems in estimating school entry age effects.

school. Elder and Lubotsky (2009) also show that having older classmates increases the probability of grade repetition and the probability of a special education diagnosis. Bedard and Dhuey (2006) using TIMSS data for 19 OECD countries show that the youngest members of the fourth and eighth grade levels obtain lower scores than the oldest members in the same cohort. Similarly, Fredriksson and Öckert (2005) using Swedish administrative data find that children who start school at a younger age achieve both lower outcomes and have less years of education than their older peers. Significant effects of school entry age on educational outcomes in primary or secondary schools are also found by Puhani and Weber (2007) for Germany, by McEwan and Shapiro (2008) for Chile, by Smith (2009) for Canada and by Strom (2004) for Norway. On the other hand, Fertig and Kluve (2005) find no relationship between entrance age and educational performance for Germany.

A second stream of the literature examines how age differences in school entrance affect longer-term outcomes such as educational attainments and earnings. Some works have examined how the choice of the secondary school track depends on relative age: Puhani and Weber (2007) show that in Germany older students in a cohort have a higher probability to attend a more academic and prestigious secondary school track (Gymnasium); similarly, Jurges and Schneider (2007) find that older pupils are more often recommended to attend the Gymnasium.

Other findings suggest that early disadvantages held by relatively young children persist into adulthood by affecting higher education participation decisions and performance (Bedard and Dhuey, 2006; Crawford, Dearden and Meghir, 2010). On the contrary, Black, Devereux and Salvanes (2010) using Norwegian administrative data document that starting school younger has little effect on educational attainments, but a significant positive effect on IQ score measured at age 18 and on the probability of teenage pregnancy.[2]

Unclear results have been reached on the impact of month of birth on earnings and on labor market performance. Black, Devereux and Salvanes (2010) find that starting school younger has a small positive effect on labor market income whereas Fredriksson and Öckert (2005) show the existence of a negative effect. Dobkin and Ferreira (2010) for the states of California and Texas find a modest relationship between school entry age and educational attainment and no effects on job market outcomes, such as wages or the probability of

[2] Angrist and Krueger (1992) document that individuals born in the early months of the year tended to obtain less years of education in the past in USA but attribute this effect to the existing laws on compulsory schooling, imposing individuals to attend school until a certain age.

employment. Relative age effects have been found extremely important for professional players in some sports: for example, Barnsley, Thompson, and Barnsley (1985) have shown that a disproportionate fraction of players in the National Hockey League are born in the earliest months of the year.

All in all, whereas from the literature analyzing school performance emerges quite clearly that children entering at school older obtain better performance than their younger peers – ambiguous results have been obtained as regards the impact of school entry age on adult outcomes.

The paper is organized as follows. Section 2 briefly describes the institutional details of the Italian education system and describes the datasets used. Section 3 reports and discusses results from Two-Stage-Least-Square estimates on the effect of age at school entry for fourth and eighth graders. Section 4 shows the effects of the month of birth for educational outcomes of 15-year-old students. Section 5 concludes.

2. Institutional Background and Data

This section provides a brief description of the Italian educational system and presents the PIRLS, TIMSS and PISA datasets, giving some descriptive statistics.

The Italian educational system consists of a first cycle covering the primary school, which lasts 5 years, and of a second cycle covering the lower secondary education, with a length of 3 years, and the upper secondary education, with a length of 5 years. After secondary education, students may decide to attend university.

Primary school is normally attended by students between 6 and 10 years of age. The lower level of secondary education is attended by students between 11 and 14 years of age. It is divided into a first two-year period and a third year for guidance and transition to the upper level. The upper secondary education is divided into a first two-year compulsory course (attended by students aged from 14 to 16 year-olds) and a second three-year course.[3]

The Italian secondary school system can be described as tripartite, with an academic generalist track (“Lyceum”), a technically oriented education (Technical school) and a more labor market orientated track (Vocational or Professional school). Track selection is a relevant factor for individual future career since the type of secondary school strongly affects university attendance. Lyceum is considered the most prestigious secondary educational track

[3] Until recently, education was compulsory from 6 up to 14 years of age. The length of compulsory education has been prolonged up to 16 years of age in school year 2007/08.

and provides an in-depth, general knowledge aimed at preparing students for university. In contrast, Technical and Vocational schools offer an education oriented toward more practical subjects, enabling the students to start searching for a job as soon as they have completed their studies.

In Italy, a child is supposed to enter at school as long as he/she has reached the age of six by December 31 of the current school year which starts in September. This rule implies that, at the start of school, children born in January (who are six years and 8 months old) are the oldest in the class and those born in December (who are five years and 9 months old) are the youngest. Thus, in the same class pupils born in December are nearly one year younger than those born in January.

Parents have some discretion in deciding the entry age, in particular they can anticipate the date of entry of their children.[4] In some cases, they can decide to delay the date of entry of their child. However, in Italy the cut-off date rules are quite strictly followed: the vast majority of students start school on time and normally advance through the grades and grade retentions are rare.

For our empirical analyses we combine three different datasets: PIRLS, TIMSS and PISA, all of which include student test scores and information on students', families' and schools' characteristics.

The Progress in International Reading Literacy Study (PIRLS) is an international assessment of the reading comprehension of children in their fourth year of schooling, conducted by the International Association for the Evaluation of Educational Achievement (IEA). PIRLS consists of a main survey focusing on a reading comprehension test and a background questionnaire. The test is designed to address the process of comprehension and the purposes for reading (that is, reading for literary experience and reading to acquire and use information). For the purpose of our analysis we use the second cycle of the study conducted in 2006 (PIRLS-2006). The Italian sample includes 3,581 students at the fourth grade coming from 150 schools.

The Trends in International Mathematics and Science Study (TIMSS) is developed and implemented every four years by the IEA. TIMSS is a system of international assessments focusing on mathematics and science knowledge and skills of fourth and eighth-graders. TIMSS also contains contextual information about teaching and learning collected

[4] A recent reform allows children turning six by the 30 April of the current school year to be enrolled, upon request of parents and conditioned on the availability of place at school.

from students, teachers, and heads of school questionnaires. We use the fourth wave of TIMSS which refers to data collected in 2007. The Italian sample includes 4,470 students in the fourth grade (approximately 9 years old) and 4,400 students in the eighth grade (approximately 13 years old) coming from a total of 340 schools randomly selected and weighted to be representative of the nation.

Finally, we use the Programme for International Student Assessment (PISA) developed every three years by the Organization for Economic Cooperation and Development (OECD). PISA is a system of international assessments focusing on 15-year-olds' capabilities in reading, mathematics and science literacy. We use the recently released fourth wave of PISA which refers to data collected in 2009 mainly focused on measuring performance in reading literacy. The PISA contains a rich set of information on students', parents' and schools characteristics. The Italian sample includes 30,780 students at the age of 15 tested in about 1,000 schools. It is stratified for 20 geographical regions and for the type of secondary schools attended (Lyceums, Technical schools and Vocational institutes).

Table 1 presents descriptive statistics for the main variables used in the analysis separately for PIRLS, TIMSS and PISA. The test scores in PIRLS, TIMSS and PISA have been standardized to an international mean of 500 and a standard deviation of 100.

Table 1. Descriptive statistics for the main variables used

	PIRLS 2006 Fourth Grade		**TIMSS 2007 Fourth Grade**		**TIMSS 2007 Eighth Grade**		**PISA 2009 15-year-olds**	
Variable	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Reading Score	550.632	61.889					488.314	91.161
Math Score			506.145	73.181	480.469	72.851	485.100	86.994
Science Score			534.628	76.343	495.071	72.980	491.052	90.532
Age	9.196	0.347	9.150	0.354	13.242	0.452	15.202	0.282
Female	0.484	0.500	0.487	0.500	0.480	0.500	0.487	0.500
Father's education	10.922	3.697			8.915	5.202	12.258	4.203
Mother's education	11.184	3.653			8.841	4.985	12.375	4.135
Books (0-10)	0.134	0.341	0.144	0.351	0.108	0.310	0.111	0.314
Books (11-25)	0.192	0.394	0.308	0.462	0.227	0.419	0.189	0.391
Books (26-100)	0.340	0.474	0.304	0.460	0.278	0.448	0.303	0.459
Books (101-200)	0.148	0.355	0.120	0.326	0.159	0.366	0.187	0.390
Books (>200)	0.185	0.388	0.124	0.330	0.229	0.420	0.211	0.408
North-West	0.234	0.424	0.240	0.427	0.217	0.412	0.240	0.427
North-East	0.174	0.379	0.180	0.384	0.158	0.365	0.169	0.375
Centre	0.167	0.373	0.174	0.379	0.188	0.390	0.182	0.386
South	0.248	0.432	0.229	0.420	0.265	0.441	0.277	0.448
Islands	0.177	0.381	0.176	0.381	0.172	0.378	0.131	0.337
Observations	3581		4470		4407		30780	

Source: PIRLS 2006; TIMSS 2007; PISA 2009.

Average PIRLS Reading score for fourth graders is 550, Math and Science scores are respectively 506 and 534 at the fourth grade, while are 480 and 495 at the eighth grade (TIMSS). Average PISA reading, math and science test scores are 488, 485 and 491, respectively. The statistics show that whereas the performance of Italian students is well above the international average at the early grades, it becomes progressively worse in secondary schools.

The actual age in months is computed at the start of the scholastic year (September) using the student's month and year of birth. At the fourth grade the average *Age* is 9.2 years, at the eighth grade is 13.2. In the PISA dataset average *Age* is 15.2.

3. The Effects of School Entry Age on Fourth and Eighth Grade Students' Performance: Instrumental Variable Estimates

In this Section, to evaluate the effects of age at school entry we use PIRLS data on students' reading literacy at the fourth grade and TIMSS data for performance in mathematics and science for pupils at the fourth and the eighth grade levels.

We estimate the following model for student achievement:

[1] $$Y_i = \beta_0 + \beta_1 Age_i + \beta_2 X_i + \varepsilon_i$$

where Y_i represents the test score (respectively, in reading literacy, mathematics and science) of student *i*, Age_i is the observed age of student *i* (in months) at the start of the scholastic year, X_i is a vector of student and school characteristics (gender, language spoken at home, family socio-economic background, geographical area, city size, school socio-economic environment, etc.), ε_i is an error term capturing idiosyncratic shocks or unobserved student characteristics.

Notwithstanding the Italian law establishes that children should start school in the year they turn six, parents have some discretion on the age at which children are enrolled in school. Therefore, Age might be correlated with unobservable factors in the error term and using OLS to identify the age effect on educational outcomes may yield biased estimates. For example, the child's maturity level is unobservable to the researcher and left in the error term; presumably, maturity positively affects school performance, but it is negatively correlated to the school entry age: more mature children tend to begin school earlier and vice versa. In addition, teachers' decisions of grade retention – although rare in primary schools – shift children with learning difficulties to a class with younger classmates: so, retained children (with lower ability) become the oldest in the class. Given these parents' and teachers' behaviors, the student's actual age is negatively correlated to the error term and the OLS estimator of β_1 will be downward biased.

Following the literature (see, among others, Bedard and Dhuey, 2006; Puhani and Weber, 2007), we handle this endogeneity problem through an Instrumental Variable (IV) estimation strategy, using the *Expected Age* (or "Assigned Age"), that is, the age a child should have according to the month of birth and the school cut-off date, as an instrument for the student's actual age in months.

More specifically, since in Italy school starts in September, children born in January have an expected entrance age of 6 years and 8 months, while children born in December have an expected entrance age of 5 years and 9 months, and so on. We then calculate the *Expected Age* at the start of a grade (September) adding to the expected entrance age 3 years for pupils in the fourth grade and 7 years for pupils in the eighth grade.

To implement the IV approach, we use a Two Stage Least Squares (TSLS) estimator. The first stage equation we estimate is the following:

[2] $$Age_i = \pi_0 + \pi_1 \left(Expected\ Age_i \right) + \pi_2 X_i + v_i$$

where v_i represents unobserved determinants of student's effective age in a given grade. *Expected Age* coincides with actual *Age* if pupils enter at school according to the rule and were never retained in a grade, while the expected age differ from the actual age for pupils who have delayed or anticipated school entry or for pupils who have been retained in some grade.

In Figure 1 we show the relationship between month of birth, the effective age and the expected age (in years, in this graph). It is evident the high degree of correlation between the effective *Age* of students and the *Expected Age* for the fourth grade (panels a and b) and for the eighth grade (panel c). Panels (a) and (b) show that compliance is almost perfect starting from children born in April, while a significant fraction of children born in January and February tend to go to school earlier. The evidence for the eighth grade suggests that pupils sent to school earlier tend to be retained more frequently, since the effective age becomes more similar to the expected age for students born in the first months of the year, while the effective age increases for students born in the later months of the year.

Figure 1 represents clear evidence that the condition of relevance, required for the validity of the instrument, is satisfied.

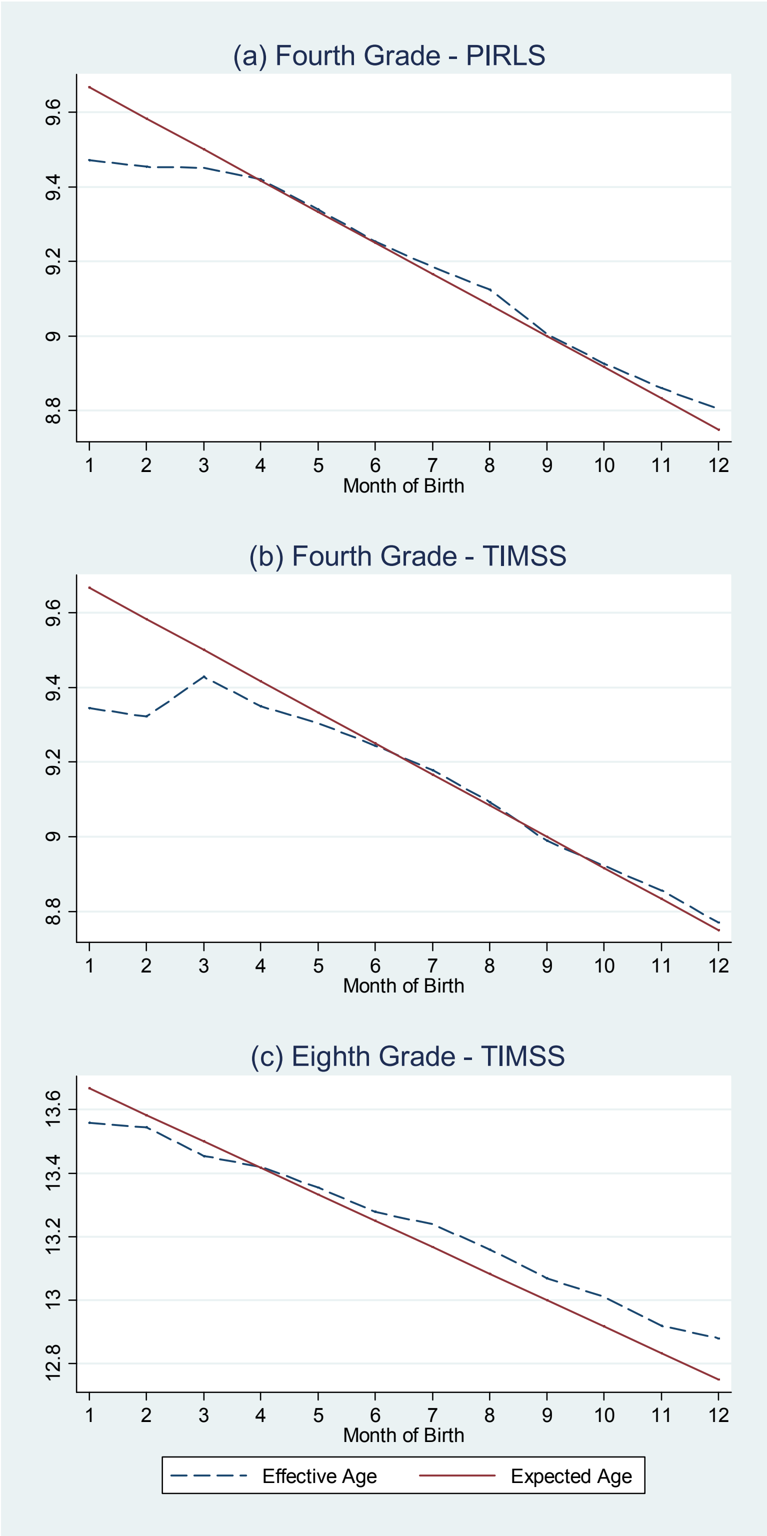

Figure 1. Expected Age and Effective Age in the Fourth and Eighth Grades

The second condition, the exogeneity, requires that the month of birth does not affect directly school achievement or it is not correlated to unobservable factors included in the error term in equation [1]. Bedard and Dhuey (2006) – thanks to a cross-countries comparison in which countries have different cut-off dates for school entry – were able to verify that the month of birth per se has no direct effect on achievement, that is, there are no “season of birth” effects. Similar findings have been obtained by Elder and Lubotsky (2009) and Datar (2006) exploiting different cut-off dates among US States.

Secondly, the exogeneity of the instrument requires that the month of birth is not correlated to other factors that may influence school performance, for example, it requires that parents with better background do not target particular months for their child’s birth. We verify if the instrument *Expected Age* is correlated with some observable characteristics by regressing *Expected Age* on all individual controls for all the datasets we use. The *F*-test for joint significance of all the regressors clearly shows that the observable variables have no effect on the student’s month of birth. Although this is not a test of exogeneity, it makes more credible that the instrument is not correlated with unobservable factors in the error term.

3.1. Age and Reading Comprehension (PIRLS)

Firstly, we analyze the impact of pupil’s age on the performance in reading comprehension at the fourth grade, measured using PIRLS data. Results from TSLS estimations in which we instrument *Age* with *Expected Age* (both measured in months) are shown in Table 2. For comparison, OLS estimations are reported in Panel C. In all the estimates, standard errors are robust to heteroskedasticity and adjusted for potential clustering at the school level.

Panel B of Table 2 reports the results from First Stage regressions with the *F*-statistics for the test of whether the instrument coefficient is equal to zero. The estimates show a strong positive correlation between the instrument, *Expected Age*, and the effective *Age* of students, reassuring us that the instrument is not “weak” (the *F*-statistic is over 800).

In panel (A) we report Second Stage estimates. In column (1) we do not include any control. The effect of *Age* is positive (2.15) and highly statistically significant (with a *t*-stat of 5.48): older students achieve a much better performance in Reading Comprehension.

In column (2) we include a set of variables to control for individual characteristics and family background: gender, number of books at home (5 categories), father’s and mother’s years of education, an indicator for parents born in Italy, a variable measuring the economic situation of the family, 5 dummies for geographical residence. The effect of age on pupils’ performance is almost identical to column (1), confirming that the *Expected Age* is not correlated to family background variables.

In column (3) we control for some school characteristics: 6 dummies for city size, 4 indicators for the percentage of students coming from disadvantaged families and 4 for the percentage coming from affluent families. In column (4) we control for school fixed effects instead of school characteristics.

The coefficient on *Age* is remarkably stable across specifications: older students achieve a higher performance of about 2.1 points for each additional month of age. This implies that a child born in January obtains nearly 24 points more than a child born in December, corresponding to an increase of 0.40 standard deviation of the dependent variable. The increase in performance caused by the difference of 11 months in school entry age corresponds to the advantage enjoyed by Italian native students with respect to immigrants or to the effect determined by about 10 additional years of education of parents. The magnitude of the effect is similar to that found in other recent works (see, for example, Puhani and Weber, 2007; Bedard and Dhuey, 2006).

Table 2. Two-Stage Least Squares Estimates. The Impact of Age at School Entry on Reading Literacy at the Fourth Grade (PIRLS data)

	(1)	(2)	(3)	(4)
Panel A: Two Stage Least Squares				
Age	2.151***	2.243***	2.179***	2.141***
	(0.392)	(0.352)	(0.363)	(0.306)
Individual Controls	NO	YES	YES	YES
School Controls	NO	NO	YES	NO
School Fixed Effects	NO	NO	NO	YES
Observations	3581	3029	2896	3029
Panel B: First Stage for Age				
Expected Age	0.803***	0.797***	0.803***	0.802***
	(0.027)	(0.028)	(0.026)	(0.025)
R-squared	0.441	0.477	0.497	0.547
First-Stage F-statistics	908.970	818.263	934.268	992.668
p-value	0.000	0.000	0.000	0.000
Panel C: OLS				
Age	0.678**	1.489***	1.492***	0.973***
	(0.322)	(0.304)	(0.291)	(0.254)

Notes: Age and Expected Age are in months. "Individual Controls" include: gender, number of books at home (5 categories), father's and mother's years of education, an indicator for whether parents are born in Italy, a variable measuring the economic situation of the family, 5 dummies for geographical residence. "School Controls" include 6 dummies for city size, indicators for the percentage of students coming from disadvantaged families and from affluent families. Standard errors, corrected for heteroskedasticity and adjusted for potential clustering at school level, are reported in parentheses. The symbols *** and ** indicate that coefficients are statistically significant, respectively, at the 1 and 5 percent level. Data source: PIRLS 2006.

It is interesting to compare IV estimates in Panel A of Table 2 with those obtained using OLS (Panel C): when we do not include any controls, the coefficient on *Age* is 0.68 (statistically significant at the 5 percent level) and becomes equal to 1.49 when we use a full set of controls for individual and school characteristics. The lower magnitude of OLS coefficients is likely due to the downward bias determined by the negative correlation between *Age* and some unobserved determinants of performance – for example, the child's level of maturity – included in the error term.

3.2. Age and Test Scores in Math and Science (TIMSS)

We now conduct the same analysis using TIMSS dataset for the fourth and the eighth grades. We consider as dependent variables, respectively, Mathematics and Science test scores. Results obtained using TSLS estimators are shown in Tables 3 (fourth grade) and Table 4 (eighth grade).

The specifications estimated are analogous to Table 2. In some cases, control variables are slightly different: we do not have available a single measure of income in TIMSS and we control for the following variables to take into account family income: "child has a computer", "child has a own study desk", "child has a own room". Moreover, we have information on parents' education only for the eighth grade and not for the fourth grade.

In Panel B of Tables 3 and 4 we show that the instrument, *Expected Age*, has very strong effects on the endogenous variable *Age*. Panel A presents TSLS estimates. Results using TIMSS data are similar to the findings obtained with PIRLS data. The age has a positive and highly statistically significant effect on the achievement in mathematics (columns 1-4) and science (columns 5-8) for children at both the fourth and the eighth grade levels. In the fourth grade, a child one month older obtains about 1.7 points more in Mathematics and 1.5 more in Science. In the eighth grade, the effect of an additional month of age is about 1.3-1.4 both in Mathematics and in Science. This means that pupils 11 months older obtain about 15 points more in test scores.

In Panel C are reported OLS estimates. For the fourth grade (Table 3), the OLS coefficients on *Age* are positive but often lower in magnitude than IV's coefficients. As regards the eighth grade (Table 4), OLS estimates are generally negative. This shows that the downward bias of OLS is more important for the eighth grade: probably the decisions of grade retention of teachers (which are rare in early primary grades and more frequent in the secondary school) play a relevant role in creating a correlation between actual age and the error term of equation [1].

Table 3. Two-Stage Least Squares Estimates. The Impact of Age at School Entry on School Performance at the Fourth Grade (TIMSS)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Panel A: Two Stage Least Squares							
	Dependent Variable: Math Test Score				Dependent Variable: Science Test Score			
Age	1.714***	1.519***	1.803***	1.770***	1.567***	1.334**	1.583***	1.561***
	(0.499)	(0.494)	(0.449)	(0.370)	(0.536)	(0.519)	(0.496)	(0.403)
Individual Controls	NO	YES	YES	YES	NO	YES	YES	YES
School Controls	NO	NO	YES	NO	NO	NO	YES	NO
School Fixed Effects	NO	NO	NO	YES	NO	NO	NO	YES
Observations	4470	4417	4195	4417	4470	4417	4195	4417
	Panel B: First Stage for Age							
Expected Age	0.674***	0.675***	0.688***	0.679***	0.674***	0.675***	0.688***	0.679***
	(0.029)	(0.028)	(0.028)	(0.027)	(0.029)	(0.028)	(0.028)	(0.027)
R-squared	0.306	0.316	0.353	0.390	0.306	0.316	0.353	0.390
First-Stage F-statistics	557.267	565.484	598.897	625.481	557.267	565.484	598.897	625.481
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Panel C: OLS							
Age	1.513***	1.545***	1.328***	1.268***	1.608***	1.717***	1.430***	1.357***
	(0.293)	(0.290)	(0.270)	(0.238)	(0.316)	(0.307)	(0.287)	(0.267)

Notes: Age and Expected Age are in months. “Individual Controls” include: gender, Italian mother tongue, computer possession, study desk, own room, 5 dummies for books at home, 5 dummies for geographical residence. “School Controls” include 6 dummies for city size, indicators for the percentage of students coming from disadvantaged families and from affluent families. Standard errors, corrected for heteroskedasticity and adjusted for potential clustering at school level, are reported in parentheses. The symbols *** and ** indicate that coefficients are statistically significant, respectively, at the 1 and 5 percent level. Data source: TIMSS 2007.

Table 4. Two-Stage Least Squares Estimates. The Impact of Age at School Entry on School Performance at the Eighth Grade (TIMSS)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Panel A: Two Stage Least Squares							
	Dependent Variable: Math Test Score				Dependent Variable: Science Test Score			
Age	1.471***	1.370***	1.213***	1.282***	1.571***	1.448***	1.329***	1.316***
	(0.373)	(0.375)	(0.360)	(0.362)	(0.375)	(0.369)	(0.369)	(0.355)
Individual Controls	NO	YES	YES	YES	NO	YES	YES	YES
School Controls	NO	NO	YES	NO	NO	NO	YES	NO
School Fixed Effects	NO	NO	NO	YES	NO	NO	NO	YES
Observations	4407	4407	3965	4407	4407	4407	3965	4407
	Panel B: First Stage for Age							
Expected Age	0.779***	0.779***	0.784***	0.770***	0.779***	0.779***	0.784***	0.770***
	(0.028)	(0.027)	(0.028)	(0.028)	(0.028)	(0.027)	(0.028)	(0.028)
R-squared	0.239	0.281	0.314	0.366	0.239	0.281	0.314	0.366
First-Stage F-statistics	783.316	815.671	776.018	748.339	783.316	815.671	776.018	748.339
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Panel C: OLS							
Age	-1.787***	-0.776***	-0.938**	-1.349***	-1.519***	-0.305	-0.476	-0.993***
	(0.281)	(0.278)	(0.286)	(0.239)	(0.280)	(0.265)	(0.265)	(0.223)

Notes: Age and Expected Age are in months. “Individual Controls” include: gender, Italian mother tongue, computer possession, study desk, own room, 5 dummies for books at home, father’s education and mother’s education, 5 dummies for geographical residence. “School Controls” include 6 dummies for city size, indicators for the percentage of students coming from disadvantaged families and from affluent families. Standard errors, corrected for heteroskedasticity and adjusted for potential clustering at school level, are reported in parentheses. The symbols *** and ** indicate that coefficients are statistically significant, respectively, at the 1 and 5 percent level. Data source: TIMSS 2007.

3.3. The Effect of Quarter of Birth for "Regular" Students

In this Section, as robustness check we carry out an alternative estimation strategy (see Cahan and Cohen, 1989) considering only "regular" students, entering at school according to the school entry rules. In practice, in each grade we exclude under-aged and over-aged students.

For the fourth grade of PIRLS 2006 we consider only those born in the calendar year 1996 (representing 93.5% of the whole sample). For the fourth grade of TIMSS 2007 we consider only students born in the year 1997 (90.6% of the sample). Finally, for the eighth grade of TIMSS 2007 we only deal with students born in the year 1993 (88.3% of the sample).

For "regular" students, the effective age coincides with the expected age and we are able to estimate by OLS: we find similar results to those shown in Tables 2-4 (not reported).

Using OLS for these samples of students it is possible to analyze the effect of the quarter of birth so to verify if the effect of age on performance is linear or not. We build three dummies respectively for the second, third and fourth quarter of birth. In Table 5 we present OLS estimates for performance in Reading Literacy (PIRLS) (column 1), Mathematics and Science in the fourth grade (TIMSS) (columns 2-3) and in the eighth grade (TIMSS) (columns 4-5), controlling for a full set of individual and school characteristics.

Results show that students born in the third and fourth quarter obtain systematically a worse performance than students born in the first quarter, with students born in the fourth quarter being systematically the worst performers. For example, in column (1) students born from July to September obtain 9.1 points less in reading comprehension (with respect to students born in the first quarter), while students born from October to December obtain 17.9 points less.

On the other hand, students born in the second quarter obtain performance not significantly different than students born in the first quarter. Considering that – as shown in Figure 1 – a fraction of students born in the first quarter tend to anticipate school entry, perhaps the latter are a selected sample and the second quarter born students could represent a better comparison group.

Table 5. Quarter of birth on "regular" students. OLS Estimates

	Reading 4th Grade PIRLS (1)	Math 4th Grade TIMSS (2)	Science 4th Grade TIMSS (3)	Math 8th Grade TIMSS (4)	Science 8th Grade TIMSS (5)
II Quarter (April-June)	-3.554	4.050	3.575	1.909	3.514
	(2.766)	(3.061)	(3.431)	(3.351)	(3.459)
III Quarter (July-September)	-9.072***	-7.932**	-8.868***	-5.544*	-5.345*
	(2.908)	(3.284)	(3.306)	(3.071)	(3.073)
IV Quarter (October-December)	-17.873***	-12.822***	-11.419***	-5.668*	-8.506***
	(2.824)	(3.122)	(3.386)	(3.307)	(3.218)
Individual Controls	YES	YES	YES	YES	YES
School Controls	YES	YES	YES	YES	YES
R-squared	0.170	0.115	0.126	0.118	0.152
Observations	2739	3806	3806	3890	3890

Notes: see Table 2 for the list of individual and school controls in column (1). See Tables 3-4 for the list of individual and school controls in columns (2)-(5). Standard errors, corrected for heteroskedasticity and adjusted for potential clustering at the school level, are reported in parentheses. The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at the 1, 5, and 10 percent level. Data source: PIRLS 2006 in column 1, TIMSS 2007 in columns 2-5.

3.4. Testing if the Age Effect Is Declining

To verify if the age effect declines or persists as pupils grow older, we pool together the TIMSS data for the fourth and the eighth grade and estimate the following model that includes an interaction term between age and grade:

[3] $$Y_i = \beta_0 + \beta_1 Age_i + \beta_2 X_i + \beta_3 Grade8_i + \beta_4 (Age_i * Grade8_i) + \varepsilon_i$$

According to equation [3], the effect of *Age* is β_1 in the fourth grade while it is $\beta_1 + \beta_4$ in the eighth grade. Therefore, β_4 measures the difference of the impact of *Age* between the two grades.

In this analysis we instrument *Age* with *Expected Age* while the variable $(Age * Grade8)$ is instrumented with $(Expected\ Age * Grade8)$. Results from the first stage estimations show that both instruments strongly determine the two endogenous variables (first stage results are not reported to avoid to clutter the Table).

Table 6 shows that the age effect for the performance in Math (columns 1-4) and Science (columns 5-8) in the fourth grade is in line with those found in Table 3, while the coefficient on the interaction term is never statistically significant. This implies that the age effect favoring older students that emerges in the early years of school tend to persist at least until the eighth grade, when students are about 13 years old.

Table 6. Is the Age Effect Declining? Pooled Fourth and Eighth Grades (TIMSS). TSLS estimates.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent Variable: Math Test Score				Dependent Variable: Science Test Score			
Age	1.714***	1.429***	1.722***	1.695***	1.567***	1.251**	1.522***	1.485***
	(0.499)	(0.493)	(0.470)	(0.372)	(0.536)	(0.521)	(0.498)	(0.409)
Age*(Grade 8)	-0.244	-0.029	-0.539	-0.398	0.004	0.206	-0.249	-0.176
	(0.623)	(0.616)	(0.590)	(0.516)	(0.654)	(0.636)	(0.618)	(0.542)
Individual Controls	NO	YES	YES	YES	NO	YES	YES	YES
School Controls	NO	NO	YES	NO	NO	NO	YES	NO
School Fixed Effects	NO	NO	NO	YES	NO	NO	NO	YES
Observations	8877	8824	8160	8824	8877	8824	8160	8824

Notes: "Individual Controls" include: gender, Italian mother tongue, computer possession, study desk, own room, 5 dummies for books at home, 5 dummies for geographical residence. "School Controls" include 6 dummies for city size, indicators for the percentage of students coming from disadvantaged families and from affluent families. Standard errors, corrected for heteroskedasticity and adjusted for potential clustering at school level, are reported in parentheses. The symbols *** and ** indicate that coefficients are statistically significant, respectively, at the 1 and 5 percent level. Data source: TIMSS 2007.

3.5. Relative Age and School Performance

In this section we investigate the effects on student achievement of the relative age of a child in the class by exploiting variations between classes in the average age of peers (see Elder and Lubotsky, 2009; Fredriksson and Öckert, 2005).

The classmates' age in principle could have both positive and negative effects on a child's school achievement. Student's performance would benefit if classmates are more mature, class is less noisy and teachers' attention is not diverted towards bad-behaving pupils. On the other hand, individual performance of relatively younger pupils would be negatively affected if classes are targeted towards more mature pupils who proceed at a faster pace or if younger students are bullied by older classmates and so on.

Understanding if the absolute age affects students' achievement or if it is the relative age that matters, has important policy implications. When absolute age is important, a postponement of the school entry age has positive effects on student achievement, while if the relative age is relevant, the postponement has no effect and probably a stratification in classes according to the month of birth would be appropriate.

To estimate the impact of the relative age versus the absolute age we estimate the following model:

[4] $$Y_i = \beta_0 + \beta_1 Age_i + \beta_2 X_i + \beta_3 \overline{Age}_{(-i)} + \beta_4 \overline{X}_{(-i)} + \varepsilon_i$$

With respect to model [1], $\overline{Age}_{(-i)}$ in [4] represents the average age of students in the class of *i* (excluding individual *i*), $\overline{X}_{(-i)}$ is a vector of averages of individual characteristics of classmates.

Since when multiple groups are formed out of a population small differences in composition will tend to emerge, there exists some variations between classes in the average

age. However, the standard deviation of $\overline{Age}_{(-i)}$ is about one third of the standard deviation of Age_i and this could be a problem in the precision of the estimates.

We instrument *Age* with *Expected Age* and the average age of classmates with the average of their expected age. In Table 7 we present TSLS estimates for school performance in Reading Literacy (PIRLS) (column 1), Mathematics and Science in the fourth grade (columns 2-3) and in the eighth grade (columns 4-5) (TIMSS). We separately evaluate the impact of the absolute age of a child and of the classmates' age on his/her performance. We control for a full set of individual and school characteristics. In all the specifications in Table 7 we cluster standard errors at the class level, given that $\overline{Age}_{(-i)}$ is defined at this level.

First stage results (not reported) show that the instruments strongly determine the two endogenous variables *Age* and $\overline{Age}_{(-i)}$.

Table 7. The Impact of Absolute and Relative Age on School Performance. Two-Stage Least Squares Estimates

	Reading 4th Grade PIRLS (1)	Math 4th Grade TIMSS (2)	Science 4th Grade TIMSS (3)	Math 8th Grade TIMSS (4)	Science 8th Grade TIMSS (5)
Age	2.195***	1.890***	1.650***	1.225***	1.347***
	(0.380)	(0.464)	(0.498)	(0.378)	(0.378)
Classmates' Average Age	0.611	-1.106	-0.996	1.757	2.537
	(3.532)	(3.707)	(3.807)	(2.596)	(2.561)
Individual Controls	YES	YES	YES	YES	YES
Class Average of Individual Controls	YES	YES	YES	YES	YES
School Controls	YES	YES	YES	YES	YES
Observations	2896	4195	4195	3965	3965

Notes: see Table 2 for the list of individual and school controls in column (1). See Tables 3-4 for the list of individual and school controls in columns (2)-(5). Standard errors, corrected for heteroskedasticity and adjusted for potential clustering at the class level, are reported in parentheses. The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at the 1, 5, and 10 percent level. Data source: PIRLS 2006 in column 1, TIMSS 2007 in columns 2-5.

TSLS estimates show that the effect of the own age on school performance is positive and significant. The magnitude is in line with the results emerging in previous estimates.

As regards the *Classmates' Average Age* we do not find any significant effect in any specification. The age of classmates never appears to affect a child performance. It is likely that the positive and negative effects related to classmates' age compensate each other. However, the estimates of the relative age effect must be taken with care, since the identification strategy is based on between classes variations of average age that has relatively limited variability.

4. The Effects of the Month of Birth for 15-year-old Students (PISA)

In this Section we focus on the educational outcomes of 15-year-old students, enrolled in the upper secondary school, using the 2009 OECD-PISA dataset. Whereas PIRLS and TIMSS data we have used in Section 3 consider the students enrolled in a given grade, regardless of their age, PISA data refer to 15-year-old students, regardless of the grade they are enrolled in. This selection of the sample has important consequences for the empirical strategy we conduct: we are not able to use the expected age as an instrument for the effective age since early and later starters and retained students differ for the grade they are attending rather than for their effective age.

The consequence is that we are able to estimate only a reduced-form equation, obtained by substituting equation [2] in equation [1]:

[5] $$Y_i = (\beta_0 + \beta_1\pi_0) + \beta_1\pi_1(Expected\ Age_i) + (\beta_1\pi_2 + \beta_2)X_i + \varepsilon_i + \beta_1 v_i$$

Expected Age is uniquely determined by the month of birth. The estimated impact of the expected age on school outcomes ($\beta_1\pi_1$) depends both on β_1 (the parameter estimated in the previous section) and on the "compliance rate" π_1, which in turn depends on the compliance of parents to the school entry rules and on the frequency of grade retentions in primary and secondary schools.

Using PISA dataset we consider how two educational outcomes are affected by the month of birth: 1) the probability of choosing a Lyceum, the academic track, versus the probability of choosing a Vocational school; 2) the performance in Mathematics, Science and Reading, controlling for the grade students attend.

4.1. Month of Birth and Choice of Secondary School Track

We estimate how the month of birth determines the probability of a student to enrol in a Lyceum (the generalist academic track) with respect to the probability of choosing a Vocational school, focusing only on upper secondary school students.

We exclude from the PISA 2009 sample the few students (125 observations, less than 0.5% of the sample) that are still in their lower secondary school (that is, in the seventh or in the eighth grade) and thus have not chosen a track. Among upper secondary school students, about 45% enrol in Lyceums, 31% enrol in Technical schools while 24% enrol in Vocational-Professional schools.

Table 8. Probability of Enrolling in a Lyceum or in a Vocational school and Month of Birth. Linear Probability Model

	(1)	(2)	(3)	(4)
	Dependent variable: Lyceum		Dependent variable: Vocational School	
Age (Month of Birth)	0.003***	0.003***	-0.003***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
Individual Controls	NO	YES	NO	YES
Observations	30780	26113	30780	26113
R-squared	0.000	0.223	0.000	0.110

Notes: In columns (1)-(2) the dependent variable is Lyceum, in columns (3)-(4) the dependent variable is Vocational School. "Individual Controls" include: gender, born in Italy, 5 dummies for books at home, father's and mother's years of education, an index for resources at home, 5 dummies for geographical areas. Standard errors, corrected for heteroskedasticity and adjusted for potential clustering at school level, are reported in parentheses. Sample weights are used. The symbols *** and ** indicate that coefficients are statistically significant, respectively, at the 1 and 5 percent level. Data source: PISA 2009.

Estimates of a linear probability model are reported in Table 8. In columns (1)-(2) we investigate the probability of enrolling in a Lyceum while in columns (3)-(4) we analyze the probability of enrolling in a Vocational school. In the first regressions (columns 1 and 3) we only use *Age* as a regressor; in the second specifications (columns 2 and 4) we include as controls some individual characteristics (gender, born in Italy, dummies for geographical areas) and a set of family background variables (5 dummies for books at home, mother's and father's years of education, an index for resources at home). Since our dependent variable is a dummy for the type of school chosen, we do not control for any school characteristics.

The effect of student's age on the probability of enrolling in a Lyceum is positive and highly statistically significant. The probability of going to a Lyceum increases of about 3 percentage points for a student born in January with respect to a student born in December. In contrast, the probability of enrolling in a Vocational school (columns 3-4) significantly decreases for students born in the first months of the year.

As robustness check, we also estimate the choice between 1) Lyceum, 2) Technical school, 3) Vocational school, using a multinomial logistic regression and we obtain qualitatively very similar findings (not reported).

Our findings – in line with the estimates of Puhani and Weber (2007) and Jürges and Schneider (2007) for Germany – have important implications: the age effect does not seem to dissipate after some initial years of school but persists and has long-lasting effects since the choice of a track at the end of the lower secondary education (grade 8) determines the type (and the quality) of upper secondary school undertaken. Importantly, the track chosen may affect the probability of enrolling in a university and lead to relevant effects on the future labor market career.

4.2. Age and Performance in the Secondary School

We now analyze, using simple OLS regressions, students' performance in Mathematics, Science and Reading in relation to their month of birth (see also Strom, 2004). Since in the PISA dataset students are enrolled in different grades – the large majority of them is in the tenth grade (81%), 17% are in grade 9 and about 2% are in grade 11 – we control for two dummies *Grade 9* and *Grade 11* to take into account the different number of years of education that students have been exposed to. [5]

Table 9 reports the results of OLS estimates. Panel A uses as dependent variable the Math test score, panel B uses the Science test score and Panel C uses the Reading test score. In column (1) there are no controls, in column (2) we control for *Grade 9* and *Grade 11*, in column (3) we add individual characteristics and family background controls.

In all the specifications results show that *Age* positively affects performance in Mathematics, Science and Reading Comprehension: older students perform significantly better than younger peers. The coefficient on *Age* reduces when we control for grade dummies, confirming that *Age* is positively associated with the grade levels.

In column (4), as a robustness check, instead of controlling for grade levels, we only consider "regular students", enrolled in the tenth grade (81% of the sample). Results are quite similar to those shown in column (3): the month of birth has a positive and significant impact on student's performance.

However, the magnitude of the coefficient on *Age* is significantly lower for 15 years old students. The difference in school achievement between a student born in January compared to a student born in December is about 8 points, corresponding to a 0.10 standard deviation of the dependent variable.

Table 9. OLS Regressions. PISA Test Scores and Month of Birth.

	(1)	(2)	(3)	(4)
	Panel A: Dependent Variable: Math Test Score			
Age (Month of Birth)	1.020***	0.539***	0.420**	0.397**
	(0.202)	(0.193)	(0.183)	(0.197)
Observations	30780	30780	26113	21235
R-squared	0.002	0.105	0.273	0.200
	Panel B: Dependent Variable: Science Test Score			
Age (Month of Birth)	1.256***	0.813***	0.739***	0.661***
	(0.209)	(0.203)	(0.189)	(0.206)

[5] Ideally, we should not control for outcome variables: if the student's age affects the grade (in fact, younger students are more likely to be retained in a grade) then we are controlling for an outcome and causing a downward bias to the age coefficient (see Angrist and Pischke, 2009). On the other hand, the grade has an influence on the materials covered and on the acquisition of skills that should be taken into account.

Observations	30780	30780	26113	21235
R-squared	0.002	0.103	0.289	0.218
	Panel C: Dependent Variable: Reading Test Score			
Age (Month of Birth)	1.357***	0.754***	0.735***	0.658***
	(0.204)	(0.193)	(0.180)	(0.196)
Observations	30780	30780	26113	21235
R-squared	0.003	0.126	0.329	0.245
Control for Grades	NO	YES	YES	Sample: only students in grade 10
Individual Controls	NO	NO	YES	YES

Notes: The table reports the coefficients of Age in regressions in which the dependent variables are Test Scores from PISA 2009 in Math (panel A), Science (panel B) and Reading (panel C). "Individual Controls" include: gender, born in Italy, 5 dummies for books at home, father's and mother's years of education, a variable measuring resources at home, 5 dummies for geographical areas. Standard errors, corrected for heteroskedasticity and adjusted for potential clustering at school level, are reported in parentheses. Sample weights are used. The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at the 1, 5, and 10 percent level. Data source: PISA 2009.

5. Concluding Remarks

We have investigated whether the age at school entry affects children school performance at the fourth, eighth and tenth grade levels for Italian students using three different datasets: PIRLS-2006, TIMSS-2007 and PISA-2009. To handle endogeneity problems plaguing the effective age of students, we have employed an IV estimation strategy, using as an instrument the student's month of birth in relation to the cut-off age.

Our findings show that the age effects are strong: younger children score substantially lower than their older peers at both the fourth and eighth grade levels. The advantage of older students does not dissipate as children grow older: we find significant effects even for 15-year-old students. In addition, we show that secondary school students are tracked in vocational rather than in more academic-generalist schools if they are relatively younger.

Therefore, the choice of school entry age is not innocuous: the age premium does not dissipate after the early grades and may have long-run consequences particularly through its effects on the choice of the secondary school track that, in turn, may affect the enrollment in university.

We confirm for Italy the results found for a number of other countries (USA, Germany, UK, Sweden) showing that school entry age is a relevant factor for student's performance. It is likely that since learning begets learning, the relatively low level of maturity of younger child preventing efficient learning in the early stages of academic career has long-lasting consequences on their school career and perhaps beyond.

The policy implications of our findings – if one is interested uniquely in school outcomes – is to delay the entry at school of children, waiting for them to have a higher level of maturity and greater ability of concentration. However, the benefits arising from increasing the school entry age must be compared with the opportunity costs deriving to individuals from a later entry into the labor market. Probably the ambiguous results found in the literature considering adult outcomes in relation to the school entry age are the result of this trade-off.

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