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ABSTRACT

The Younger, the Better? Relative Age Effects at University*

In this paper we estimate relative age effects in academic performance using a unique database of students at Bocconi University. The identification exploits school entry cut-off ages that generate up to 11 months difference between the youngest and the oldest students within each cohort. Our data allow to control for potential selection issues as well as for differences in cognitive ability, as measured by an attitudinal entry test. Contrary to most of the existing evidence for primary school children, we document that in university the youngest students perform better compared to their oldest peers, particularly in the most technical subjects. To rationalize this result we produce additional evidence on relative age effects in cognitive ability and in social behavior using a combination of data from Bocconi admission tests and from a survey on the social behavior of Italian first-year university students. We find that the youngest students in the cohort perform slightly better in cognitive tests and also appear to have less active social lives: they are less likely to do sports, go to discos and have love relationships. These results suggest that negative relative age effects in university performance might be generated by two mechanisms: (i) a profile of cognitive development that might be decreasing already around age 20; (ii) psychological relative age effects that lead the youngest in a cohort to develop social skills (self-esteem, leadership) at a slower pace. Younger students, thus, have less active social lives and devote more time to studying, as confirmed by additional evidence from the PISA study.

JEL Classification: J13, I21

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1. Introduction

A number of studies document that the oldest pupils in a given class or cohort typically outperform their youngest mates in a wide array of cognitive and academic outcomes (Bedart and Dhuey 2006; Crawford *et al.* 2007; Mayer and Knutson 1999). Such differences are more marked at early ages and fade away as children grow older, usually during early teenage hood.[2]

In this paper we analyze the academic results of university undergraduate students and, contrary to most of the existing evidence, we find that at the university level the youngest students perform better than their oldest peers, particularly in the most technical subjects.

Our main estimates are based on an extremely rich dataset of students who enrolled at Bocconi University between 1995 and 1998. These data allow to compare a homogeneous group of students for whom we have very complete information about their pre-university school careers as well as about their performance in the attitudinal entry test. We can thus control for selection issues and unobservable institutional features that plague most of the previous studies.

In the final part of the paper (Section 5), we explore two possible explanations for why the youngest students in a cohort outperform their oldest mates in our data while they are consistently observed to do worse at lower schooling levels by many other authors.

The first of such explanations is a combination of early learning and progression over the age-profile of cognitive development. Several papers have shown that starting school earlier is associated with better long-run outcomes (Fredriksson and Öckert 2005; Goodman and Sianesi 2005; Skirbekk 2005; Skirbekk *et al*. 2004). This is consistent with the recent theories in Cuhna and Heckman (2007a and 2007b), who argue that early investment in skills improves the productivity of later human capital investments. Thus, younger students should be advantaged by early learning either at school or in the family. On the other hand, since the profile of cognitive development is naturally inversed-U shaped (Salthouse *et al.* 2004), the youngest in a cohort are penalized at early stages and such a disadvantage levels off and possibly reverses at some later age.[3]

The combination of these two effects can easily reconcile our results with previous findings. While in earlier school levels the cognitive disadvantage of being young overcomes the

[2] Although, Crawford *et al.* (2007) do find some effects on 18 year olds.
[3] Satlhouse *et al.* (2004) and Jones (2005) suggest that the turning point in the profile of cognitive development might, in fact, be between age 20 and 25.

advantages of early learning, in university this second effect dominates. Consistently with this idea, we do find evidence of negative age effects in cognitive ability, as measured by entry test scores. However, these effects account only for a relatively minor fraction of the observed age based differences in academic performance.

We, thus, explore a second explanation that is motivated by a series of studies that look at the psychological effects of relative age (Thompson *et al.* 2004; Dhuey and Lipscomb 2006 but also Persico *et al.* 2004), where it is shown that the youngest pupils in a group develop important personality traits, such as self-esteem and leadership, to a lower extent or at a slower pace than their oldest mates. To explore the potential of this psychological mechanism, we produce additional evidence from a survey of the social behaviour of a sample of first-year university students in Italy, the *International Survey on Affectivity and Sex*.[4] We find that the youngest students in a given birth cohort are also those with the least active social lives: they are less likely to do sports, go to discos and have love relationships. Having less active social lives, younger students plausibly devote more time to studying and perform better at university. Consistently with this interpretation, we also document that, in the PISA study, younger students spend more time on their homework. These psychological effects become more and more important as students grow older and gain control over their time, and, thus, they emerge more evidently in our analysis than in previous works that focused on younger pupils.

Our results contribute to the literature in several directions. First, we produce evidence suggesting that a correct understanding of the long term consequences of early life events requires the analysis of both the mechanic of skill formation and the interaction of this process with endogenous choices on the allocation of time and effort. Given the recent emphasis on early policy intervention (Carneiro and Heckman, 2003; Cunha and Heckman, 2007b; Heckman and Masterov, 2007) we believe this to be a very relevant issue. Second, our findings support the idea that anticipating the age of school-entry as well as school-leaving might increase the efficiency of the school system by focusing on an age interval with higher returns to human capital investment (Mayer and Knutson 1999; Lutz and Skirbekk 2005). Finally, although relative age effects cannot be completely eliminated, as one will always be either younger or older than her peers, merely revising the rules of class formation can at least reduce relative age differences in the school

[4] The survey covers several countries but, for comparison with our Bocconi data, we limit our analysis to the Italian sample.

environment and, thus, potentially promote equality of later outcomes. For example, school cohorts could be defined by semester instead of year of birth so that the maximum age difference between students in a school class would be reduced from 11 to 5 months. Given the almost complete randomness of birth dates, this simple policy can be costlessly applied in any set up where the current school cohort is divided into more than just one class.

The paper is organized as follows. Section 2 describes our data and the institutional details of both the Italian school system and Bocconi university. Section 3 presents the main results on relative age effects at university. Section 4 contains a series of robustness checks. Section 5 provides additional evidence that helps rationalizing our results with the previous findings in the literature. Section 6 concludes.

2. Data and institutional details

The Italian educational system is such that most students turn 19 during their freshmen year at university.[5] The typical pupil would in fact start primary school the year she turned 6. Primary school lasts 5 years, unless the student fails one (or more) grades, in which case she would have to retake it and spend one (or more) additional years in primary school. At the end of the fifth grade all students take an exam to obtain their primary school certificate. The next schooling level is a 3-year junior high school, which also ends with a national exam. Primary and junior-high schools are compulsory so, regardless of the outcome of the primary school final exam, all children are required to enroll at a junior-high school.[6] Both primary and junior-high schools are completely homogeneous with no differentiation in curricula.

After junior-high school, students can voluntarily continue their studies at one of the several different types of high schools (lyceums, technical schools, et.), which normally lasts 5 years.[7]

[5] As we discuss later in this section, the main data used in our analysis include students born between 1976 and 1979. The school system described in this section is the one pupils born in these years were subject to. The system has been modified since then, with the most important change occurring in 1999, when compulsory schooling was increased by one year. None of the students in our data is affected by this change.

[6] The pre-1999 actual legal requirement imposes that all pupils aged between 6 and 14 should compulsorily attend school. However, students can satisfy the requirement by either passing the junior-high school final exam (thus even before they turn 14) or by having attended at least 8 years of full-time schooling as they turn 14.

[7] Some technical institutes offer 3-year degrees. However, only students graduating from 5-year high schools can go to university.

Thus, unless a student anticipated enrolment in primary school and/or failed one (or more) grades during her educational track, she would normally enrol at university the year she turns 19.[8]

Importantly, students are never streamed by ability in any school level. If anything primary and secondary school classes are formed either completely randomly or with the objective of maintaining a rather uniform distribution of family backgrounds, ethnicity, gender and other key characteristics both across and within classes.[9]

Our data come from the administrative archives of Bocconi university, a private and highly selective institution of higher education that specializes in Economics and Management. The database covers all students enrolled between 1995 and 1998, whose distribution of birth months is synthetically described in Table 1.[10] The first column shows the year of actual enrolment at Bocconi while in the second column we report the year of birth for the *regular* students in each cohort, where we define *regular* students those who turn 19 during the year of enrolment. The third column shows the fraction of such students in each cohort, while the following columns report the fraction of *older* and *younger* students, i.e. students who were older or younger than 19 when they enrolled.

[Table 1 about here]

Regular students represent on average about 86% of the cohort. *Older* students are typically those who failed one or more grades in their previous educational tracks and some (few) students who enrolled at Bocconi after having enrolled at a different university and then changed their minds.

Younger students are normally those who anticipated school entry. In fact, parents do have some limited freedom in deciding when exactly to enrol their children in primary school.

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[8] Students willing to go to high school could not be refused a place (at least within the public system) regardless of their junior-high school perfromance.

[9] In educational systems where students are streamed into classes on the basis of observed performance already at the very initial stages of their academic careers, early differences in childhood development are perpetuated over a long period of time. In fact, the oldest pupils typically end up in the highest tiers (i.e. the classes of the best performing students) simply because at very young ages they are substantially more developed (Allen and Barnsley, 1993). This type of mechanism has been documented to be very important in sports, where a large fraction of professional players are indeed born in the earliest months of the year (Dudink, 1994; Barnsley *et al.*, 1992; Helsen *et al.*, 2005).

[10] The most complete version of our data covers all students enrolled from 1989 to 2004. We exclude the earlier cohorts because data on the admission tests are not available. Moreover, we also limit the sample to cohorts with at least 80% of students who have completed their degrees, thus leading to our focus on the 1995-1998 freshmen.

Students in our cohorts could attend preparatory classes (typically in private, mostly religious, institutions) at age 5 during their last year in kindergarten and apply to enter directly into the second grade in primary school at age 6. Admission was subject to an entry test and schools had some discretionary power over the decision to accept younger children. Normally, it was difficult to anticipate school entry for children born after March. Postponing school entry was forbidden by the law, which required all pupils to be attending school starting in September of the year of their sixth birthday.

[Figure 1 about here]

Figure 1 shows the distribution of student types (*regular*, *older* and *younger*) by month of birth. As it is evident, many of the children who could reasonably hope to anticipate school entry did so. The fraction of *younger* students is as high as 30% among the January born and it declines rapidly over the month of birth. When we produce our main results in Section 3 we focus exclusively on *regular* students but, given the potentially important selection problems related to the choice to anticipate school entry, we return to this issue in Section 4, when we present several robustness checks.

Table 2 describes the distribution of month of birth within the *regular* students in each cohort. The bimodal pattern of birth months (with local maxima in April and August) is consistent with what is known from research on the seasonality of births on the overall population (Rizzi and Dalla Zuanna, 2007).

[Table 2 about here]

Eventually we end up working with a sample of 5,269 *regular* students. The university's administrative archives contain detailed data about the entire academic history of these students, including entry test scores, some high school results and a set of family background variables (residence and income).

Our preferred empirical strategy consists of comparing the youngest and the oldest individuals within each cohort of regularly enrolled students, that is those born in January with those born in December.[11] Table 3 reports the descriptive statistics for the variables used in our analysis separately for the students born in January, December and the months between February and November. Exams are graded on a scale 1 to 30 with 18 being the minimum pass grade and graduation marks range from 66 (pass) to 110.

The numbers in Table 3 already show that the youngest students tend to perform slightly better in terms of final graduation mark and in all subjects (but foreign languages). All these differences are significant at conventional statistical levels, apart from the average grades in foreign languages and history courses. Interestingly, all pre-university performance indicators show the same patter: younger students do better at high school and also at the admission test. However, these differences are never significant.

[Table 3 about here]

In Section 5.2 we complement our analysis with evidence from the Italian sample of the *International Survey on Affectivity and Sex* (*ISAS*).[12] This is an internationally comparable survey of first and second year university students that collects information on various aspects of their social and sexual lives. The Italian data are collected from a sample of 23 public universities selected at random among all those that offer degrees in economics and/or statistics (47 in total). During the academic year 2000-2001 a lecture in one first or second year basic compulsory course of either economics or statistics was selected. At this lecture the students were distributed the questionnaires in sealed envelopes. They were asked to fill them and put them back into the sealed envelopes so as to guarantee anonymity. These procedures allowed to obtain almost non-existent non-participation rates and non-response rates that are never above 15% for the most delicate questions. For a detailed description of the survey see Billari *et al.* (2007).

For the analysis in Section 3 we selected only *regular* students (in the sense discussed earlier) enrolled as freshmen in the academic year 2000-2001. Table 4 reports some descriptive statistics for these students distinguishing by month of birth. The first set of variables synthetically

[11] Although in the main text we present results based on month of birth, all our findings are confirmed when we measure age in days. However, the university does not allow us to distribute the exact day of birth to external users and therefore only results produced using information on month and year of birth can be replicated by external researchers.
[12] The survey was prepared for a large international project in demography which has been published in Billari *et al.* (2006).

describes some features of social behaviour. About one fourth of all students are not engaged in any regular sport activity during the school year. This percentage is slightly higher for the December-born individuals and slightly lower for the older January born. A similar patter can be detected also for the other indicators about discos and sexual intercourse. Particularly this last set of variables shows a marked trend towards more active sexual lives for the oldest students in the cohort. About 66% of the January-born individuals is in a stable relationship at the time of the interview, as compared to about 50% among the younger December-born. Also, 59% of the oldest students in the cohort have already had their first sexual experience at age 20 while the same percentage is only 50% for their youngest mates. This difference is reflected in the average monthly frequency of sex intercourses, which is coded to zero for those students who have not yet had their first experience. Differences in this variable across birth months remain strong also within students who have already had their first sexual experience.[13] The remaining variables describe other demographic characteristics of the sample.

[Table 4 about here]

3. Relative age effects at university

In this section we present our main estimates of the relative age effects among Bocconi students. For presentational ease, we concentrate on the comparison of the youngest and the oldest in each cohort, rather than imposing a linear relationship between relative age and performance, as in Bedard and Dhuey (2006). In fact, most of the effect is generated by differences between students at the opposite ends of the age distribution within cohort. For completeness, however, in Section 4 we also present other comparisons as robustness checks.

The presence of early and late enrollers generates an obvious identification problem, which is analogous to the one faced by Bedard and Dhuey (2006). They solve it by instrumenting observed age with relative age, however such approach does not seem suitable in our setting. At

[13] The original question reads: *"How often have you had sexual intercourse during the last three months?"* Possible answers are: *never*, *less than once a month*, *once a month*, *two or three times a month*, *once a week*, *two or three times a week*, *four or five times a week*, *almost every day*. Based on self-reported interval-coded answers we construct a continuous estimated frequency of intercourses taking the mid point of each interval. Results are robust to alternative specifications.

university students choose the dates of their exams within a set of available sessions.[14] Thus, the learning process is much more segmented than in lower schooling levels: first, one attends lectures, then, depending on the exam date, one studies by herself or with a group of mates and, finally, the exam is sat. And each of these learning steps can take place at different times and, thus, also at different ages. Moreover, students often prepare more than just one subject at a time and they may substitute time and effort across exams in order to maximize a combination of their final graduation mark and the time to complete their degrees. For all these reasons, observed age at the time of the exam is a highly endogenous variable and perhaps not a particularly meaningful one in our setting.

Hence, we adopt a different strategy and we estimate the reduced-form effect of relative age on academic performance. In this section we concentrate only on *regular* students and in Section 4.1 we extend our analysis to early and late enrollers. Eventually, our estimating equation looks as follows:

$$y_i = \alpha + \beta_1 Feb\_Nov_i + \beta_2 Dec_i + \gamma X_i + \varepsilon_i$$

where Feb_Nov_i is a dummy equal to 1 if student *i* was born in any of the months between February and November and Dec_i is a dummy equal to 1 if student *i* was born in December. X_i is a set of control variables that generally includes high school grades, dummies for the type of high school, cohort and region dummies as well as a set of indicators for the particular degree chosen.[15] Our data allow us to look at a wide set of academic outcomes so that y_i can be a specific exam result but also graduation mark or time of degree completion.

In this specification, the coefficient on the December dummy can be readily interpreted as the percentage difference in graduation marks between the youngest and the oldest students in the cohort, students that were born 11 months apart. Such age difference amount to 4-5% of total biological age at the time of university attendance (19 to 23 years of age).

Table 5 reports our main estimates. In column 1 the dependent variable is the log of the graduation mark and our estimates show that the December-born students graduate with a final

[14] This is particularly true at Bocconi where the number of available exam sessions has traditionally been very high. During the academic years that we consider in this paper there could be up to 7 sessions per exam.

[15] In the period covered by our data Bocconi offered 6 types of bachelor degrees with different specializations. The most popular ones were management (with acronym CLEA) and economics (CLEP). A third option was a more academic version of the BA in economics (DES). Other programmes specialised in financial markets (CLEFIN), public administration (CLAPI), law and economics (CLELI).

mark that is about 0.9% higher than that of their oldest peers (and statistically significant at conventional levels). The dummy for the months between February and November is also positive – equal to about 0.3% - but not significant. Given an average graduation mark of approximately 102 over 110 in the entire population, our estimates imply that the difference between the youngest and the oldest students in a cohort is on average slightly less than 1 grade point (0.92), or about 0.13 of a standard deviation.

[Table 5 about here]

In the second column we explore how this relative age effect varies over the course of students' university lives. To do this, we compute the average grade in the exams taken in each academic year, pooling the fourth year together with any subsequent one.[16] This leads to a dataset with 4 observations for each student. The regression in column 2 of Table 5 pools all observations together and interacts the month-of-birth dummies with indicators for the academic year (the errors are clustered at the individual level). The dependent variable is the log average grade in each course year.

The largest and most significant relative age effect is found in the first year at university, when the difference in average grades is about 1.3% and significant at the 5%-level. Although the coefficients on the interaction dummies are often at the margin of the 10% significance level, they are all negative indicating a decline in age differences over the course of one's university career. During the first one and a half years Bocconi students have very little choice over the courses they want to take, while later they attend mostly elective subjects. Thus, the fading out of the relative age effect with time spent at university is likely to be due to heterogeneity in preferences and subject complexity as students start to self-select themselves into different courses and majors. Moreover, the presence of peer effects, which have been widely documented in the educational setting and particularly within Bocconi (see De Giorgi *et al*., 2007), should mitigate the impact of differences in age levels as students interact with peers of various ages.[17]

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[16] A good fraction of students (about 10% in our data) graduate after the official duration of the degree (4 years for all but one program). Late graduation is a well-known problem of the Italian university system, see Garibaldi *et al.* (2007) for an analysis of this phenomenon on our same set of data.

[17] Peer effects are probably present in high school as well. However, in most cases one's reference group dissolves at the end of high school and it may take time to establish a new one at university.

In the last column of Table 5 we explore the effect of age on the duration of university studies, measured in quarters.[18] Results indicate no significant relative age effect in this dimension, although the point estimate suggests shorter durations for the youngest students.[19]

Overall, the results in Table 5 show that relative age has a significant effect on overall performance but our data also allow to look at specific subjects. In Table 6 we categorize exams by subject on the basis of the department that is responsible for organizing and teaching the course. In order to exclude any potential bias due to students self-selecting themselves into elective courses, we consider (the log of) the grade obtained in the first exam taken in each subject, which is always compulsory, and run separate regressions for each of them.

[Table 6 about here]

Results indicate that students born in December perform better than their oldest mates born in January in Economics and Math&Statistics, that is the most technical subjects. On the other hand, there appears to be no significant difference for Management, History, Foreign Languages and Law. From the students' evaluation questionnaires, Economics and Math&Statistics also appear to be the courses with the heaviest workload, which would be consistent with our interpretation that youngest students spend more time studying (see Section 5.2). The results of Table 6 are confirmed also when differences in the degree of grade dispersion across subjects are taken into account, either by normalizing the dependent variables or by computing standardized coefficients.

One important feature of our data is the availability of both measures of academic achievement and of cognitive ability for the same students. In Table 7 we replicate our main results augmenting the set of controls with entry test scores as a measure of cognitive ability. For this exercise we consider only the four outcomes that showed significant relative age effects in our previous analysis of Table 5 and Table 6.

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[18] More specifically, we compute the number of quarters between September of the year of first enrolment at Bocconi and the day of graduation.

[19] Results are obtained controlling for graduation mark, which is clearly negatively correlated with the time-to-graduation. In fact, the best students often took several months to write their final dissertations. Things have changed in the most recent years with simpler and shorter dissertation, but for the students in our sample a good final paper could improve one's final mark quite substantially and it also represented a strong signal of ability.

[Table 7 about here]

Interestingly, conditioning on ability does not significantly change the estimated relative age effects, whose absolute value decreases only by approximately 10%. We will return to a more detailed analysis of entry test scores in Section 5.1, however, the results in Table 7 already suggest that differences in cognitive ability are only one of the channels through which age differences influence academic performance and, perhaps, not the most important.

4. Robustness checks

In this section we provide additional evidence to exclude some simple mechanical explanations of the effects estimated in Section 3. First (Section 4.1), we document that our focusing on *regular* students is not pivotal. Second (Section 4.2), we show that the selection of students into Bocconi is not correlated with month of birth. Finally (Section 4.3), we check that our estimates are robust to conditioning on season of birth.

4.1. Selection due to early and late enrolment

In the analysis of Section 3 we have excluded students who enrolled either earlier or later than usual, arguing that they might be a selected group of individuals. Since *older* students are for the large majority those who have failed one (or more) grades prior to university, they are obviously negatively selected. Figure 1 shows that, consistently with the finding that the youngest students perform worse than their older mates in primary and high school (Bedart and Dhuey 2006; Crawford *et al.* 2007; Mayer and Knutson 1999), there are more *older* students among the December-born than among the January-born. Hence, excluding them raises the average performance of the youngest compared to the oldest, potentially leading to the results that we documented in the previous section.

Similarly, those who anticipated school entry at age 5 are likely to be positively selected because parents certainly take this decision on the basis of some signal of their children's ability. Again, Figure 1 shows that there are more early enrollers among the youngest students, hence excluding them reduces the average ability of the January-born in favour of the December-born. To investigate this particular selection process, we present here two pieces of evidence.

[Table 8 about here]

First, in Table 8 we replicate the results of Section 3, using all the students in our four (1995 to 1998) enrolment cohorts, thus including *regular*, *older* and *younger* students. In this enlarged group of students month of birth and relative age do not coincide. For example, a late enroller who is born in December one year earlier than *regular* students will be among the oldest in the cohort despite her late month of birth. Hence, in Table 8 we use a continuous measure of relative age that is equal to zero for *regular* students born in January and increases by 1 unit for each additional month of age. Results show that relative age is still negatively correlated with the four outcomes for which we found significant effects in our main analysis in Section 3. Such correlations are significant in all cases but for the first exam in Mathematics/Statistics. The effects are also quantitatively comparable with what we found in Section 3.

[Figure 2 about here]

As a second piece of evidence, in Figure 2 we report a more detailed analysis with relative age effects estimated for each single month of birth and for the same outcomes of Table 8. The effects are reported in absolute levels so that on the vertical axis one can read the (conditional) average of the dependent variable for each month of birth. For comparison purposes, we also include effects for students born from October of the year preceding the regular one to March of the following year.

As expected, students older than *normal* (those born between October and December of year *t-1*) perform worse. In fact, these students typically enrol late because they have failed one or more grades in some previous school level (primary, junior-high or high school). Consistently with the descriptive evidence presented in Table 3, the small number of later enrollers leads to very wide confidence intervals around the estimated mean outcomes. Also, the conditional mean outcomes of the early enrollers are higher than for the other students, but such difference does not appear to be statistically significant, especially when compared with the youngest *regular* students.

Taken together the evidence of Table 8 and Figure 2 suggests that excluding early and late enrollers from the analysis does not affect the results significantly. Late enrollers are very negatively selected but they are too few to meaningfully affect the analysis. Early enrollers are more numerous but they don't seem to differ that much from the youngest *regular* students. Moreover, conditioning on high school results already captures most of the selection effect due to early and late enrolment.

Notice, however, that the estimates in Table 7 already showed that relative age effects in academic performance are only marginally affected by conditioning on cognitive ability, as measured by the attitudinal entry test, thus suggesting that selection based on ability is unlikely to play a major role in our setting.

4.2. Selection at entry in Bocconi

Bocconi university is a highly selective institution in Italy and it also specialises in a few areas of Economics and Management. Thus, the students in our sample are clearly a very selected sample and our results may not generalise to the population of Italian university students. In particular, our result that the youngest students perform better might be generated by these students being less likely to either apply to or attend Bocconi. To look at this issue we compare the distribution of month of birth of *regular* Bocconi students with that of the population of Italian *regular* university students in the same cohorts.[20]

[Figure 3 about here]

The upper panel of Figure 3 describes the relative distribution of month of birth for *regular* students who took the entry test at Bocconi in the years 1995 to 1998 (a bar taller than 1 indicates that the percentage of students born in that month is higher among *regular* Bocconi applicants than in the population of *regular* students in the same cohorts). Although the relative incidence of applicants born in January is slightly above 1, Bocconi does not seem to attract particularly older or younger students.[21]

The bottom panel of Figure 3 focuses on students who have been eventually admitted at Bocconi. Similarly to the upper panel, the relative incidence of students born in any month is

[20] We derive the distribution of regular students in the four birth cohorts 1976-1979 from the European Community Household Panel (ECHP) by selecting persons born in those years who completed their secondary education and enrolled tertiary education at the age of 19.
[21] None of the bars is significantly different from 1.

never statistically different from 1 and there seems to be no indication of a trend towards *older* students being more likely to enrol at Bocconi.

The evidence in this section also answers some obvious questions about the external validity of our analysis. The distribution of month of birth in our sample does not seem to differ significantly from the population of *regular* university students. Moreover, being Bocconi a very selective institution, the ability distribution of admitted students is likely to be more compressed than in the population. Hence, if anything, it would be reasonable to expect larger relative age effects in the population than within Bocconi.

4.3. Season of birth effects

In Table 9 we perform a further robustness check. Several previous studies have documented statistically significant differences in various outcomes between children born in different seasons of the year (Wilson, 2000). Usually, such differences, especially as far as health outcomes are concerned, are explained with environmental, biological and medical factors like weather conditions and temperature at the time of gestation or birth. These factors are known to affect the health conditions of newborn children such as birth weight and height.

In our analysis, the comparison of students born in January and December should not be affected by season of birth effects, given that both are winter months. Moreover, even when season of birth effects have been detected, they have also been shown to disappear rather rapidly with age, especially in industrialized countries. However, for robustness and comparison, Table 9 reports estimates of relative age effects conditional on season of birth for our students. Like in Figure 2 and Table 8, we consider only outcomes for which relative age differences have been detected by our previous analysis.

[Table 9 about here]

Although our main comparison is between students born in January and December of the same year, who were both born in winter, they were born in the winter seasons of different years, which might have indeed been meteorologically different. And if there is a secular trend towards winter seasons changing systematically over the years, than our estimates might be capturing such trend.[22] To make our specification robust to this particular issue, we include among the control variables a full set of interactions between month of birth and cohort dummies.

The estimates of Table 9 show that relative age effects remain significant also in this more sophisticated specification. Only the significance of the effect on the first economics exam goes below the conventional 10% level, although only marginally (the coefficient is significant at the 11% level). In general, the effects seem to be slightly lower than in previous specifications.

As far as season effects are concerned, students born in the spring (the reference season in our specification) seem to be slightly advantaged as compared to their mates. Although the estimated coefficients on winter, summer and fall are never statistically distinguishable from each other, the point estimates indicate a trend that mimics fluctuations in temperature across seasons.

5. Why are relatively younger students performing better?

As already mentioned, the evidence that we presented in the previous sections contrast with what many other authors have found when focusing on younger students. Bedard and Duhey(2006), for example, find significant positive age effects among Italian 8th-graders. In this section we investigate two possible explanations that may not only rationalise our results but also reconcile them with previous findings.

The first explanation is a combination of early learning and progression over the age-profile of cognitive development. Previous studies (Fredriksson and Öckert 2005; Goodman and Sianesi 2005; Skirbekk 2005; Skirbekk *et al*. 2004) have shown that going to school earlier improves later outcomes. At the same time, the medical and psychological literature documents that, just like physical strength, cognitive abilities first develop and then deplete with age, with the turning point for the average person being probably around age 20 (Jones 2005; Salthouse *et al.* 2004). Hence, in the early stages of childhood development the effect of older students being more mature probably dominates the benefits of early learning. Later, such advantage fades out and possibly reverses, thus leading to the observed better performance of the youngest students in the cohort.

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[22] Although the scientific evidence on the matter is still mixed, the obvious suspect here is climate change that might have made winter seasons milder and milder over time.

In Section 5.1 we analyse entry test scores in more details and find some evidence in support of the idea that the youngest students in our data perform slightly better in terms of cognitive outcomes. However, the results in Table 7 already showed that differences in academic outcomes persist also when conditioning on cognitive ability.

We, thus, explore a second possible explanation in Section 5.2. Several psychological studies (Thompson *et al.* 2004; Dhuey and Lipscomb 2006) document the important role of relative age differences in the development of personality traits that favour the oldest pupils in a group. According to these studies, the youngest students in a cohort, who have likely been the smallest kids in their reference groups at early ages, should be less socially active. We find evidence of these effects and we also document that the youngest in a cohort devote more time to studying, which eventually leads them to achieve better academic results.

5.1. Relative age differences in cognitive ability and academic performance

Table 10 explores the existence of relative age effects in cognitive ability in our Bocconi data by analyzing students' results in the admission test. Such test was – and still is – meant to measure ability rather than actual knowledge and was designed by professional educational psychologists. It includes several different sections, such as reading comprehension and problem solving, and it is taken by all students on exactly the same date and location.[23]

[Table 10 about here]

This particular setting lends itself easily to the IV strategy of Bedard and Dhuey (2006). Such strategy consists of regressing test scores on absolute age (measured in month since birth) and instrumenting this variable with *assigned age*, i.e. a continuous variable for the student's month of birth. For *regular* students relative and assigned age are perfectly collinear while for early and late enrollers they exhibit some independent variation. Still, those born in the earlier months of the year are more likely to anticipate school and those born towards the end of the year are more

[23] This has changed in the most recent years, with additional admission test sessions organized in different locations around the country.

likely to enrol late (see Figure 1).[24] Moreover, assigned age is arguably an exogenous variable, thus making it a valid instrument for absolute age.[25]

The first three columns of Table 10 report the OLS, IV and reduced form (RF) results from this strategy, while in the last column we adopt our preferred approach of restricting the sample to *regular* students and comparing the oldest and the youngest in the cohort. The dependent variable is the standardized test score so that the coefficients should be read in terms of standard deviations. Consistently with our findings in Section 4.1, the presence of early and late enrollers does not affect the results significantly, as suggested by the similarity of the OLS and IV estimates. Overall, results show a modest but significant advantage of about 0.06-0.08 of a standard deviation in favour of the youngest students, depending on the specification.[26]

[Table 11 about here]

In Table 11 we analyze in details the different sections of the test for some more recent cohorts, namely for students who applied to Bocconi in the years 2000, 2001 and 2002. These cohorts were administered a different newer version of the test which consists of 8 sections and results have been recorded separately for each of those sections: reading comprehension, spatial and perceptive abilities, computer use, mathematical reasoning, verbal relations, logics of images, verbal patterns and general culture. In the appendix we present a brief description of the actual content and questions in each of these 8 sections. Note that two of the sections refer directly to skills that come mostly from the accumulation of previous knowledge, namely computer use and general culture. In Table 11 we do not report results for general culture while we do present the estimates for computer use as well as for all the other sections that are meant to directly measure

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[24] Notice that for regular students such instrument differs from the endogenous regressor only up to a constant, while it does exhibit independent variation for students at the two ends of the age distribution, i.e. those who are most likely affected by the instrument itself. In this sense, the IV strategy adopted here is likely to estimate a truly average rather than a local effect.

[25] One additional source of endogeneity would arise from parental targeting of month of birth. However, since conception and pregnancy still are largely stochastic events, it is unclear whether such targeting can go beyond the seasonal frequency. Moreover, the direction of the bias would be unclear. More educated or more work-oriented parents may prefer to have their kids born in December, so that they go to school earlier. However, they would also be the youngest in their class, which is often believed to be psychologically problematic. The distribution of cesarean sections in Italy does show a spike at December but this phenomenon appears to be largely uncorrelated with the socio-demographic characteristics of the parents.

[26] Both admitted and rejected students are included in the regression although results change only slightly when the analysis is limited to admitted students.

different types of cognitive abilities.[27] In all columns the dependent variable is the standardized test result, so that the estimated coefficients can be readily compared across test areas.

We start in column 1 with the overall result, which is simply a weighted average of the results in the single sections, where the youngest students seems to have a relatively large advantage of over 0.14 of a standard deviation. Also, students born in the middle months February to November show a considerable 0.08 advantage over the oldest January-born. These effects are much larger that the ones estimated in Table 10 for the earlier cohorts, although the comparison is complicated by the fact that the structure of the test is different. For example, the section on computer use, where relative age effects seem very important, was not present in the earlier version of the test. The following columns (2 to 8) present results for the different test sections (excluding only general culture). All the point estimates indicate a relative advantage of the youngest over the oldest students in the cohort, however such differences are statistically significant only in three sections - spatial perception, computer use and logics of images - and are particularly strong in computer use.

These results suggest that cognitive ability is subject to mild relative age differences, while our interpretation of the effect on computer use is more in line with the psychological mechanism that we discuss below. Students with less active social lives also have more time to spend on other things such as using a computer, an activity that does not necessarily require interacting with others.

5.2. Relative age differences in social behaviour

The final set of results that we present come from the *ISAS* survey, which we described in Section 2.

[Table 12 about here]

In Table 12 we use these data to analyze differences in various aspects of social behaviour between the oldest and the youngest students in the cohort. As for the previous analyses we concentrate only on *regular* students, thus excluding early and later enrollers. In the first column of Table 12 we look at sport activity. The dependent variable is a dummy equal to 1 if the

[27] In unreported results we find that age differences are not significant in general culture.

respondent answers *never* to the following question: “During the school year, do you practice any sport or physical activity?”. The other possible answers are *sometimes*, *often* and *very often* and are all coded to zero in our right-hand-side variable. The model is estimated using a probit specification and conditioning on a large set of controls. The estimated effect of being born in December is not significant although the sign of the coefficient is positive and increasing over the calendar year of birth (0.045 for February to November and it doubles to 0.083 for December) suggesting that younger individuals are more likely to do little sport. We obtain very similar results in column 2 for another aspect of social behaviour. The dependent variable is coded 1 for students who answer *never* to the question “Do you go to clubs or other places where you can dance?”.

The last three columns of Table 12 explore love and sexual behaviours. In column 3 we run a linear regression of the self-reported mean number of monthly sexual intercourses on our month-of-birth dummies and the usual set of controls. The estimates show a very large effect with the youngest students in the cohort having on average 1.2 intercourses less than their oldest mates. This is about 35% over the average of approximately 3 and corresponds to almost 20% of a standard deviation. This result is confirmed (and actually reinforced) in column 4, where we restrict the sample only to those students who already had their first sexual intercourse. Finally, in the last column we explore the probability of being in a stable love relationship at the time of the interview. Here we also find a very strong and significant effect of the youngest students being 18 percentage points less likely to be in such relationship over an average of approximately 60%.

To the extent that these differences in social behaviours also reflect differences in the allocation of time and effort between studying and other activities, these results support the interpretation that relative age effects in psychological development might be a powerful determinant of differences in academic outcomes. Unfortunately, we do not have information on both social activity and time allocation for the same sample of students. However, the PISA study does include information on time allocation. The Programme for International Student Assessment (PISA) is a well known database constructed by the OECD that contains information on standardised tests administered to comparable samples 15-year-olds students in a large number of countries (57 in the last 2006 edition).[28]

[Table 13 about here]

In Table 13 we use the data from the Italian 2003 PISA survey to analyse relative age effects in the amount of time students allocate to self-studying at home. As in most of our previous analysis we focus exclusively on *regular* students and we regress the number of hours devoted to self-studying at home on month of birth dummies and a set of controls.[29] Consistently with our suggested interpretation, we do find that the youngest students in the cohort devote more time to doing their homework. This finding is confirmed also when we break down the total number of hours by subject. The December-born students appear to spend more time on their mathematics and language homework while the effect is not significant for science. The estimates in Table 13 suggest that already at age 15 the youngest students in a cohort spend more time studying at home and thus, possibly, less time on other activities like sports or socialising. To the extent that these differences are due to psychological relative age effects, they are likely to expand as people grow older and gain more and more control over the allocation of their time.

6. Conclusions

In this paper we documented that relative age effects are still present at the age of university attendance and such effects work in favour of the youngest students within a given cohort. This contrasts with the results of most previous studies that looked primarily at earlier schooling stages and typically found better outcomes for the oldest students.

Exploring data on cognitive entry test and a survey of social behaviours of first-year university students, we produce some additional evidence that help rationalize our results according to two main mechanisms.

On the one hand, cognitive development appears to flatten and even invert direction already at the age of university enrolment, thus penalizing the performance of the oldest students in the

[28] For more information on the PISA study visit www.pisa.oecd.org.
[29] All students in the PISA are aged 15 and the data also report the exact grade in which they are enrolled. Hence, we have all the necessary information to select only the *regular* students.

cohort. Moreover, the youngest students also appear to have less active social lives and, thus plausibly devote more time to studying. This argument is consistent with results from psychological studies showing that being the youngest in a reference group slows down the development of personality traits like self-esteem and leadership at early ages.

Our results have important implications for the study of cognitive development and show that the mechanical evolution of abilities over the life cycle interacts with endogenous individual choices about the allocation of time and effort. Moreover, such interaction involve both productive and non-productive skills and attitudes. In a policy perspective, the most commonly discussed options focus on the advantages and disadvantages of anticipating the age of school entry. Our results support the idea that anticipating school entry might indeed improve performance, however such policy intervention cannot eliminate relative age differences and thus their implications. Rather, if the policy objective is guaranteeing equal opportunities to everybody, relative age differences – which are shown to be an important source of later inequality in outcomes - should be limited. In principle, achieving this result is relatively easy, at least as far as the schooling environment is concerned. For example, the rules of class formation could be redefined by conditioning students in a class to be at most 6 months apart in terms of biological age.

Implementing this type of policy is straightforward and costless, other than in some very special cases, for example when there are only very few students in a school grade. One may also think of changing the actual definition of school grades, by having a grade for each semester instead than for each year. This alternative policy option, however, might require additional inputs in the education production process (smaller class sizes, more teacher, et.).

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Figures and Tables

Figure 1. Distribution of student types by month of birth

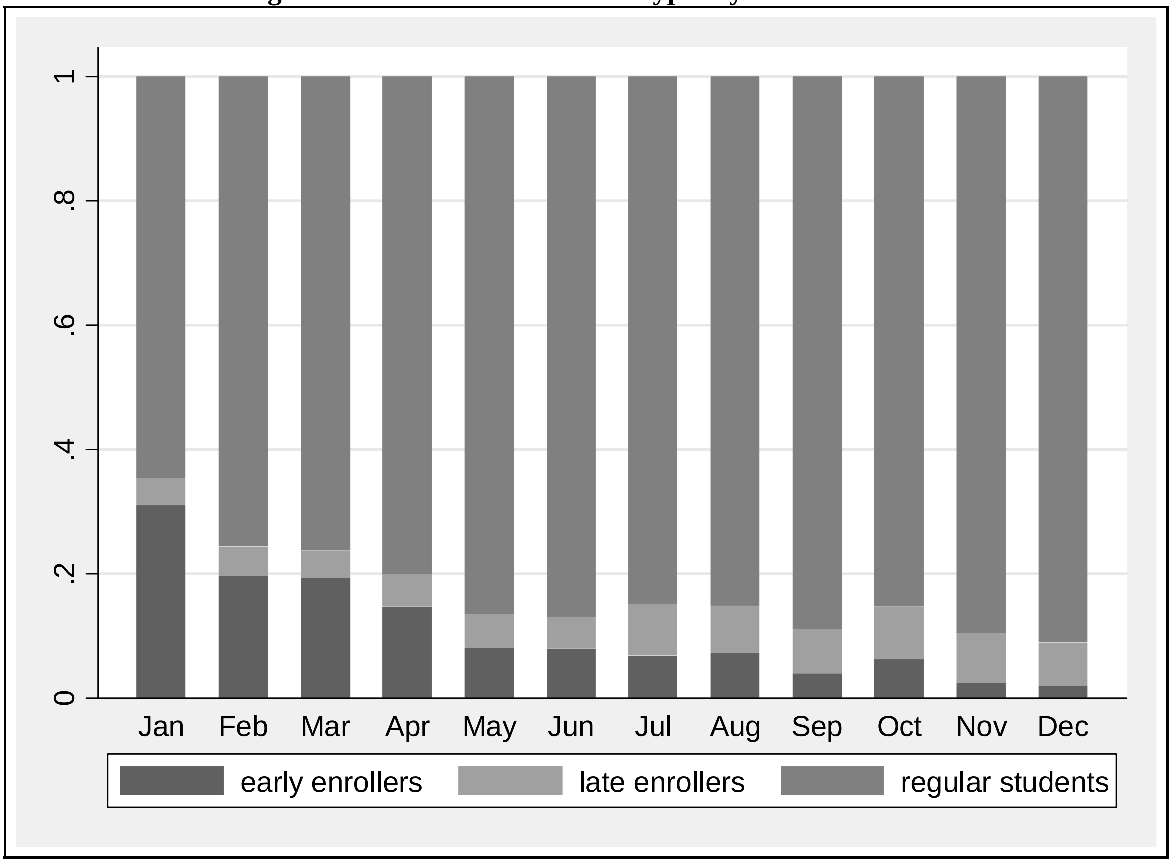


Figure 2. Conditional academic performance by month of birth

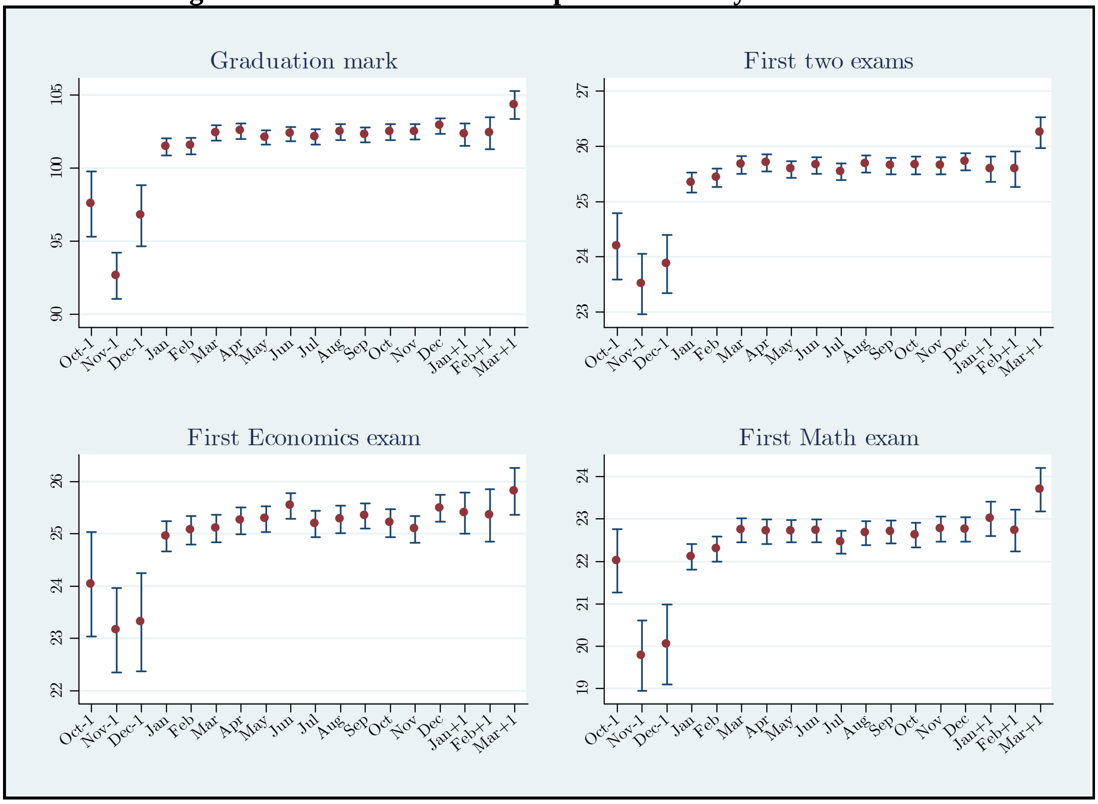


Figure 3: Relative distributions of month of birth

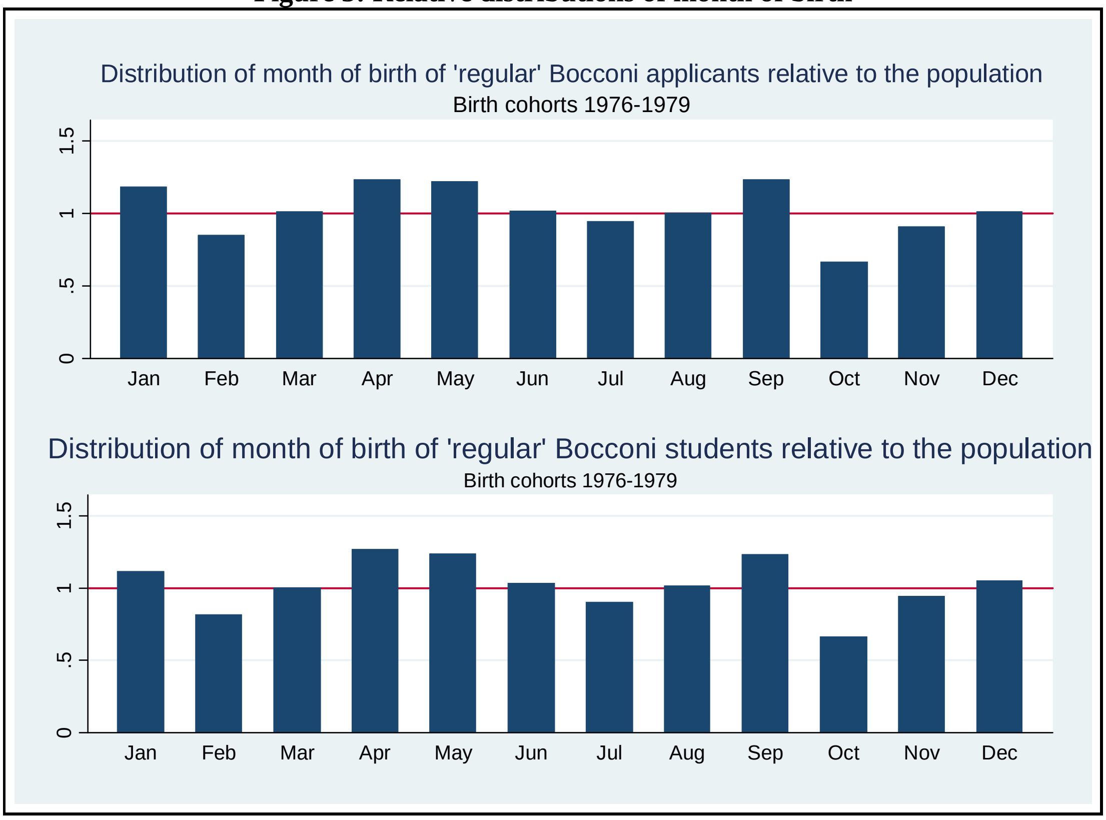


Table 1. Distribution of student births by cohort

year of first enrolment	typical year of birth	% of *regular* students	% of *older* students	% of *younger* students
1995	1976	0.837	0.069	0.108
1996	1977	0.857	0.059	0.106
1997	1978	0.882	0.047	0.093
1998	1979	0.861	0.044	0.123
	Total	0.857	0.045	0.121

Table 2. Distribution of month of birth by cohort

	Year of first enrolment				
	1995	**1996**	**1997**	**1998**	**Total**
January	0.066	0.062	0.074	0.058	0.065
February	0.073	0.074	0.068	0.066	0.070
March	0.084	0.076	0.083	0.076	0.080
April	0.087	0.081	0.086	0.089	0.086
May	0.107	0.109	0.092	0.114	0.105
June	0.106	0.091	0.094	0.100	0.098
July	0.085	0.091	0.075	0.092	0.086
August	0.073	0.083	0.078	0.082	0.079
September	0.093	0.082	0.093	0.094	0.090
October	0.065	0.085	0.080	0.085	0.080
November	0.078	0.079	0.083	0.075	0.079
December	0.084	0.088	0.093	0.069	0.083
Total	1.00	1.00	1.00	1.00	1.00

Table 3. Descriptive statistics of Bocconi data

Variable	January mean	January (s.d.)	February to November mean	February to November (s.d.)	December mean	December (s.d.)	Total mean	Total (s.d.)
Graduation mark[1]	101.51	(7.61)	102.27	(7.31)	102.86	(6.92)	102.27	(7.30)
Average grades by subject[2]:								
management	26.50	(2.04)	26.69	(1.89)	26.83	(1.81)	26.69	(1.90)
economics	25.80	(2.47)	26.04	(2.43)	26.16	(2.34)	26.03	(2.43)
math	23.78	(2.92)	24.09	(2.93)	24.34	(2.89)	24.09	(2.92)
history	27.51	(2.78)	27.52	(2.59)	27.71	(2.35)	27.53	(2.59)
foreign languages	27.63	(2.15)	27.56	(2.22)	27.53	(2.20)	27.56	(2.21)
law	25.44	(2.42)	25.58	(2.39)	25.82	(2.22)	25.59	(2.38)
Specialization:								
public administration	0.07	-	0.05	-	0.06	-	0.05	-
management	0.59	-	0.60	-	0.54	-	0.59	-
financial markets	0.09	-	0.09	-	0.09	-	0.09	-
law & economics	0.11	-	0.12	-	0.14	-	0.12	-
economics	0.07	-	0.09	-	0.10	-	0.09	-
economics & social sciences	0.07	-	0.06	-	0.07	-	0.06	-
High school results[3]	59.61	(33.22)	57.85	(35.06)	61.78	(32.66)	58.29	(34.76)
Admission test score[4]	70.75	(7.53)	71.41	(7.57)	71.38	(7.51)	71.36	(7.56)
Time to graduation[5]	22.10	(4.10)	21.95	(3.92)	21.81	(3.71)	21.95	(3.91)
Type of high school:								
lyceum	0.79	-	0.75	-	0.75	-	0.76	-
technical-professional school	0.20	-	0.23	-	0.24	-	0.23	-
foreign school	0.01	-	0.01	-	0.01	-	0.01	-
1=female	0.42	-	0.44	-	0.46	-	0.44	-
1=resident outside Milan[6]	0.56	-	0.61	-	0.61	-	0.61	-
Family income (log)[7]	10.26	(1.01)	10.30	(1.15)	10.27	(1.26)	10.29	(1.15)
1=highest income bracket[7]	0.18	-	0.18	-	0.24	-	0.19	-
Number of students	340		4,488		441		5,269	

1. Maximum = 110; pass = 66.

2. Maximum = 30; pass = 18.

3. Summary evaluation of high school performance, including final grade and marks in selected courses during the last two years. Range 0-100.

4. Range 0-100. Average over various sections (reading comprehension, problem solving, computer use, et.)

5. Time between September of the year of first enrolment and the graduation date (measured in quarters).

6. Dummy = 1 if residence of the family of origin is outside the province of Milan.

7. As recorded on the first year of registration. For students in the highest income bracket the actual income is not recorded.

Table 4. Descriptive statistics of ISAS data

Variable	January mean	January (s.d.)	February to November mean	February to November (s.d.)	December mean	December (s.d.)	Total mean	Total (s.d.)
Social behavior								
1=no sport[1]	0.22	-	0.25	-	0.27	-	0.25	-
1=no discos[2]	0.12	-	0.11	-	0.14	-	0.11	-
1=stable relationship[3]	0.66	-	0.60	-	0.50	-	0.60	-
1=ever had sex[4]	0.59	-	0.58	-	0.51	-	0.58	-
monthly frequency of sex intercourses	3.44	(6.29)	3.16	(5.62)	1.84	(4.13)	3.06	(5.56)
monthly frequency of sex intercourses (>0)	7.20	(7.48)	6.65	(6.57)	5.07	(5.57)	6.58	(6.58)
Background characteristics								
1=female	0.57	-	0.59	-	0.60	-	0.60	-
1=live with parents	0.81	-	0.72	-	0.68	-	0.72	-
High school grade[5]	83.13	(13.34)	84.72	(11.77)	83.15	(11.79)	84.47	(11.89)
Father's education								
secondary	0.46	-	0.42	-	0.45	-	0.43	-
tertiary	0.16	-	0.17	-	0.21	-	0.17	-
Mother's education								
secondary	0.48	-	0.42	-	0.39	-	0.42	-
tertiary	0.16	-	0.14	-	0.18	-	0.15	-
Number of students	124		1,551		162		1,837	

1. Dummy coded 1 for students who answer *"never"* to the following question: *During the school year, do you practice any sport or physical activity?*
2. Dummy coded 1 for students who answer *"never"* to the following question: *Do you go to clubs or other places where you can dance?*
3. Dummy coded 1 for students who have a steady relationship at the time of the interview.
4. Dummy coded 1 for students who answer *"yes"* to the following question: *Have you ever had sexual intercourse?*
5. Range 0-100.

Table 5. Month of birth and academic performance

	(log) graduation mark[1]	(log) average grade by academic year	Time to graduation[3]
	[1]	[2]	[4]
Month of birth			
1=February to November [F_N]	0.003	0.005	-0.001
	(0.003)	(0.005)	(0.008)
1= December [Dec]	0.009**	0.013**	-0.004
	(0.004)	(0.006)	(0.010)
Interactions with academic year			
[Dec] x [acc. year=2]	-	-0.008	-
		(0.006)	
[Dec] x [acc. year=3]	-	-0.011*	-
		(0.006)	
[Dec] x [acc. year≥4]	-	-0.008	-
		(0.006)	
[F_N] x [acc. year=2]	-	0.001	-
		(0.005)	
[F_N] x [acc. year=3]	-	-0.007	-
		(0.005)	
[F_N] x [acc. year≥4]	-	-0.005	-
		(0.005)	
Controls			
1=female	-0.001	-0.003**	0.001
	(0.002)	(0.001)	(0.004)
High school results[4]	0.454***	0.437***	-0.148***
	(0.009)	(0.010)	(0.028)
1=resident outside Milan (province)	0.000	0.001	-0.009*
	(0.002)	(0.002)	(0.005)
Family income (log)[5]	0.001	0.001	-0.005***
	(0.001)	(0.001)	(0.002)
1=highest income bracket[5]	0.012	0.015*	-0.084***
	(0.010)	(0.009)	(0.025)
Average grade in previous years	-	0.008***	-
		(0.000)	
Graduation mark (log)	-	-	-0.999***
			(0.035)
Dummies for academic year	No	Yes	No
Dummies for degree type (6)	Yes	Yes	Yes
Dummies for type of high school (5)	Yes	Yes	Yes
Regional dummies (18)	Yes	Yes	Yes
Cohort dummies (4)	Yes	Yes	Yes
Observations	5,269	20,947	5,269
R-squared	0.40	0.44	0.31

1. Maximum = 110; pass = 66.
2. Probit regression
3. Time between September of the year of first enrolment and the graduation date (measured in quarters).
4. Summary evaluation of high school performance, including final grade and marks in selected courses during the last two years. Range 0-100.
5. As recorded on the first year of registration. For students in the highest income bracket the actual income is not recorded.
Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 6. The effect of month of birth on first grades by subject areas[1]

	Manag. [1]	Econ. [2]	Math [3]	History [4]	Language [5]	Law [6]
Month of birth						
1=February to November	0.001	0.007	0.013*	-0.002	-0.000	-0.000
	(0.005)	(0.008)	(0.008)	(0.006)	(0.005)	(0.007)
1=December	0.003	0.018*	0.021**	0.006	0.004	0.009
	(0.006)	(0.010)	(0.010)	(0.007)	(0.006)	(0.009)
Controls						
1=female	-0.001	-0.026***	-0.019***	0.001	0.007***	0.003
	(0.002)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)
High school results[2]	0.489***	0.597***	0.693***	0.342***	0.354***	0.528***
	(0.014)	(0.021)	(0.023)	(0.016)	(0.015)	(0.020)
1=resident outside Milan	0.006*	0.000	0.003	0.002	0.003	-0.011**
(province)	(0.003)	(0.005)	(0.005)	(0.004)	(0.003)	(0.005)
Family income (log)[3]	0.000	0.003*	0.000	0.001	0.001	0.001
	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)
1=highest income bracket[3]	-0.000	0.032	-0.001	0.010	0.021	0.017
	(0.014)	(0.020)	(0.021)	(0.016)	(0.018)	(0.022)
Dummies for degree type (6)	Yes	Yes	Yes	Yes	Yes	Yes
Dummies for type of high school (5)	Yes	Yes	Yes	Yes	Yes	Yes
Regional dummies (18)	Yes	Yes	Yes	Yes	Yes	Yes
Cohort dummies (4)	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,269	5,269	5,269	5,269	5,269	5,269
R-squared	0.27	0.21	0.30	0.14	0.16	0.18

1. Defined according to the department responsible for organising and teaching the subject. The dependent variable is the log of the grade obtained in the first exam taken in each subject area, which ranges from 18 (pass) to 31 (full marks with honours)
2. Normalized between 0 and 1.
3. As recorded on the first year of registration with the university. For students with income in the highest income bracket the actual income value is not recorded.
Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 7. Month of birth, admission test and academic performance

	(log) graduation mark[1]	(log) av. grade in the first two years[2]	(log) first Economics grade[2]	(log) first Math/Stat. grade[2]
	[1]	[2]	[3]	[4]
Month of birth				
1=February to November	0.002	0.004	0.006	0.012
	(0.003)	(0.004)	(0.007)	(0.008)
1= December	0.008*	0.008*	0.017*	0.019*
	(0.004)	(0.005)	(0.009)	(0.010)
(log) admission test score[3]	0.087***	0.137***	0.236***	0.221***
	(0.009)	(0.011)	(0.021)	(0.024)
Observations	5,269	5,269	5,269	5,269
R-squared	0.41	0.43	0.23	0.31

1. Maximum = 110; pass = 66.
2. Exam grades range from 18 (pass) to 31 (full marks with honours)
3. Range 0-100. Average over various sections (reading comprehension, problem solving, computer use, et.).

All regressions include the following set of controls: gender, high school results, residence outside Milan, family income, dummies for academic year, high school type, regional dummies, cohort dummies and a constant.

Robust standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 8: Relative age and academic performance – all students

	(log) graduation mark[1]	(log) av. grade in the first two years[2]	(log) first Economics grade[2]	(log) first Math/Stat. grade[2]
	[1]	[2]	[3]	[4]
Relative age[3]	-0.001***	-0.000**	-0.001***	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Controls				
1=female	-0.002	-0.007***	-0.013***	-0.005*
	(0.002)	(0.002)	(0.002)	(0.003)
High school results[4]	0.452***	0.542***	0.518***	0.560***
	(0.009)	(0.010)	(0.011)	(0.014)
1=resident outside	0.002	0.003	0.003	-0.000
Milan (province)	(0.002)	(0.002)	(0.003)	(0.003)
Family income (log)[5]	0.001	0.001*	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)
1=highest income	0.012	0.016	0.011	0.010
bracket[5]	(0.010)	(0.011)	(0.014)	(0.014)
Dummies for degree type (6)	Yes	Yes	Yes	Yes
Dummies for type of high school (5)	Yes	Yes	Yes	Yes
Regional dummies (18)	Yes	Yes	Yes	Yes
Cohort dummies (4)	Yes	Yes	Yes	Yes
Observations	6303	6303	6303	6303
R-squared	0.42	0.42	0.37	0.37

1. Maximum = 110; pass = 66.
2. Exam grades range from 18 (pass) to 31 (full marks with honours)
3. Relative age is zero for students born in January of the *regular* cohort year and increases or decreases with each month of age.
4. Normalized between 0 and 1.
5. As recorded on the first year of registration with the university. For students with income in the highest income bracket the actual income value is not recorded.
Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 9: Relative age, season of birth and academic performance

	(log) graduation mark[1]	(log) av. grade in the first two years[2]	(log) first Economics grade[2]	(log) first Math/Stat. grade[2]
	[1]	[2]	[3]	[4]
Month of birth				
1=February to November	-0.004	-0.002	-0.002	-0.000
	(0.004)	(0.005)	(0.006)	(0.007)
1=December	0.009**	0.009*	0.009	0.017**
	(0.004)	(0.005)	(0.006)	(0.007)
Season of birth[3]				
1=winter	-0.015***	-0.018***	-0.018**	-0.001
	(0.005)	(0.006)	(0.007)	(0.009)
1=summer	-0.011**	-0.015***	-0.015***	-0.005
	(0.004)	(0.005)	(0.006)	(0.008)
1=fall	-0.007	-0.009*	-0.013**	0.010
	(0.005)	(0.005)	(0.006)	(0.008)
Controls				
1=female	-0.001	-0.007***	-0.013***	-0.005*
	(0.002)	(0.002)	(0.002)	(0.003)
High school results[4]	0.456***	0.550***	0.527***	0.577***
	(0.009)	(0.010)	(0.012)	(0.016)
1=resident outside Milan (province)	0.001	0.001	0.001	0.000
	(0.002)	(0.002)	(0.003)	(0.004)
Family income (log)[5]	0.001	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
1=highest income bracket[5]	0.012	0.016	0.011	0.009
	(0.010)	(0.011)	(0.014)	(0.014)
Interactions of cohort and season of birth	Yes	Yes	Yes	Yes
Dummies for degree type (6)	Yes	Yes	Yes	Yes
Dummies for type of high school (5)	Yes	Yes	Yes	Yes
Regional dummies (18)	Yes	Yes	Yes	Yes
Cohort dummies (4)	Yes	Yes	Yes	Yes
Observations	5,269	5,269	5,269	5,269
R-squared	0.41	0.42	0.36	0.37

1. Maximum = 110; pass = 66.
2. Exam grades range from 18 (pass) to 31 (full marks with honours)
3. Spring is reference category.
4. Normalized between 0 and 1.
5. As recorded on the first year of registration with the university. For students with income in the highest income bracket the actual income value is not recorded.

Robust standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 10: Relative age and admission test scores

Admission years:	*1995-1998*			
	OLS	IV	RF	Only *regular* students
	[1]	[2]	[3]	[4]
Absolute age	-0.006***	-0.006**	-	
	(0.001)	(0.003)		
Assigned age	-	-	-0.004**	
			(0.002)	
1=February to November				0.043
				(0.031)
1=December				0.079**
				(0.040)
Controls				
1=female	-0.215***	-0.215***	-0.211***	-0.213***
	(0.014)	(0.014)	(0.014)	(0.016)
High school results[2]	4.345***	4.346***	4.427***	4.406***
	(0.052)	(0.064)	(0.051)	(0.058)
1=resident outside Milan (province)	-0.016	-0.016	-0.014	0.687***
	(0.019)	(0.019)	(0.019)	(0.112)
Dummies for degree type (6)	Yes	Yes	Yes	Yes
Dummies for type of high school (5)	Yes	Yes	Yes	Yes
Regional dummies (18)	Yes	Yes	Yes	Yes
Cohort dummies	Yes	Yes	Yes	Yes
Observations	12676	12676	12676	9,607

The dependent variable is the normalised test score
1. Absolute age is measured as months since birth.
2. Assigned age is measured as an numerical indicator of the month of birth, 0 for January, up to 11 for December.
3. Normalized between 0 and 1.
Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 11. Month of birth and admission test by areas

Admission years:	2000-2002							
	Overall result [1]	reading compreh. [2]	spatial-perception [3]	computer use [4]	math reasoning [5]	verbal relations [6]	logics of images [7]	verbal patterns [8]
Month of birth								
1=February to November	0.084*	0.041	0.075	0.108**	0.022	0.023	0.007	0.030
	(0.046)	(0.048)	(0.059)	(0.052)	(0.045)	(0.047)	(0.044)	(0.050)
1=December	0.142**	0.081	0.130*	0.186***	0.032	0.041	0.105*	0.077
	(0.057)	(0.059)	(0.067)	(0.063)	(0.058)	(0.059)	(0.054)	(0.062)
Controls								
1=female	-0.352***	-0.104***	-0.069***	-0.161***	-0.481***	-0.142***	-0.021	-0.043*
	(0.021)	(0.023)	(0.024)	(0.023)	(0.022)	(0.023)	(0.022)	(0.023)
High school results	2.118***	1.238***	0.544***	0.841***	1.713***	1.376***	0.401***	0.885***
	(0.082)	(0.085)	(0.101)	(0.088)	(0.083)	(0.086)	(0.091)	(0.085)
1=resident outside	0.093***	0.065*	0.020	0.018	0.115***	0.004	-0.073**	0.080**
Milan (province)	(0.033)	(0.034)	(0.034)	(0.033)	(0.034)	(0.035)	(0.035)	(0.035)
Dummies for degree type (6)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dummies for type of high school (5)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional dummies (18)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,619	7,619	7,619	7,619	7,619	7,619	7,619	7,619
R-squared	0.19	0.09	0.03	0.04	0.14	0.10	0.02	0.05

The dependent variable is the normalised test score.
See the appendix for a description of the content of each test section.
Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 12. Month of birth and social behaviour

	1=no sport[1]	1=no discos[2]	monthly sex frequency[3]	monthly sex frequency (>0)[4]	1=current relationship[5]
Estimation method	probit	probit	OLS	OLS	probit
mean of dep. variable	*0.24*	*0.11*	*3.06*	*6.60*	*0.59*
	[1]	[2]	[3]	[4]	[5]
Month of birth					
1=February to November	0.045	-0.072	0.184	-0.626	-0.160
	(0.139)	(0.159)	(0.544)	(0.977)	(0.153)
marg. effect	*0.007*	*-0.013*	*0.184*	*-0.626*	*-0.062*
1=December	0.083	0.076	-1.223*	-2.588**	-0.460**
	(0.177)	(0.198)	(0.629)	(1.204)	(0.188)
marg. effect	*0.011*	*0.014*	*-1.223**	*-2.588***	*-0.181***
Controls					
1=female	0.625***	0.024	0.578**	-0.003	0.392***
	(0.077)	(0.084)	(0.279)	(0.515)	(0.076)
(log) High school results[6]	0.255	0.170	-3.420***	-2.738	0.404
	(0.253)	(0.295)	(1.044)	(1.774)	(0.258)
1=live on one's own	0.114	-0.196**	0.188	0.315	0.004
	(0.080)	(0.099)	(0.332)	(0.562)	(0.086)
Dummies for region of birth (3)	Yes	Yes	Yes	Yes	Yes
Dummies for university region (3)	Yes	Yes	Yes	Yes	Yes
Home-town size dummies (3)	Yes	Yes	Yes	No	Yes
Dummies for father's education (3)	Yes	Yes	Yes	Yes	Yes
Dummies for mother's education (3)	Yes	Yes	Yes	Yes	Yes
Observations	1,689	1,690	1,647	810	1,319

1. Dummy coded 1 for students who answer *"never"* to the following question: *During the school year, do you practice any sport or physical activity?*
2. Dummy coded 1 for students who answer *"never"* to the following question: *Do you go to clubs or other places where you can dance?*
3. Coded to zero for students who have never had sexual intercourse.
4. Students who have never had sexual intercourse are excluded. Dummies for home-town size are omitted to increase sample size.
5. Dummy coded 1 for students who have a steady relationship at the time of the interview.
6. Range 0-100.

Robust standard errors in parentheses. The marginal effects are computed at the average of the explanatory variables.
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 13. Hours of self-studying at home – PISA 2003 (Italy)

	total time	science	By subject: mathematics	language
	[1]	[2]	[3]	[4]
1=February to November	0.215	0.013	0.055	0.102**
	(0.148)	(0.046)	(0.048)	(0.050)
1=December	0.418**	0.027	0.119*	0.157**
	(0.195)	(0.062)	(0.064)	(0.064)
1=female	1.175***	0.083***	0.130***	0.465***
	(0.104)	(0.033)	(0.031)	(0.034)
Additional controls:	dummies for father and mother education; foreign born dummy; second generation dummy; school type dummies			
Observations	16,149	16,405	16,385	16,462
R-squared	0.14	0.04	0.07	0.11

The dependent variable is the self-reported number of hours dedicated to self-studying at home.
Standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Appendix: Brief description of the attitudinal entry test

The test, in its 1995-1998 version, includes 8 sections. The total score is the sum of the scores obtained in each section. Below we report one sample question for each of the 8 sections. The number in brackets next to section’s name indicates the maximum score that is obtained by answering correctly to all the questions in the section.

1. **Reading comprehension (20)**

   Sample question. *Franz Joseph was crowned Emperor of Austria following the Austrian crisis of 1848, on the abdication of his uncle Ferdinand I and the renunciation of his father, the Archduke Franz Karl […].*

   Questions: *Franz Joseph was crowned Emperor of Austria following: a) the death of the Archduke Franz Karl; b) the renunciation of his uncle Ferdinand II; c) the abdication of his mother; d) the Austrian crisis of 1848; e) the death of his mother.*

   Answer. d).

2. **Spatial perception abilities (20)**

   Sample question. *In the following table you find five Original sequences on the left and five Copies on the right. You have to identify which copy or copies are not identical to the originals.*

qzbafjnioacrirceijyy	-------*A*-------	*qzbafjnioacrirceijyy*
cdefgiouuuimqsyankgi	-------*B*-------	*cdefgiouuuimqsyhnkgi*
rtsqlaqueapuiuelusgo	-------*C*-------	*rtsqlaqueapsiuelusgo*
ahmpzjyioankuuliesay	-------*D*-------	*ahmpzjyioankuuliesay*
mcuvryalduhjyrofeozn	-------*E*-------	*mcuvryalduhjyrofeozn*

   Answer. *C and B*

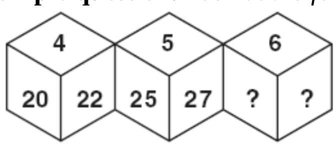
3. **Computer use (15)**

   Sample question. *Which of the following Microsoft Office software would you use to open a file named ‘students.mdb’: a) MS Word; b) MS Excel; c) MS Powerpoint; d) MS Access.*

   Answer. *d) MSAccess.*

4. **Math reasoning (20)**

   Sample question. *Look at the following figure:*



   Which of the following pairs of numbers should go where the question marks are placed: a) 30-32; b) 15-17; c)30-28; d) 50-52; e) 35-40?

   Answer. *a) 30-32*

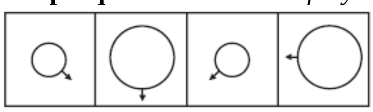
5. **Verbal relations (20)**

   Sample question. *Which of these words is not similar to the others? Genoa, Turin, Vienna, Milan, Venice.*

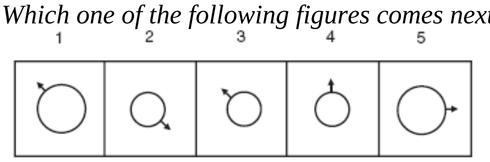
   Answer. *Vienna, since it is the only non Italian city.*

6. **Logics of images (10)**

   Sample question. *Look carefully at the following sequence:*



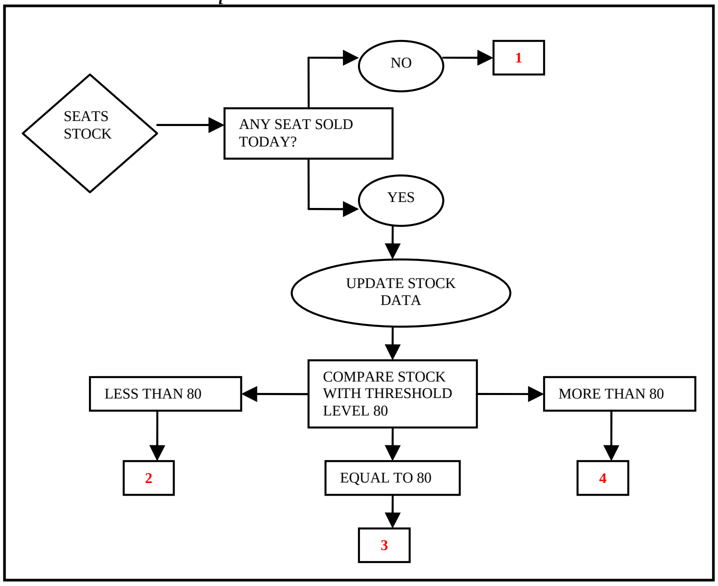
   Which one of the following figures comes next in the above sequence?



Answer. *The third figure. In fact, in the original sequence small and large figures alternate and rotate by 45° at each step.*

7. Verbal and logical patterns (10)

Sample question. *A retailer who sells seats wants to have in stock enough seats to be able to satisfy her clients' requests at all times. She decides to always have at least 80 seats in stock. If there are more than 80 seats in stocks, she does not file a new order to the producer. When there are exactly 80 seats in stocks, she files a regular order to the producer. When there are less than 80 seats in stock, she files an urgent order to the producer. At the end of each day, the retailers counts the seats in stock and decides whether to submit a new order and of which type (regular or urgent). Now, look at the diagram below and, according to the above description, indicate what action the retailer should take at each numbered square.*



Answer. *1 = no action; 2 = submit urgent order; 3 = submit order; 4 = no action*

8. General knowledge (15)

Sample question. *Where does the Gulf Stream originate from? a) from the Gulf of St. Lawrence; b) from the Gulf of California; c) from the Gulf of Mexico; d) from the Hudson Bay; e) from the Indian Ocean.*

Answer. *c) from the Gulf of Mexico.*