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Determinants of Grades in Maths for Students in Economics.

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Abstract

This paper investigates the determinants of grades achieved in mathematics by first-year students in Economics. We use individual administrative data from 1993 to 2005 to fit an educational production function. Our main findings suggest that good secondary school achievements and the type of school attended are significantly associated with maths grades. Ceteris paribus, females typically do better than males. Since students can postpone the exam or repeat it when they fail, we also analyze the determinants of the elapsed time to pass the exam using survival analysis. Modeling simultaneously maths grades and the hazard of passing the exam, we find that the overall hazard rate of passing the exam is higher for those students who get the higher grades. The longer students wait to take the exam, the less likely they are to obtain high grades.

JEL classification: I21, I23, C50.

Keywords: maths grades, quantile regression, survival analysis.

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1 Introduction

Renewed emphasis is being placed by governments and employers on numeracy skills for all people to enhance their employability, job satisfaction, level of remuneration, community participation and social well-being. Recent OECD research (2005) has indicated that raising a country literacy and numeracy score by 1 per cent leads to a raise in productivity of 2.5 per cent with the flow-on increase of 1.5 per cent in GDP. Recent studies show that numeracy skills influence labour market performance and income in specific ways other than educational attainment (Charette and Meng, 1998; McIntosh and Vignoles, 2001). Proficiency in quantitative skills has been observed to improve job performance due not only to the array of computational tasks that are routinely performed in most jobs, but also because of the greater general productivity associated with quantitative literacy (Bishop, 1989; Murnane 1988; Ma, 2001). Rivera-Batiz (1992) found that quantitative literacy skills are a major factor raising the likelihood of full-time employment. Previous research also suggests that cognitive skills proficiency including adult numeracy are strongly and positively related with educational achievements (Kirsch et al., 1993; Tuijnman and Boudard, 2000; Desjardins, 2004). A recent OECD research (2000), using the Adult Literacy and Life Skills (ALL) Survey, indicates that higher average proficiency scores are associated with higher levels of educational attainment in all countries considered. More specifically, McNabb et al. (2002) and Smith and Naylor (2001) have found that grades obtained in the first-year mathematics exam can be a good predictor of the subsequent academic performance of students in Economics. Given the importance of numeracy skills widely documented in the economics literature, we decide to investigate their main determinants at the university level.

This paper, in particular, is concerned with the factors that determine individual success in the first-year mathematics exam for students in Economics. There is a substantial international literature that investigates the determinants of success in first-year college courses, using student level data. A number of previous works both for the US and for the UK (Sabot and Linn, 1991; Durden and Ellis, 1995; Hanushek, 1995; Anderson et al., 1994; King, 1999; Cohn et al., 1999) document that the most important determinants of the academic achievements in first-year courses are prior qualifications, gender, age, family background and to some extent also the course attendance. The academic performance has been extensively researched also in Italian empirical works. Checchi et al. (2000) show that students' performance is positively correlated with family income and take this result as supporting the idea of family networking: students from richer families tend to go quicker because they have better prospects when they exit university. Cappellari (2004) studies the relationship between the type of high school attended and indicators of subsequent performance. He finds that general high schools increase the probability of transition to university and improve performance once at university. He also shows that private high schools are associated with lower academic performance, suggesting the higher quality of education provided by state schools. Finally, Bratti et al. (2006) investigate the effects of recent university reforms[1] on academic performance. They find that, in Mathematics and Economics courses, the reform produced a reduction in the likelihood of failing the exams and an increase in the probability of passing them in the first year. They observe that the last two effects are directly produced by the reduced workload and simplification of the courses, since the average grades do not increase in such courses after the reform. We will not consider the role of this structural reform, because the evaluation of its effects on maths grades is behind the scope of this analysis.

Recently, Dolado and Morales (2006) have analyzed the determinants of grades

[1] In 2001 a "3+2" (unitary two tier) university reform system was introduced in Italy where a 3-year First Level degree followed by a 2-year Second Level degree replaced a one-tier system where the old degree (Laurea) institutional duration varied between a minimum of four (economics, for example) and a maximum of six years.

in an introductory course of maths by first-year Economics undergraduate students at Universidad Carlos III, Madrid, over the period 2001-2005. Their main findings suggest that students with a technical specialization at high school tend to do better than those who attended a social sciences degree, controlling for pre-college skills through university entry-exam scores. By means of quantile regressions, they also find that students from state schools with a (non) technical degree are predominant in the upper (lower) parts of the grade distribution and that females tend to perform better than males. Their empirical analysis is, however, based on a sample which is limited both in terms of the variables included as controls and with respect to the number of academic years.

As we have already mentioned, also in this study we analyze the students' performance in maths. The aim of this paper is twofold. On the one hand, we will shed some light on the main factors associated with maths grades fitting an educational production function. On the other hand, we analyze the determinants of the elapsed time to pass the exam through a survival analysis. The latter objective is primarily related to the the didactic organization of Italian universities. This organization determines that students are free to choose whether to attend lectures and classes or not and when to sit exams. Courses are usually assessed at the end of the teaching periods and exams can be repeated without limitations in multiple alternative sessions during the same year or the following academic years. Students can refuse a grade in case they are not satisfied with their performance in a specific exam and attempt the exam in subsequent sessions. Exam failures are not registered in the students' records and there are no constraints on the number of exams to be passed in order to enroll in the following year. Another important feature of the Italian university is that even though the secondary school system is stratified into academic and vocational schools [2], there is no formal

[2]The Italian secondary consists of four types of high schools: licei (General high schools), istituti tecnici (Professional high schools), istituti professionali (Vocational high schools) and finally scuole magistrali and istituti artistici (Teaching and Art schools). The first type of school lasts five years

selection procedure at the enrollment and no limitation exists in relation to ability or the type of education acquired at secondary level. This may cause great heterogeneity of university students' ability especially in the first academic years. In this situation we could observe, on the one hand, the most able students passing the maths exam immediately and with good grades and, on the other hand, their peers coming from vocational tracks who need to put more effort and to study longer in order to enter the tournament and pass the minimum required numeracy ability threshold. But students who take longer could also be those who deliver a very low effort and repeat the exam several times until they get the minimum required maths ability threshold to pass the exam.

This "mass" tertiary education system implies considerable costs for demanders of such a service. For students wasted time is associated with the unsatisfactory experiences of failure and the consequent decision of interrupting university studies or of failure and repetition of the exam without limitations, the latter prolonging the time to graduation. The importance of these two problems is particularly evident in Italy. Dropout rates are very high during the first years of degree courses: in the academic year, 20% of first-year students did not renew their enrollment in the second year.[3] The Italian university dropout rates are also the highest among the European countries.[4] Furthermore, the Italian higher education system has always been characterized by an actual time of graduation much longer than in most other developed countries. The gap between actual and legal degree duration is partly due to the high percentage of

and provides its graduates with general and academic skills useful for higher education. The second and third types are generally five-year studies and provide their students with professional skills that can be exploited in the labour market immediately after graduation. However, graduates from either Professional or Vocational high schools are allowed to enroll at the university if they choose to go on to further education. The fourth type, typically for those students who want to become teachers, lasts four years plus an additional year for those students who wish to go to university. So students from any of these tracks are formally entitled to enroll at university, conditional on having attended 5 years of secondary school

[3]Source: Miur Cnvsu (2005).

[4]OECD student survival rates in 2000 are lowest for Italy (42%) compared to an OECD average of 70%.

inactive students, i.e. those who did not pass any exam during a given academic year.[5]

All these characteristics of the Italian university system explain why it is so important to consider both the grades achieved and the speed at which a student undertakes the exam to analyze individual academic performance. Previous research (Checchi et al., 2000) on this topic combined the two dimensions in one indicator. We prefer to consider them separately using two different econometric approaches. Given that data requirements are very demanding especially for duration analyses, we analyze students' performance in maths using a very informative and large sample covering 10 years, drawn from the administrative database of Cattolica University.[6] One important advantage of this dataset is that the materials (contents, subjects and books) covered over the sample period and the way the exam is structured remain almost identical. Moreover, the different lecturers of maths courses have always been working in close collaboration with each other in order to coordinate their teaching and assessment activities.[7]

The main results of this "case" study indicate that final high school grades and the type of high school attended are significantly correlated with maths grades and that females, ceteris paribus, typically do better than males. We also find that the students who pass the exam in the first year have higher grades than students who pass it from the third year on. Finally, the longer students wait to take the exam, the less likely they are to obtain high grades, confirming the idea that the most able students are more likely to pass the exam immediately and with good grades compared with their less able peers who need to study longer in order to pass the minimum required maths ability threshold.

[5]According to Miur Cnvsu (2005), in the academic year 1999/2000 23% of Italian students were inactive.

[6]This is a very large private Italian college which offers undergraduate and graduate degrees in several subject areas, namely education, law, economics, the humanities, languages, maths, banking science and political science.

[7]We are particularly indebted with Anna Torriero for helpful discussions on the didactic organization of maths courses over the period considered.

The structure of the paper is as follows. Section two describes the dataset and the estimation sample. In section three, we present the methodology used in this paper and the results of the empirical analysis. Section four concludes.

2 Data

We use a specific dataset to examine the performance of university students in terms of first-year maths grades. Data are drawn from the administrative records of Cattolica University. In this analysis, we focus on Economics students enrolled or with a completed degree from the academic year 1992/93 to 2005/2006.[8]

The dataset provides the following information: i) administrative information collected at enrollment (age, gender, region of residence, previous education); ii) information on academic career (faculty and grades and date of every exam); iii) all information collected to calculate the university fee (family income; if the student is a full-time worker; number of family components; paid fees).

From the original sample, we excluded individuals who declared to work full-time as well as individuals for whom we miss data either on personal characteristic or on family income. The resulting sample consists of almost 11,000 students.

Grades in the Italian education system are numerical, ranging from 18 to 31 over 30.[9] As we mentioned in the introduction, Italian students are not obliged to take exams at the end of courses: they can take them in some fixed periods of the year throughout the duration of the degree course. From Table **??**, we can see that the percentage of students who passed the exam in the first year decreases till the academic year 1995/96 and increases thereafter, especially after the academic year 2001/2002. As Bratti et al. (2006) argue, this could be related to the fact that the university

[8]Students who passed the math exam and dropped out later are retained in the sample.

[9]It is possible to pass an exam with the grades ”30 cum laude”: we coded this outcome as 31.

reform implemented in 2001 tends to simplify university courses and not to an increase in the student academic ability, as the mean of final high school grades of enrolled students has not changed significantly in the period considered.

Table **??** reports the distribution of students used in the sample according to their maths grades. Most students (70%) show grades up to 24 over 31 while about 10% show full grades (28-31 over 31). An analysis by gender indicates that women obtain the highest grades.

The definitions of variables used in the analysis are reported in Table **??** along with their sample means. Concerning the variables the following clarifications should be made. As indicator of pre-college performance we used the variable "final high school grades"This variable is strongly correlated with maths grades: Table **??** shows that students with the lowest final grades are more likely to come out badly in the math exam. The other way around, if we consider students with the highest final grades. High school types have been regrouped into 3 different categories (General, Professional/Vocational, Other) and we take into account whether they are private or state institutions. Tables **??** and **??** indicate that also high school types seem to be correlated with academic performance. The dummy variables "first year" and "second year" are equal to 1 if the student passed maths exam in the first and in the second academic year, respectively. From Table **??**, we can see that on average only 59% of students pass the exam in the first academic year, suggesting that a consistent fraction of students takes a lot of time to pass maths exam. Finally, we decided to use the precise year, ranging from 1993 to 2006, in which students take and pass the exams rather than the first academic year of enrollment as a time fixed effect because, as previously mentioned, students can take the exam in some fixed periods of the year throughout the duration of the degree course. We finally include among the covariates a dummy variable related to whether the maths exam is a prerequisite to pass other exams.[10]

3 Empirical strategy and main results

3.1 The determinants of mathematics skills among university students

Following Hanushek (1995) Case and Deaton (1999), Dolado and Morales (2006) and Bratti and Staffolani (2002), we analyze student performance using educational production function approach, according to which maths grades are assumed to be a function of several inputs such as:

$$G_m = g\left(X, A, Y, T, P\right) \tag{1}$$

where G_m represents maths grades (ranging from 18 to 31), X is a vector of personal characteristics including gender (reference category: females) and cohort dummies (reference category: students born after 1980 [11]); A contains all information on previous education, such as high school type (reference category: other high school), whether the high school is a state institution, final high school grades, whether the high school is located in the North of Italy (reference category: high school located in a central or southern region) ; Y includes the dummy variables "first year" and "second year" relating to whether the student passed the exam in the first or second year of her academic career (reference category: the student passed the exam from the third year on),

[10]Until the academic year 1994/1995, if a student did not pass the most fundamental exams of the first year, including the maths exam, he could not enroll at the second year. For those students enrolled from the academic year 1995/1996 onwards, this is no longer the case.

[11]Year of birth has been grouped into the following cohorts: born before 1974, born between 1974 and 1979 and born after 1979.

T are time fixed effects capturing the exact year in which the student passed the exam which is not necessarily the first year of enrollment (reference category: academic year 1992/1993) and P is a dummy variable related to whether maths exam is a prerequisite to pass other exams.

Table ?? reports the OLS estimates of equation (1) with heteroskedasticity-robust standard errors [12]. One of the strongest effects comes from high school type: graduates from General high schools (licei) have almost 1 extra point in maths exam compared to those from other high schools. In column two of Table ??, we also report the effect of General high schools in case it is distinguished into "Scientific" (licei scientifici) and "Humanities" (licei classici) high schools. As one may expect, the effect on grades is more pronounced for the former track, indicating that the scientific general education may provide more basic calculus skills than the humanistic one. We then find that graduates who took their high school degree in the North of Italy have a better performance than those who got their secondary education either in the Centre or in the South of Italy. Students from the North of Italy have 1 extra point compared with their peers coming from the South. This could be consistent with recent results about regional differences in the quality of maths training in high schools. Using Italian data from the 2003 wave of the OECD Programme for International Student Assessment (PISA), Checchi et al. (2007) find that the median difference between a Northern and a Southern region exceeds one standard deviation even if the organization of secondary education is strongly centralized. Checchi et al. (2007) argue that these differences may stem from different regional endowments in cultural and social capital. Hence our results seem to confirm that territorial variables are crucial in shaping student mathematical competencies at the secondary school level.

[12] It is worth noting that OLS methodology does not take into account that: i) we don't observe the grades for exams attempted but not passed; ii) grades higher than 31 are recorded as 31. Our results, however, seem to be quite robust to the above mentioned problems, given that using a censored regression model we obtain fairly similar results to the OLS ones.

Graduating from a state high school leads to a 0.5 extra point in maths. This could be an indication of the higher quality of education provided by state schools as it has been found by other empirical works applied to the Italian context (Cappellari, 2004; Bertola and Checchi, 2001). In order to analyze the impact on grades of having graduated from a certain high school track in a given school (state or private), we also report the estimated coefficients of equation (1) augmented with the interactions between high school degree and school type. These interactions, however, are never statistically significant.

The final high school grades is only weakly related to maths grades and males seem to perform worse than females. All the cohort dummies are significantly positive: students born before 1974, for example, have 1.6 extra points compared to younger students. This could give some evidence to the extended opinion that maths training at the secondary level has been deteriorating over time (Checchi et al., 2007).

The first year fee, which is a proxy for family income, seems to be unimportant for maths grades, and finally students who pass the exam in the first (second) year of the academic career have 1.2 (0.4) higher grades than students who take the exam from the third year on, indicating that the former are better and more motivated students than the latter. Finally whether, maths exam is a prerequisite to pass other exams or not does not affect grades achievement.

Estimating equation (1) year by year or by high school type does not reveal any particular difference in associations between student characteristics and grades obtained over the years or according to the secondary school track (see Tables **??** and **??** in the Appendix).

The OLS estimates allow us to make statements about how factors shift the mean of maths grades distribution. To get a more complete picture of how various factors impact different quantiles of the conditional maths grades distribution, we use a quantile regression approach (Koenker and Bassett, 1978).

Table **??** reports the quantile regressions estimates of equation (1). Quantile regressions are estimated at four different quantiles (0.25; 0.50; 0.75; 0.90). To avoid the bandwidth choice required by the kernel estimator, we decide to use a bootstrap estimator for the standard errors. For each quantile estimator, 500 bootstrap replications are performed and the standard deviations are computed. For comparison, the results from the ordinary least squares regression are reported in the last column.

The ordinary least squares are quite similar to the 50%-quantile (median) regression estimates, but the varying nature of the estimates at the other quantiles provides an interesting picture of how the distribution of maths grades is related to the covariates.

Note that the magnitude of the estimates for many of the variables (Humanities and Scientific high schools [13], state high schools, cohort dummies) increases when moving from a lower quantile to a higher quantile; i.e. the marginal effects of the variables are larger at higher quantiles. Ordinary least squares overestimate the magnitude of these effects at the 10% quantile and underestimate the magnitude of these effects at the 90% quantile.

The Scientific and Other high schools differential in maths grades at the 10% quantile is 0.8 point. That is, holding all other things equal, the 10% quantile of maths grades for a student from a Scientific high school is 0.8 point higher the 10% quantile of maths grades for a student from an Other high school. The Scientific-Other high school differential increases to 1.5 at 75% quantiles. This is also true for cohort differential in maths grades (this is 0.7 at the 10% quantile and increases to 2.7 at the highest quantile), for the high school location variable (0.9 at the 10% quantile, 1.1 at 75% quantile) and for the dummy indicating whether the exam is taken in the first academic year (0.9 at the 10% quantile, 1.5 at 75% quantile).

The estimates for male dummy, on the other hand, decrease monotonically from the

[13] Contrary to the OLS estimates, we only report the effect of general high schools in case it is distinguished into "Scientific" (licei scientifici) and "Humanities" (licei classici) high schools

lower quantiles to the higher quantiles (i.e. lower marginal effects at higher quantiles). The gender differential in maths grade seems to be more evident at lower quantiles of the maths grades distribution. The changing behavior of the coefficients along the distribution could be related to a latent individual characteristic, such as unobserved ability, implicitly indexed by each quantile of the maths grades distribution. If the latent characteristics were observable ex ante, then one could view the estimated coefficients of each quantile of maths grades distribution as an explicit interaction with this observable variable.

3.2 The determinants of the elapsed time to pass maths exam

The peculiarities of the Italian didactic organization mentioned above, lead us to investigate also the determinants of the time to take maths exam. Survival analysis is used to overcome the difficulties conventional statistical techniques have in modeling probability (Jenkins 2004). The duration variable of interest (time to take the exam) is measured in months and it is calculated as the difference between the date in which the student takes the exam and the first available date for taking the exam after the end of the maths course.[14]

The fact that the duration variable of interest is measured in months means that the appropriate approach to modeling the elapsed time to pass maths exam is the discrete-time hazard model. Following Meyer (1990), the discrete time hazard of passing the exam can be modeled using the discrete-time proportional hazards model. In particular, the hazard of passing the exam in the jth month, $h(t_j)$, for individual i with a vector of covariates, x, given that the exam has not been taken before t_{j-1} can be given by:

[14] This has been identified conventionally with the month of June for the academic years 1993/1994 and 1995/1996 and with the month of January for the following academic years. The explanation is that initially the first available date for taking the exam was in June and after 1996 it was in January.

$$h_{ij} = 1 - \exp\left(-\exp\left(\gamma_j\left(t\right) + \left(z_i\beta\right) + u_i\right)\right),\ where\ \gamma_j\left(t\right) = \int\limits_{-\infty}^{\infty} h_o(u)du \qquad (2)$$

where $\gamma_j\left(t\right)$ represents the baseline hazard which has been specified flexibly[15], z includes the vector of personal characteristics, X, all information on previous education A, the dummy variable related to whether the maths exam is a prerequisite to pass other exams and time fixed effects T. Unobserved heterogeneity is represented by u_i which is the log of a positive-valued random variable (mixture). The unobserved heterogeneity term is assumed to be independent of observed covariates, z_i, and the random duration variable. Given that unobserved heterogeneity could be potentially correlated with both the elapsed time to take maths exam and the grades, we simultaneously model the probability of taking low, average, above average and high grades and the hazard of taking the exam. The probability of falling in each of the above grade categories depends on the same explanatory variables of the hazard model and an unobserved component is specified as an ordered probit model with discrete random effects. The categorized maths grades, CG_{im}, are determined from the model as follows:

$$\begin{aligned}
CG^{*}_{im} &= z_i^{'}\pi + \varepsilon_i + v_i \qquad (3)\\
CG_{im} &= low\ grades\ if\ y_i^* < 0\\
CG_{im} &= average\ grades\ if\ 0 \leqq\ y_i^* < \zeta_1\\
CG_{im} &= above\ average\ grades\ if\ \zeta_1 \leqq y_i^* < \zeta_2\\
CG_{im} &= high\ grades\ if\ y_i^* \geqq \zeta_2
\end{aligned}$$

[15] The baseline hazard function has a piecewise constant specification, such that it is constant within duration intervals.

where ε_i is unobserved heterogeneity and v_i is an error term, assumed to follow a standard normal distribution. We assume that all sources of correlation between the two processes beyond those captured by the observed explanatory variables can be represented by the individual-specific heterogeneity terms. Assuming that we observe a student i's spell from month k=1 through the end of the jth month, at which point i's spell is either complete (c_i=1) or right-censored (c_i=0), and defining a new binary indicator variable y_{ik}=1 if student i passes the maths exam in month k, and y_{ik}=0 otherwise, the individual contribution to the likelihood function in our model is:

$$LogL = \int_{-\infty}^{+\infty} (\prod_{j}^{t} h_j(t, z_i|u_i)^{y_{ij}} (1 - h_j(t, z_i|u_i)^{1-y_{ij}}) \prod_{CG_{im}=s} (\Phi(\zeta_s - z_i^{'}|\varepsilon_i) - \Phi(\zeta_{s-1} - z_i^{'}|\varepsilon_i))) dG(u, \varepsilon) \tag{4}$$

$G(u, \varepsilon)$ is the joint cdf of the unobservables. We use a flexible and widely applied specification of the distribution of the unobservables; it is assumed that u and ε can take two values. Thus, there are two possible combinations of this bivariate unobserved heterogeneity distribution, each with an associated probability. For more details on this class of mixture distributions in duration models, see, e.g., Van den Berg (2001).

A first impression of the association between the grades and the time to pass the exam is obtained by plotting different Lifetable estimates of the hazard of passing the exam. In Figure 1, we show the non-parametric single risk hazard functions for taking the maths exam. We distinguish between the grades categories presented above. As can be seen, over the first months students with high grades have a consistently higher hazard rate than students with average or low grades. The other way around if we consider very long durations, i.e. the longer students wait to take the exam, the less likely they are to obtain high grades. Moreover, the null hypothesis of equality of survivor functions for different groups is rejected by both the log-rank and Wilcoxon tests (see Table **??**).

The results of the simultaneous model described above are given in Table **??**. The first column shows estimated coefficients and their standard errors of the hazard of passing maths exam, while the second one contains paramater estimates and standard errors of the maths grades equation. With respect to explanatory variables of maths grades, it appears that women and students with higher high school grades are more likely to get higher grades in maths exam, as the OLS and quintile regressions suggest. Also, graduates from Scientific or Humanities high schools are more likely to achieve higher grades, as the students graduated from a state high school or coming from the North of Italy. Younger students are more likely to perform bad compared to their older counterparts. Finally, contrary to the previous models, when the maths exam is a prerequisite to pass other exams, the students are more likely to achieve lower grades. From the first column of Table **??**, we can see that the probability of passing maths exam is increasing with final high school grades and scientific secondary education and is negatively correlated with technical education. With regard to gender differences, female students have a 6% higher hazard of passing maths exam compared with their male counterparts. The results also indicate that state versus private high schools slightly improves the speed at which the students pass maths exam: graduating from a state high school significantly increases the hazard rate of taking the exam. The probability of taking maths exam is also significantly correlated with high school location: graduates from a high school located in the North of Italy have a higher hazard of taking maths exam than graduates from the Centre or South of Italy. This result confirms again the territorial differences in Italian students' mathematical competencies. Another interesting result is that younger students (born after 1980) have a higher hazard of taking maths exam than their older counterparts. Finally, when the maths exam is a prerequisite to pass other exams, the students seem to be faster to take it. The unobserved heterogeneity terms in the grades equation and in the hazard rate are clearly correlated, so it is of importance to estimate them simultaneously. The estimated correlation is positive indicating that the longer students wait to take the exam, the less likely they are to obtain high grades. This result may suggest that the students taking longer to pass maths exam are not only those who need to put more effort to catch up the most brilliant students but are also those who repeat the exam several times until they pass the minimum required maths ability threshold.

All these results confirm that there is great heterogeneity of ability among Italian university students, given that no selection procedure exists at the enrollment. The most able students pass the exam immediately and with good grades while their peers with fewer numeracy skills need to put more effort and to study longer in order to pass the minimum required maths ability threshold, given that their learning process is longer. But we show that among students who take longer to take maths exam some put a very low effort and repeat the exam several times until they get the minimum required maths ability threshold to pass the exam. As we mentioned in the previous sections, only 60% of the sampled students pass the exam in the first academic year. Hence about one half of the students take longer to pass the exam and are more likely to perform worse than those students who pass the exam immediately. One important policy implication of these results is that the actual didactic organization of Italian universities[16] implies considerable costs for students in terms of wasted time associated with the unsatisfactory experiences of failure and repetition of the exam without limitations, the latter prolonging the time to graduation with lower chances to perform well. If a different system was adopted where the exam could not be repeated without limitations and a strong selection procedure at the enrollment (like in most other European countries), this would permit any enrollment target that limits

[16]The didactic organization of Italian universities remained largely untouched by the recent university reforms.

enrollment below the unconstrained demand to be met, but in such a way that the loss of students most likely to succeed is minimized as well as the gain of students who would take longer to graduate and who are more likely to have a low performance. This would allow the latter to select into more appropriate fields of study where they could have better chance of success.

4 Conclusions

This paper is concerned with the factors that determine individual success in the first year mathematics exam for students in Economics. The aim of this study is twofold. On the one hand, we will shed some light on the main factors associated with maths grades fitting an educational production function. On the other hand, we analyze the determinants of the elapsed time to pass the exam through a survival analysis. Given that data requirements for the empirical analysis are very demanding, we analyze students' performance in maths using a very detailed and large sample covering 10 years, drawn from the administrative database of Cattolica University.

The overall results of the empirical analysis indicate that final high school grades and higher pre-college maths knowledge are positively correlated. Females typically do better than males, controlling for all other factors, and family income influences the academic performance negatively. Consistent with other studies (Checchi et al., 2007), we find some evidence of territorial differences in Italian students' mathematical competencies. Finally, duration analysis on the elapsed time to take maths exam indicate that the longer students wait to take the exam, the less likely they are to obtain high grades. This confirms that there is great heterogeneity of ability among Italian university students, given that no selection procedure exists at the enrollment. The most able students pass the exam immediately and with good grades while their peers with fewer numeracy skills need to put more effort and to study longer in order to pass the minimum required maths ability threshold, given that their learning process is longer. But we also show that among students who take longer to take maths exam some put a very low effort and repeat the exam several times until they get the minimum required maths ability threshold to pass the exam.

One important policy implication of these results is that if a different system was adopted where the exam could not be repeated without limitations and a strong selection procedure at the enrollment (like in most other European countries), this would permit any enrollment target that limits enrollment below the unconstrained demand to be met, but in such a way that the loss of students most likely to succeed is minimized, as well as the gain of students who would take longer to graduate and who are more likely to have a very low performance.

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Table 1: Summary Statistics.

Variables	N	Mean	Std.	Min	Max
Maths grades	10793	22.41	3.61	18	31
Exam year					
1993	10812	0.03	0.16	0	1
1994	10812	0.07	0.25	0	1
1995	10812	0.09	0.28	0	1
1996	10812	0.05	0.22	0	1
1997	10812	0.09	0.28	0	1
1998	10812	0.08	0.26	0	1
1999	10812	0.08	0.27	0	1
2000	10812	0.07	0.25	0	1
2001	10812	0.07	0.25	0	1
2002	10812	0.10	0.30	0	1
2003	10812	0.07	0.26	0	1
2004	10812	0.07	0.25	0	1
2005	10812	0.07	0.26	0	1
2006	10812	0.05	0.22	0	1
Exam taken in the first year	10812	0.59	0.49	0	1
Exam taken in the second year	10812	0.24	0.42	0	1
Exam taken in the third year	10812	0.17	0.37	0	1
Personal characteristics					
Gender (males)	10812	0.56	0.49	0	1
Final high school grades	10758	78.29	11.66	60	100
First year fee	10812	28.89	12.54	0	249.61
General high school	10812	0.58	0.49	0	1
Professional/Vocational high school	10812	0.37	0.48	0	1
Other high school	10812	0.05	0.22	0	1
Public high school	10812	0.75	0.43	0	1
Cohort 1	10812	0.21	0.40	0	1
Cohort 2	10812	0.35	0.47	0	1
Cohort 3	10812	0.44	0.49	0	1
Location school (South or Centre)	10812	0.08	0.26	0	1
Location school (North)	10812	0.92	0.27	0	1
Maths exam prerequisite	10812	0.26	0.43	0	1

Table 2: Percentage of students who passed the maths exam in first year.

Academic year	Enrolled students	Percentage passing the maths exam in the first year	Mean of final high school grades of enrolled students
1992/93	1,220	0.29	78.29
1993/94	1,170	0.31	81.44
1994/95	1,116	0.43	79.62
1995/96	1,091	0.32	78.07
1996/97	1,127	0.47	77.4
1997/98	874	0.52	76.88
1998/99	703	0.69	76.31
1999/2000	724	0.78	78.51
2000/2001	1,096	0.69	75.43
2001/2002	1,374	0.81	76.79
2002/2003	1,195	0.71	80.47
2003/2004	1,076	0.76	81.17
2004/2005	1,151	0.90	81.06
2005/2006	1,160	0.90	80.07

Table 3: Distribution of maths grades by gender.

	maths grades				
gender	**18-20**	**21-24**	**25-27**	**28-31**	**Total**
female	35.72	34.42	18.76	11.10	43.66
male	40.27	33.65	17.40	8.68	56.34
Total	38.28	33.98	17.99	9.74	100.00

Table 4: Distribution of maths grades by final high school grades.

	maths grades				
high school final grades	**18-20**	**21-24**	**25-27**	**28-31**	**Total**
60-70	47.28	33.13	14.47	5.12	30.93
71-80	40.11	34.85	17.93	7.10	30.79
81-90	33.51	35.23	20.32	10.95	20.66
91-100	24.89	32.40	21.83	20.88	17.61
Total	38.29	33.97	18.04	9.71	100.00

Table 5: Distribution of maths grades by high school type.

	maths grades				
high school	**18-20**	**21-24**	**25-27**	**28-31**	**Total**
General	34.80	34.00	19.78	11.42	57.91
Professional/Vocational	42.76	33.93	16.01	7.30	36.92
Other	45.34	34.23	12.19	8.24	5.17
Total	38.28	33.98	17.99	9.74	100.00

Table 6: Distribution of maths grades by secondary school institution type.

	maths grades				
institution type	**18-20**	**21-24**	**25-27**	**28-31**	**Total**
private	44.64	32.12	16.06	7.18	25.16
public	36.15	34.61	18.64	10.60	74.84
Total	38.28	33.98	17.99	9.74	100.00

Table 7: Log-rank and Wilcoxon (Breslow) tests.

Log-rank test for equality of survivor functions	**Events observed**	**Events expected**	
Low grades	5020	5887.56	
Average grades	4464	4288.54	
Above average grades	2337	2045.51	
High grades	1199	798.4	
Total	13020	13020	
	chi2(4) =	444.92	
	Pr≥chi2 =	0	
Wilcoxon (Breslow) test	**Events observed**	**Events expected**	**Sum of ranks**
Low grades	5020	5887.56	-7916472
Average grades	4464	4288.54	1042448
Above average grades	2337	2045.51	2567327
High grades	1199	798.4	4306697
Total			
	chi2(4)=	604.62	
	Pr≥chi2=	0	

Table 8: Ols estimates; dependent variables: Maths grades.

	Model1	**Model2**
Gender(males)	–0.170**	–0.195***
	(0.069)	(0.069)
Final high school grades	0.080***	0.081***
	(0.003)	(0.003)
First year fee	–0.001	–0.001
	(0.003)	(0.003)
General high school	1.029***	
	(0.224)	
Humanities high school		0.751***
		(0.289)
Scientific high school		1.113***
		(0.227)
Professional/Vocational high school	0.069	0.071
	(0.237)	(0.237)
Public high school	0.570*	0.574*
	(0.306)	(0.306)
Public school*General	0.139	
	(0.321)	
Public school*Scientific		0.154
		(0.323)
Public school*Humanities		–0.065
		(0.387)
Public school* Professional/Vocational	–0.272	–0.279
	(0.332)	(0.332)
Cohort1	1.583***	1.584***
	(0.205)	(0.205)
Cohort2	1.046***	1.041***
	(0.156)	(0.157)
Location school (north)	1.005***	0.948***
	(0.126)	(0.127)
Exam passed in the first year	1.196***	1.152***
	(0.115)	(0.116)
Exam passed in the second year	0.420***	0.414***
	(0.113)	(0.113)
Maths exam prerequisite	–0.085	–0.084
	(0.168)	(0.168)
R sq.	0.131	0.132
N	10743	10743

Notes: Robust standard errors in parentheses; ***Significant at the 1% level **Significant at the 5% level *Significant at the 10 % level. All regressions include time dummies.

Table 9: Quantile regressions estimates; dependent variables: Maths grades.

	q25	**q50**	**q75**	**q90**
Gender(males)	–0.201***	–0.216**	–0.184*	–0.153
	(0.070)	(0.103)	(0.109)	(0.135)
Final high school grades	0.058***	0.099***	0.102***	0.101***
	(0.004)	(0.005)	(0.004)	(0.006)
First year fee	0.000	–0.004	0.000	0.002
	(0.003)	(0.004)	(0.004)	(0.006)
Humanities high school	0.732***	0.596*	0.898	0.892
	(0.250)	(0.362)	(0.578)	(0.578)
Scientific high school	0.804***	1.248***	1.541***	1.231***
	(0.202)	(0.328)	(0.403)	(0.419)
Professional/Vocational high school	0.243	–0.051	0.020	0.043
	(0.211)	(0.347)	(0.433)	(0.413)
Public high school	0.613**	0.771*	0.745	0.981
	(0.280)	(0.415)	(0.557)	(0.650)
Public school*Scientific	0.109	0.085	–0.041	–0.316
	(0.302)	(0.462)	(0.594)	(0.666)
Public school*Humanities	–0.333	0.084	0.051	–0.712
	(0.345)	(0.518)	(0.739)	(0.829)
Public school* Professional/Vocational	–0.349	–0.438	–0.367	–0.700
	(0.303)	(0.465)	(0.610)	(0.677)
Cohort1	0.714***	1.745***	2.633***	2.748***
	(0.227)	(0.278)	(0.344)	(0.404)
Cohort2	0.675***	1.183***	1.673***	1.602***
	(0.168)	(0.215)	(0.289)	(0.339)
Location school (north)	0.884***	1.274***	1.071***	0.730***
	(0.123)	(0.184)	(0.225)	(0.283)
Exam passed in the first year	0.897***	1.316***	1.449***	1.528***
	(0.112)	(0.167)	(0.205)	(0.260)
Exam passed in the second year	0.292***	0.586***	0.531***	0.410*
	(0.105)	(0.165)	(0.200)	(0.238)
Maths exam prerequisite	–0.170	–0.286	0.153	0.163
	(0.154)	(0.258)	(0.292)	(0.281)
R sq.	0.05	0.08	0.08	0.09
N	10743	10743	10743	10743

Notes: Bootstrapped (500 replications) standard errors in parentheses; ***Significant at the 1% level **Significant at the 5% level *Significant at the 10 % level. All regressions include time dummies.

Table 10: Simultaneous model estimates (time to pass maths exam and grades).

	Duration model	**Ordered Probit model**
Gender(males)	-0.043**	-0.052***
	0.019	0.005
Final high school grades	0.018***	0.026***
	0.001	0.001
First year fee	0.001	0.000
	0.001	0.000
Humanities high school	0.088	0.281***
	0.078	0.022
Scientific high school	0.411***	0.339***
	0.061	0.018
Professional/Vocational high school	-0.163***	-0.026
	0.064	0.017
Public high school	0.226***	0.247***
	0.081	0.023
Public school*Scientific	-0.014	0.015
	0.086	0.024
Public school*Humanities	-0.139	-0.082***
	0.105	0.028
Public school* Professional/Vocational	-0.035	-0.114***
	0.089	0.024
Cohort1	-1.845***	0.340***
	0.067	0.016
Cohort2	-1.313***	0.189***
	0.047	0.012
Location school (north)	0.189***	0.319***
	0.033	0.011
Maths exam prerequisite	-1.331***	-0.154***
	0.052	0.012
Cut-off point 1		2.341***
		0.058
Cut-off point 2		3.451***
		0.081
Cut-off point 3		4.341***
		0.097
Mass point 1 location	-0.299	0.194
Mass point 1 probability	0.394	0.606
Mass point 2 location	-0.769	0.499
Mass point 2 probability	0.394	0.606
Covariance between discrete random effects	0.15	
Number of person period obs	602567.00	
Log Likelihood	-401527.52	
AIC	803191.04	
BIC	803960.05	

Notes: Standard errors in parentheses; ***Significant at the 1% level **Significant at the 5% level *Significant at the 10 % level. All regressions include time dummies.

Appendix: Additional Results.

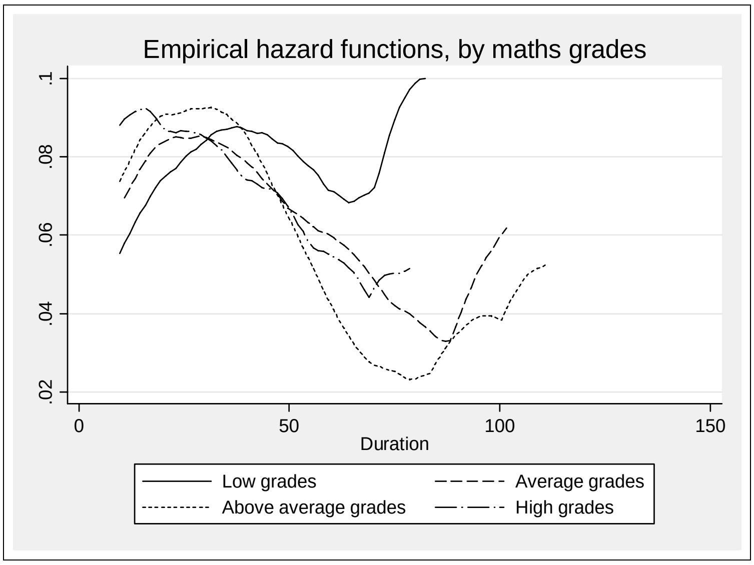

Figure 1: Empirical Hazard Function.

Table 11: OLS estimates; dependent variables: Maths grades. School by school estimates.

	Humanities high school	**Scientific high school**	**Professional/Vocational high school**	**Other high school**
Gender(males)	0.300	–0.458***	0.021	–0.429
	(0.216)	(0.105)	(0.106)	(0.343)
Final high school mark	0.084***	0.102***	0.060***	0.062***
	(0.011)	(0.005)	(0.005)	(0.015)
First year fee	–0.008	0.005	–0.008*	0.011
	(0.010)	(0.004)	(0.005)	(0.013)
Public high school	0.540**	0.719***	0.340***	0.755**
	(0.249)	(0.109)	(0.131)	(0.324)
Cohort1	0.231	1.004***	1.980***	1.490
	(0.912)	(0.379)	(0.268)	(0.922)
Cohort2	0.733	0.638**	1.408***	0.610
	(0.603)	(0.265)	(0.225)	(0.633)
Location school (north)	1.111***	1.302***	0.665***	–0.624
	(0.292)	(0.186)	(0.218)	(0.794)
Exam passed in the first year	0.491	1.086***	1.373***	0.203
	(0.383)	(0.204)	(0.162)	(0.500)
Exam passed in the second year	0.016	0.216	0.763***	–0.144
	(0.376)	(0.205)	(0.154)	(0.515)
Maths exam blocking the academic career	0.277	–0.021	–0.198	–0.135
	(0.626)	(0.308)	(0.228)	(0.877)
R sq.	0.1159	0.1504	0.0948	0.1116
N	979	5266	3981	517

Notes: Robust standard errors in parentheses; ***Significant at the 1% level **Significant at the 5% level *Significant at the 10 % level. All regressions include time dummies.

Table 12: OLS estimates; dependent variables: Maths grades. Year by year estimates.

	1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Gender(males)	0.353	–0.474*	0.150	0.147	–0.418*	–0.777***	–0.129	–0.281	–0.105	0.030	0.074	0.077	–0.491*	–0.216
	(0.432)	(0.283)	(0.233)	(0.270)	(0.219)	(0.248)	(0.230)	(0.259)	(0.257)	(0.217)	(0.251)	(0.276)	(0.290)	(0.319)
High school final mark	0.043*	0.054***	0.084***	0.029**	0.087***	0.088***	0.094***	0.077***	0.064***	0.076***	0.074***	0.057***	0.108***	0.131***
	(0.023)	(0.013)	(0.012)	(0.014)	(0.011)	(0.012)	(0.012)	(0.013)	(0.012)	(0.010)	(0.011)	(0.011)	(0.011)	(0.013)
First year fee	–0.014	0.012	–0.009	–0.017	0.012	0.002	–0.016	–0.002	–0.006	–0.013	–0.010	0.006	–0.004	0.034***
	(0.018)	(0.012)	(0.010)	(0.012)	(0.010)	(0.010)	(0.010)	(0.011)	(0.011)	(0.009)	(0.010)	(0.010)	(0.011)	(0.011)
Humanities high school	–1.139	1.498	–0.425	–0.989	1.723	–0.154	1.519*	0.466	1.374**	–0.641	1.685**	2.315***	1.593	1.079
	(0.885)	(1.465)	(1.144)	(1.430)	(1.391)	(1.151)	(0.828)	(0.973)	(0.660)	(0.769)	(0.834)	(0.843)	(1.230)	(1.512)
Scientific high school	1.806*	0.209	–0.599	–0.257	1.415	–0.544	1.858***	0.782	2.649***	0.257	1.476**	2.108***	2.339***	1.384
	(1.002)	(1.071)	(0.952)	(1.354)	(1.062)	(1.023)	(0.589)	(0.826)	(0.591)	(0.552)	(0.614)	(0.618)	(0.846)	(1.044)
Professional/Vocational high school	0.511	0.343	–0.774	0.010	–0.225	–1.152	1.170*	1.108	0.532	–0.830	0.067	1.025	0.370	–1.490
	(1.087)	(1.137)	(0.970)	(1.325)	(1.049)	(1.020)	(0.600)	(0.890)	(0.617)	(0.608)	(0.639)	(0.691)	(0.915)	(1.126)
Public high school	–0.581	–0.397	1.083	–0.268	–0.374	–0.244	1.519	2.288*	0.842	–0.616	0.763	1.787**	1.047	1.246
	(1.622)	(1.777)	(1.412)	(1.602)	(1.125)	(1.279)	(0.937)	(1.233)	(0.825)	(0.799)	(0.867)	(0.854)	(1.067)	(1.183)
Public school*Scientific	1.104	1.128	0.080	1.266	0.535	1.096	–0.798	–1.467	–0.862	1.794**	–0.110	–0.873	–0.183	–0.291
	(1.754)	(1.825)	(1.462)	(1.680)	(1.190)	(1.335)	(1.000)	(1.274)	(0.910)	(0.860)	(0.946)	(0.934)	(1.142)	(1.263)
Public school*Humanities	4.591**	–0.574	0.278	2.144	–0.542	0.414	–1.603	–1.662	0.684	1.314	–0.537	–1.855	–0.944	–0.605
	(2.004)	(2.143)	(1.670)	(1.858)	(1.535)	(1.497)	(1.204)	(1.449)	(1.082)	(1.043)	(1.200)	(1.166)	(1.516)	(1.754)
Public school* Professional/Vocational	2.286	0.009	–1.038	0.561	0.794	0.141	–1.781*	–2.765**	–0.059	0.801	–0.006	–0.890	–0.349	0.460
	(1.838)	(1.868)	(1.470)	(1.658)	(1.187)	(1.340)	(1.014)	(1.344)	(0.947)	(0.905)	(0.967)	(0.997)	(1.205)	(1.347)
Location school (north)	–0.894	1.182**	–0.256	0.687	0.520	1.054**	0.921*	1.240***	1.412***	1.207***	1.517***	1.187**	0.194	1.485***
	(0.825)	(0.498)	(0.517)	(0.511)	(0.514)	(0.425)	(0.516)	(0.457)	(0.418)	(0.377)	(0.404)	(0.471)	(0.434)	(0.476)
Exam passed in the first year	0.000	0.923***	2.307***	1.000**	1.069***	0.692**	–0.017	0.665*	0.303	0.700	1.103**	0.432	1.221***	1.111***
	(0.000)	(0.277)	(0.306)	(0.387)	(0.273)	(0.294)	(0.263)	(0.347)	(0.398)	(0.462)	(0.524)	(0.505)	(0.415)	(0.424)
Exam passed in the second year	0.000	0.000	1.023***	–0.090	1.050***	–0.150	0.151	0.727*	–0.433	–0.394	0.427	–0.274	0.492	0.635
	(0.000)	(0.000)	(0.288)	(0.357)	(0.284)	(0.287)	(0.295)	(0.376)	(0.461)	(0.483)	(0.578)	(0.533)	(0.484)	(0.567)
R sq.	0.1113	0.1039	0.0987	0.1465	0.0651	0.1244	0.1392	0.1019	0.0982	0.1045	0.1235	0.128	0.0869	0.1836
N	293	739	936	584	939	823	916	772	753	1111	781	753	780	563

Notes: Robust standard errors in parentheses; ***Significant at the 1% level **Significant at the 5% level *Significant at the 10 % level.

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