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Students enrolled in STEM disciplines in Italy: patterns of retention, dropout and switch

Studenti iscritti nelle discipline STEM in Italia: i percorsi di chi prosegue gli studi, abbandona o cambia corso

Valentina Tocchioni, Carla Galluccio, Maria Francesca Morabito, Alessandra Petrucci

Abstract Ongoing technological change has led to a steadily growing demand for Science, Technology, Engineering and Mathematics (STEM) graduates worldwide. But not only do STEM disciplines have a low attractiveness in some contexts, such as in the US and Italy; it is also a matter of persistence of pursuing STEM studies, affected by high rates of dropout and course switches in several countries. Using administrative microdata from the Italian Ministry for Universities and Research and selecting students enrolled in a STEM discipline between 2010 and 2015, our objective is twofold: understanding which distinct patterns characterise students towards retention, dropout, or switch; investigating to what extent each individual and contextual characteristic predict students' outcomes. Identifying at-risk STEM students to dropout/switch is an essential and challenging issue for the delivery of university interventions aiming to reduce failure and dropout rates.

Abstract *Il cambiamento tecnologico ha portato a una domanda sempre crescente di laureati in scienze, tecnologia, ingegneria e matematica (STEM) in tutto il mondo. Nonostante ciò, le discipline STEM sono scarsamente attrattive in vari contesti, come negli Stati Uniti e in Italia; inoltre, sono contraddistinte da alti tassi di abbandono e cambi di corso. Utilizzando i microdati amministrativi del Ministero dell'Università e della Ricerca, abbiamo selezionato gli studenti iscritti a una disciplina STEM tra il 2010 e il 2015 con l'intento di perseguire due obiettivi: individuare quali pattern caratterizzano gli studenti che proseguono gli studi, li abbandonano o cambiano corso; comprendere in che misura ciascuna caratteristica individuale e di contesto*

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predice i tre percorsi degli studenti. Riuscire a identificare gli studenti STEM a rischio rappresenta un elemento cruciale per la definizione di interventi volti a ridurre i tassi di fallimento e abbandono.

Key words: university students, STEM, graduation, dropout, course switch, Italy

Introduction

Ongoing technological change has led to a steadily growing demand for graduates from Science, Technology, Engineering and Mathematics (STEM) worldwide, due to their prominence in the development, productivity and growth of contemporary economies. Skills in STEM disciplines are thus becoming an increasingly important part of basic literacy in today's economy. Several actions have been put in place to increase the attractiveness of degree programs in science and technology, and thus satisfy the growing demand for future scientists for engineers: as stated by the European Schoolnet, "to keep Europe growing, we will need one million additional researchers by 2020". Also, in the US, increasing the number of undergraduate STEM majors has recently emerged as a national priority (Kuenzi, 2008); thus, in the last years, they have concentrated on expanding existing STEM education programs, but also on implementing new programs to increase the number of students entering STEM disciplines (Thompson and Bolin, 2011).

Despite it, the STEM disciplines have different attractiveness in diverse contexts. In this respect, Ireland, with 37 people aged 20-29 over 1,000 of the same age class in 2019, is at the forefront of the number of highly-talented graduates in these fields, followed by France, the UK and Germany, with around 24-28 people aged 20-29 graduated in STEM fields over 1,000 of the same age class in 2019 (Eurostat, 2022). In Italy, the interest in STEM majors is not very pronounced: as a consequence, the number of people who graduated in these fields is below the mean number of graduates in the European Union, equal to 21.6 people aged 20-29 who graduated in STEM fields over 1,000 of the same age class in 2019 (Eurostat, 2022). Despite it, the annual rate of graduates slightly increased over the last years, passing from 13.8% in 2013 to 16.4% of people aged 20-29 in 2019 (Eurostat, 2022).

Not only do STEM disciplines have an issue of attraction, but also of retention. Indeed, many students who decide to enrol in a STEM discipline then change their minds, thus switching to another course or, even worse, dropping out of university studies. The first few years of enrolment are crucial in this respect, and this is a particular concern for the STEM disciplines, which are the most affected by both practices with respect to other disciplines such as Business or Education fields (Chen et al., 2018; Thompson and Bolin, 2011). Moreover, among those who switch to another course, most students switch to a non-STEM field (Isphording and Qendrai, 2019). Consequently, despite the increase in enrolment in STEM fields in some countries such as the US, this rise has not been followed by a higher number of graduates. Against these premises, the high number of undergraduate students leaving STEM courses represents an issue of societal concern (Seymour and Hewitt, 2000).

Students enrolled in STEM disciplines in Italy: patterns of retention, dropout and switch

Various individual and contextual characteristics may influence this unsuccessful academic outcome. At the individual level, students' prior math achievement and quantitative skills have been identified as the most important predictor of STEM study success (De Winter and Dodou, 2011). As for gender, an association has been identified in previous studies between students' gender and dropout, with female students more likely to dropout than males (Thompson and Bolin, 2011; Isphording and Qendrai, 2019); conversely, a lack of association seems to occur between student's gender and course switch (Thompson and Bolin, 2011). On the other hand, no association has been identified between ethnicity and students' dropping out or switching.

At the contextual level, previous studies have identified a negative association between high school ranking and students' dropout or switch, with students from schools with a higher ranking less prone to dropout or switch the course (Thompson and Bolin, 2011). The social context and the peer effect also have a role, with female students retaining their STEM preferences when other females in their classroom do so (Raabe et al., 2019).

1.1 Objective of the work

Our work aims at investigating the academic outcomes of university students who decided to enrol in a STEM course for the first time in Italy. More specifically, we are interested in understanding which micro-, meso- and macro-level characteristics play a role in predicting students' graduation, dropout or course switch among those enrolled in a STEM course, such as gender, the number of credits attained during the first year of enrolment, and the type of high school. Moreover, we intend to verify if there is a relationship between the athenaeum of enrolment and students' performances in terms of graduation, dropout or course switch. In doing so, we rely on some characteristics of the athenaeum where the student is enrolled, such as admission requirements and rates, service offered, and so on.

Identifying at-risk STEM students is an essential and challenging issue at the individual, university, and societal levels. At the individual level, a successful academic career is undoubtedly beneficial for the students themselves. At the university level, from 2014 funds and economic incentives for universities are related to their success in providing degrees within the prescribed time (Viesti, 2018). Finally, society has both direct and indirect interests in university students' success, given that public universities in Italy receive funds from the government (deriving from taxes) and that the prosperity of a country is strongly affected by its citizens' education and skills, as well as its quality of human resources (Becker, 2009; Schultz, 1971). In this respect, understanding which factors could predict the early failure of undergraduate students in those disciplines, and creating a series of student performance indicators could provide opportunities for the timely delivery of educational interventions, aiming to reduce the high failure and dropout rates.

In the light of these premises, we wonder if there are factors attributed to STEM students who graduated that might serve as predictors or indicators of successful

navigation in STEM majors. If factors can be identified, they may be used as tools by high school counsellors and college advisors in the recruitment and, possibly more importantly, the retention of future STEM students. Conversely, we intend to verify if there are characteristics among STEM students who dropped out or switched the course that might act as warnings for identifying students with weaker paths at the beginning of their academic careers. University advisors may use these signals of poor performance to address specific educational interventions for those students and thus mitigate the significant dropout rates observed in undergraduate STEM education.

2 Data and sample selection

In the present contribution, we used data coming from the National Archive of Students and Graduates (i.e., *Archivio Nazionale degli Studenti e dei Laureati*, ANS), an administrative database that was created¹ with the aim of recording and monitoring the careers of all university students enrolled in a degree program at an Italian university. The database is provided by the Ministry of Education, University, and Research (MIUR) with the involvement of Italian universities.

In the following, we describe the features of the database used and the criteria we considered to select the sample.

2.1 Data description

The ANS database concerns university students enrolled in a degree program at an Italian university since 2010. More specifically, it contains individual longitudinal data, with information about students' demographic characteristics (i.e., gender, region of residence, citizenship) and information on both high school careers (i.e., type of high school attended, final mark) and university careers (i.e., degree program chosen, number of formative university credits achieved per year, type of degree, year in which they get the degree and final grades).

2.2 Sample selection criteria

In this contribution, we decided to focus on the cohorts of students enrolled from the academic years 2010–2011 through 2015–2016.

¹ This database has been realised thanks to the Italian Ministerial grant PRIN 2017 “From high school to job placement: micro-data life course analysis of university student mobility and its impact on the Italian North-South divide” (PI: Massimo Attanasio).

Students enrolled in STEM disciplines in Italy: patterns of retention, dropout and switch

Moreover, considering the aim of our study, to obtain a set of students consistent with our research goals, we selected students who chose a STEM bachelor's degree at their first university enrolment, and removed from our sample students who did not pay university fees in the year of enrolment. Regarding the definition of a STEM bachelor's degree, according to the ISCED classification of fields of education, we kept only students enrolled in the following three categories: Natural sciences, mathematics, and statistics (ISCED code 5); Information and Communication Technologies (ISCED code 6); Engineering, manufacturing, and construction (ISCED code 7).

The final sample comprises 364,608 students (36.2% females, 63.8% males). Overall, 46,629 students dropped out during the second year or after (until the fifth year after their academic enrolment), whereas 82,532 students switched the course.

Among all the students, about 41.4% came from Northern Italy, 37.6% from South Italy and the Islands, and 21.0% from Central Italy. In relation to high school, the majority of the students attended scientific high school (55.5%), followed by technical institute (18.1%), professional institute and classical high school (both 8.6%), other institutes (5.7%), and foreign language high school (2.1%). There were missing values for 1.4% of students. Finally, regarding the field of study chosen (ISCED code) in the first year, 35.2% enrolled in Natural sciences, mathematics, and statistics courses, 6.6% in Information and Communication Technologies courses, whereas 58.2% of students were enrolled in Engineering, manufacturing, and construction courses. Most of the students were Italian (96.6%).

The number of students per cohort included in the analysis with some descriptive statistics is shown in Table 1.

Table 1: Demographic information of the selected sample per cohort. Absolute and column percentage values.

<i>Variables</i>	<i>Cohort 2010</i>	<i>Cohort 2011</i>	<i>Cohort 2012</i>	<i>Cohort 2013</i>	<i>Cohort 2014</i>	<i>Cohort 2015</i>
Number of students	62,258	60,640	59,688	57,980	59,989	64,053
Gender						
<i>Female</i>	23,332 (37.5%)	22,591 (37.3%)	21,972 (36.8%)	20,399 (35.2%)	21,046 (35.1%)	22,603 (35.3%)
<i>Male</i>	38,926 (62.5%)	38,049 (62.7%)	37,716 (63.2%)	37,581 (64.8%)	38,943 (64.9%)	41,450 (64.7%)
Citizenship						
<i>Italian</i>	60,310 (96.9%)	58,568 (96.6%)	57,652 (96.6%)	55,971 (95.3%)	57,992 (96.5%)	61,906 (96.6%)
<i>Foreign</i>	1,948 (3.1%)	2,072 (3.4%)	2,036 (3.4%)	2,009 (4.7%)	2,826 (3.5%)	2,147 (3.4%)
Region of residence						
<i>North-West</i>	14,583 (23.4%)	14,086 (23.2%)	13,981 (23.4%)	13,636 (23.5%)	14,205 (23.7%)	15,165 (23.7%)
<i>North-East</i>						

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<i>Centre</i>	10,962 (17.6%)	10,793 (17.8%)	10,392 (17.4%)	10,500 (18.1%)	11,014 (18.3%)	11,629 (18.2%)
<i>South</i>	12,746 (20.5%)	12,975 (21.4%)	12,682 (21.2%)	12,015 (20.7%)	12,685 (21.1%)	13,429 (20.9%)
<i>Island</i>	17,659 (28.4%)	16,993 (28%)	16,557 (27.8%)	16,010 (27.6%)	16,043 (26.8%)	17,062 (26.6%)
	6,308 (10.1%)	5,793 (9.6%)	6,076 (10.2%)	5,819 (10.1%)	6,042 (10.1%)	6,768 (10.6%)
High School						
<i>Classical</i>	5,527 (8.9%)	5,463 (9%)	5,318 (9%)	4,779 (8.2%)	5,138 (8.6%)	5,117 (8%)
<i>Scientific</i>	33,659 (54%)	33,710 (55.6%)	33,622 (56.3%)	31,936 (55.1%)	33,183 (55.3%)	36,230 (56.6%)
<i>Foreign Language</i>	1,233 (2%)	1,182 (1.9%)	1,148 (1.9%)	1,077 (1.9%)	1,207 (2%)	1,677 (2.6%)
<i>Technical Institute</i>	11,036 (17.7%)	10,325 (17%)	10,319 (17.3%)	10,897 (18.8%)	11,459 (19.1%)	12,016 (18.8%)
<i>Professional Institute</i>	5,893 (9.5%)	5,332 (8.8%)	4,877 (8.2%)	5,136 (8.8%)	5,289 (8.8%)	5,001 (7.8%)
<i>Other</i>	3,922 (6.3%)	3,607 (6%)	3,420 (5.7%)	3,353 (5.8%)	3,185 (5.3%)	3,384 (5.3%)
<i>Missing</i>	988 (1.6%)	1,021 (1.7%)	984 (1.6%)	802 (1.4%)	528 (0.9%)	628 (0.9%)
ISCED classification						
<i>Natural sciences, mathematics, and statistics</i>	23,123 (37.1%)	21,556 (35.5%)	21,114 (35.4%)	19,804 (34.2%)	20,083 (33.5%)	22,594 (35.3%)
<i>Information and Communication Technologies</i>	3,297 (5.3%)	3,504 (5.8%)	3,740 (6.3%)	4,181 (7.2%)	4,513 (7.5%)	4,912 (7.7%)
<i>Engineering, manufacturing, and construction</i>	35,838 (57.6%)	35,580 (58.7%)	34,834 (58.3%)	33,995 (58.6%)	35,393 (59%)	36,547 (57%)

3 Methodology

We run a multinomial logistic model to investigate the role of micro-, meso- and macro-level characteristics in predicting individual academic outcomes.

The response variable *Outcome* has four categories, distinguishing between students who graduated (*Graduated on time*), who dropped out of the course (*Dropped out*), who have changed the course (*Course switch*), and those who were still enrolled

Students enrolled in STEM disciplines in Italy: patterns of retention, dropout and switch at the same course (*Still enrolled*). The students' outcome is observed four years after enrolment.

As micro-level covariates, we include gender, citizenship (Italian or foreign), the high school final mark (in classes of width 10), the number of credits attained during the first year of enrolment (in classes: 0-24; 25-40; 41-56; 57-72), if the student resides outside the region where the athenaeum is located. Furthermore, regarding meso-variables, we look at the type of high school (scientific high school, technical institute, professional institute, classical high school, other institutes, and foreign language high school), and the ISCED code of the course (5, 6, or 7). Finally, among macro-characteristics, we control for the macro area of athenaeum (North-West, North-East, Centre, South, Islands).

4 Results

Figure 1 shows the number of students enrolled in a STEM discipline who graduated, dropped out or switched each academic year by cohort. As for graduates, the highest number of graduates for the cohorts 2010-2012 is during the fifth year of enrolment, whereas for the cohorts 2013-2014 the highest number of graduates is in the fourth year of enrolment (namely, within the legal duration of the course). Instead, most students dropped out or switched the course during the second year of the course and, to a lesser extent, during the third year; starting from the fourth year of enrolment, drops out or switches are considerably less. Moreover, the patterns of those students who dropped out or switched the course are very similar, with a replicating pattern over the different cohorts, too; finally, the number of students who switched is always higher than those who dropped out.

Figure 1: Students graduated, dropped out and switched by cohort of enrolment. 2010-2014.

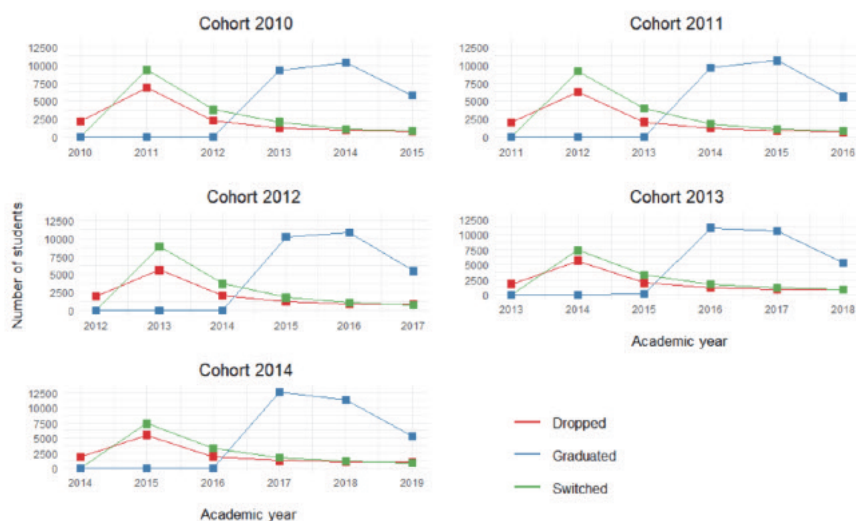


Table 2 shows the relative risk ratios for the estimation of the multinomial logistic regression. As for individual characteristics, the relative risk of dropping out over graduation is lower for women than for men, whereas the opposite is true for course switches. Italian students have a relative risk of dropping out, course switching and not graduating within 4 years over graduation on time lower than their foreign counterparts. Moreover, a high final mark at high school implies a lower relative risk of dropping out, course switching and not being graduated within 4 years over graduation with respect to those students with a low grade. The same holds for the number of credits attained during the first year of enrolment, which is the variable showing the lowest relative risk ratios, thus seeming to be the most relevant in explaining students' academic successful or unsuccessful outcomes. Finally, students who live outside the region where the athenaeum is located have a slightly smaller relative risk of dropping out with respect to those who live in the same region, whereas their relative risk of course switching or not graduating within 4 years over graduation is higher.

Looking at the meso and macro characteristics, students enrolled in ICT courses or in Engineering, manufacturing, and construction have a lower relative risk of course switch over graduation on time with respect to students enrolled in Natural sciences, mathematics, and statistics. Conversely, they all have a higher relative risk of not being graduated within 4 years over graduation on time with respect to students enrolled in Natural sciences, mathematics, and statistics. Also, only students enrolled in Engineering, manufacturing, and construction have a lower relative risk of dropout over graduation on time with respect to students enrolled in Natural sciences, mathematics, and statistics. Furthermore, students enrolled in an athenaeum outside the South of Italy have a lower relative risk of dropping out, course switching and not graduating within 4 years over graduation on time with respect to students enrolled in an athenaeum in the South of Italy. As regards the type of high school, students who attended a scientific lyceum have a lower relative risk of course switching and not graduating within 4 years over graduation on time compared to students who attended a classical lyceum; other students, such as those who attended a linguistic lyceum have a higher relative risk of dropping out, course switch and not being graduated within 4 years over graduation on time with respect to students who attended a classical lyceum; finally, students who attended a technical or a professional institute have a higher relative risk of dropping out and not being graduated within 4 years, but a lower relative risk of course switch over graduation on time with respect to students who attended a classical lyceum.

Table 2: Model results of the multinomial logistic regression model. Relative risk ratios and standard errors (in brackets).

Variable	Ref: Graduated in 4 years		
	Dropped	Switched	Enrolled not graduated after 4 years
Constant	4.540*** (0.303)	46.998*** (2.333)	70.927*** (3.544)

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Female	0.862*** (0.017)	1.050*** (0.013)	0.994 (0.012)
Italian citizenship	0.629*** (0.028)	0.667*** (0.024)	0.546*** (0.020)
High school final mark (ref: 60 – 69)			
70 – 79	0.514*** (0.011)	0.620*** (0.011)	0.650*** (0.012)
80 – 89	0.275*** (0.007)	0.386*** (0.007)	0.436*** (0.008)
90 – 99	0.166*** (0.005)	0.251*** (0.005)	0.313*** (0.006)
100 and 100 cum laude	0.091*** (0.004)	0.167*** (0.004)	0.215*** (0.005)
Missing	0.283*** (0.018)	0.189*** (0.010)	0.276*** (0.014)
Credits (ref: 0 – 24)			
25 – 40	0.016*** (0.001)	0.115*** (0.003)	0.169*** (0.004)
41 – 56	0.002*** (0.0002)	0.052*** (0.001)	0.031*** (0.001)
57 – 72	0.001*** (0.0001)	0.027*** (0.001)	0.005*** (0.0001)
Missing	5.399*** (0.170)	0.578*** (0.015)	0.090*** (0.002)
Student outside region	0.948** (0.024)	1.333*** (0.021)	1.259*** (0.020)
ISCED code (ref: Natural sciences, mathematics and statistics)			
Information and Communication Technologies	0.977 (0.032)	0.542*** (0.014)	1.373*** (0.034)
Engineering, manufacturing and construction	0.698*** (0.013)	0.796*** (0.009)	1.194*** (0.015)
High School (ref: Classical lyceum)			
Scientific lyceum	0.946 (0.033)	0.661*** (0.012)	0.874*** (0.017)
Technical Institute	4.506*** (0.169)	0.924*** (0.021)	1.448*** (0.034)
Foreign Language lyceum	2.520*** (0.161)	1.344*** (0.054)	1.235*** (0.052)
Professional Institute	5.168*** (0.214)	0.854*** (0.023)	1.555*** (0.043)
Other	4.501***	1.508***	1.607***

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	(0.208)	(0.045)	(0.050)
Missing	3.010***	0.502***	1.905***
	(0.208)	(0.031)	(0.098)
Geographical area of University (ref: South)			
Island	0.873***	0.841***	0.762***
	(0.028)	(0.019)	(0.017)
Centre	0.820***	0.854***	0.706***
	(0.020)	(0.014)	(0.011)
North-East	0.430***	0.429***	0.349***
	(0.011)	(0.008)	(0.006)
North-West	0.556***	0.634***	0.426***
	(0.013)	(0.010)	(0.007)

Note: * $p < .10$; ** $p < .05$; *** $p < .01$

5 Preliminary conclusions and further steps

In this paper we investigate the determinants of the academic outcomes of university students who decided to enrol in a STEM course for the first time in Italy. Our preliminary analyses show that several micro, meso and macro characteristics play a role in predicting students' graduation, dropout or course switch among those enrolled in a STEM course, such as the high school final mark, the number of credits attained during the first year of enrolment and the type of high school.

In order to fully understand the relationship between micro, meso and macro characteristics and students' academic outcomes, we will estimate separate models by ISCED code and test the inclusion of interaction terms in the model. Moreover, we will estimate a multilevel version of the model, with students nested within the athenaeum where they are enrolled, to assess the overall performance of the athenaeum in terms of graduates and dropout.

Further research is required to deepen STEM students' academic outcomes in Italian public universities and to investigate if there exists a relationship between the athenaeum of enrolment and students' performances, and if so, which features of the athenaeum play a major role.

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