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Research of Students' Performance in Higher Education through Sequence Analysis

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Abstract

The paper aims to prove how suitable the Sequence Analysis' tools are for studying the complexity of Italian Higher Education System. Through longitudinal administrative data of a cohort (AY 2001-2002) of enrolled for the first time at Sapienza University of Roma, this approach permits to: (1) describe the phenomena of late graduate and late performance (retention); (2) identify different type of students' dropping out (attrition); (3) evaluate others particular phenomena (that are frequent in Italy) that can delay the students' career (as such as intra or extra faculty mobility).

Introduction

This paper aims to prove that the Sequence Analysis (SA) tools are suitable for studying the complexity of Italian higher education students' careers (Blanchard, Bühlmann and Gauthier 2014; D'Alessandro 2015). The SA is an efficient method that involves examination of the ordered social process (such as university career, life course trajectory, etc.). Actually, SA is commonly used to study professional careers, occupation histories, school-to-work transitions, etc.

Italian university system is confronted by the three main problems (Benvenuto et al. 2012; Moscati and Vaira 2008): (1) low number of graduates; (2) excessively long university careers; (3) very high number of drop outs. In the course of the last fifteen years in Italy, "Bologna process" has introduced radical reforms with the principal aim to control the phenomena of dropping out, perpetual students and low number of graduates. More specifically, the AY 2001-02 represents the transition from a university education based on a single level degree (4 or 5 year-courses) to a dual level degree: bachelor - BA (3 years)/master - MA (2 years) or other types of master (5 or 6 year-course, such as Architecture or Medicine).

For the purpose of our research, Sapienza University of Rome was identified as a representative case due to its dimensions (i.e. in AY 2015-16 there are 101,492 students - 6,1% of Italian university students and 3,555 professors - 6,9% of Italian university professors) and its variety, in terms of scientific and educational areas of academic training.

1 Research aims

This paper shows a secondary analysis of longitudinal administrative data. We use SA in order to (1) describe in detail the phenomena of late graduation and late performance (retention); (2) identify different kinds of students who are dropping out from the university (attrition); (3) evaluate other particular phenomena that could delay the careers (such as the mobility within and between faculties). Our interest is focused on the linearity of the university career. The non-linearity of career (mobility is a relevant aspect of retention), from a student's point of view, can have a double value. On one hand, it might be a prelude to a successful outcome, in case that a student who is taking up a new university career obtains a degree; on the other, it might cause delay or even dropping out in a student's career. From the university point of view, however, student mobility could determine important impacts, such as increasing the phenomena of late performance and dropping out, but also contributing to the creation of new graduates. The hypothesis is that different types of mobility could cause different outcomes. Mobility between faculties represents a greater educational transition than mobility within faculty.

The case study shows the construction of a longitudinal dataset of information extracted from the administrative archives of the Sapienza University, which refer to the registered students.

SA allows us to identify useful longitudinal measures for describing and analysing the students' careers (Gabadinho et al. 2009; 2011). In particular, the main interests of this study are to 1) identify pattern of the entire sequences; 2) analyse their diffusion; 3) identify groups of similar careers; 4) highlight relations between career outcomes and students' characteristics (micro-level variables); 5) characterize relation between career outcomes and university context characteristics (meso-level variables).

The SA approach has proven to be valuable for pointing out the relevance of phenomena in temporal order (Blanchard, Bühlmann and Gauthier 2014). The main hypothesis is that the timing (i.e. the observation point when an event occurs) is the most relevant aspect which determinates the career outcome. For instance, a change of study course during the first part of career could be more advantageous than the one performed in the central part of studies (McCormick and Carroll 1997). Indeed, an early change could be an admission of a choice of study course that does not correspond to a student's interest and aspiration (career reorientation); whereas, a late change could be a proof of a student's difficulties in reaching the attainment in the first enrolment study course.

2 Data

Due to the relevance of the AY 2001-02, since it represents the turning point for the passing from the old to the BA/MA university system, the analysis focuses only on this cohort (AY 2001-02) (23,854 students). Information concerns the students enrolled for the first time and without previous university career[1]. The cohort was monitored until March 2014 (the end of AY 2013-14). Therefore, each student is monitored up to 25 semesters. It means that, even if a student graduated at the sixth semester, all his/her following states would be "graduate".

Such information are collected for administrative purposes, like, for example, monitoring fee payments and exam registrations. However, the information are collected in different archives. These archives of Sapienza are related to four main areas: socio-economic profile, high school education, higher education career (first enrolment course, graduations, possible second enrolment course, etc.), and university performance indicators (number of exams, credits, etc.). This kind of (de)structuration is not suitable for the purpose of temporal dynamics studying.

Furthermore, the information are registered in a synchronic way (each information refers to a single moment) and this represents a further critical issue for temporal dynamics studying (Menard 2007; Scherer 2013). Indeed, the phenomena characterized by continuous process of change, such as university careers, can be studied in a more appropriate way through the use of longitudinal data (Blossfeld et al. 1989).

Starting from these archives, a unique dataset has been re-constructed in a longitudinal way, using the key codes (such as the identification numbers of the study course and of the students) in order to joint the data. Through the recording of the events related to each student's career (payment of every semester fees from the first enrolment to graduation or dropping out, passing the exams, etc.), a longitudinal data vector for each student was created. By positioning the

[1] Since the AY 2001-2002 was the first year of the "3+2 system" (in this way it is known the Anglo-Saxon university education system in Italy), in this cohort there are no students that enrol for the first time at Sapienza in a MA study course.

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events on a chronologically ordered string, it is possible to control the dynamics of each academic career and to highlight specific phenomena (dropping out, stopping out, mobility, degree attainment, etc.). In fact, these data allow us to follow students' careers from the enrolment until graduation (or dropping out).

The data query was very complicated and it required a large quantity of Structured Query Language (SQL) code writing in order to obtain a longitudinal data vector for each student from the first semester of AY 2001-02 to the first semester of AY 2013-14. Firstly, the dataset consisted of several vectors for each student. Every vector matched every degree course that student had taken up at Sapienza University (i.e. one for BA and one for MA). A unique data vector for each student was created with the use of the key codes. In this way, it was possible to reconstruct the entire career for each student, including the temporary stopping outs and mobility (between the different and within the same degree courses).

In the final dataset, the data referring to the socio-demographic characteristics and high school training are synchronic (registered at students' first enrolment), whereas those referring to university career and performance indicators are diachronic (repeated for each semester of students' university careers).

The used data encoding format is the STS (State Sequence). It is «a natural way of representing list is a (row) vector of k elements» (Ritschard et al. 2009, p. 159). In the dataset, the row vector has variables as moments of observation for each student's career. Therefore, the column vector corresponds to a predetermined unit of time (the semester).

The structure of the database implies the persistence of the last observed state (dropping out or graduation) for the student throughout the following observation period. Indeed, the aim to observe how different types of careers within the University would lead to different outcomes is well accessible through the University monitoring viewpoint, which suggests the non-use of missing values.

3 Methodology

The basic idea is to list each student's academic trajectories at Sapienza as an ordered list of administrative states, which are defined on a time axis. The time interval being used is the semester.

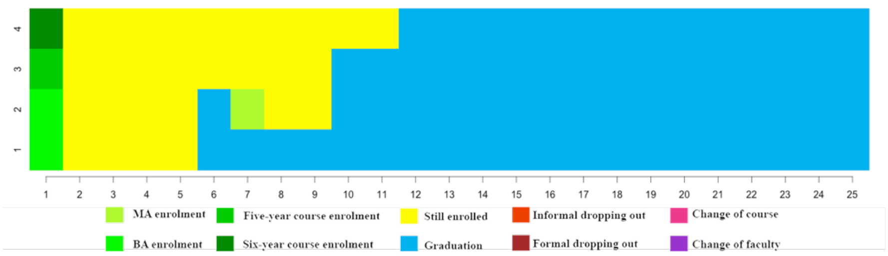
For the scope of this analysis, we consider ten different administrative "states", that define the alphabet for the SA. They are: (1-4) four types of enrolment (due to the course length: 2, 3, 5 or 6 year-course); (5) continuation (after the previous semester); (6) graduation; (7) formal dropping out (with a formal request of study interruption, probably due to a transition to another university); (8) informal dropping out (due to no six-month fee payment); (9) change of faculty (between two faculties); (10) change of the course (within the same faculty).

A distance matrix between each pair of careers was calculated by Optimal Matching (OM) algorithm (MacIndoe and Abbott 2004; Studer and Ritschard 2014; Blanchard, Bühlmann and Gauthier 2014). The OM produced a huge matrix[2], used for Wald cluster analysis (Studer 2013). The purpose is to achieve well-defined clusters and to characterise them with reference to the information regarding the students (i.e. personal data, high school information – micro-level variables) and the first year performance indicator (i.e. number of exams, number of university credits – micro-level variables), the university context (i.e. length of first enrolment study course and limited enrolment course – meso-level variables).

4 Results

The first step is to give an overview that takes into account the homogeneity/heterogeneity of the students' careers within the University.

Students act within a regulated framework and their chances of action are limited in various ways. In a chart of ideal careers (each student enrolls and continues his/her career until graduation, Graph 1), immediately after the different types of enrollment (three different tones of green: soft green for BA, medium green for 5-year course, such as Architecture, and dark green for 6 year-course, such as Medicine), can be observed only continuation (yellow) and graduation (blue) states. In addition, there can be observed the graduation states in different points of students' careers, coherently to study course length. In particular, the possible ideal careers for students enrolled in BA are two: the first one stops with graduation in the second semester of the third year (sixth moment of observation); the second one continues in MA from the seventh point of observation (first semester of the fourth year, very soft green in the middle of the plot) until the tenth point (second semester of the fifth year).



Graph. 1. Ideal index-plot

[2] The matrix had about 566 million of cells.

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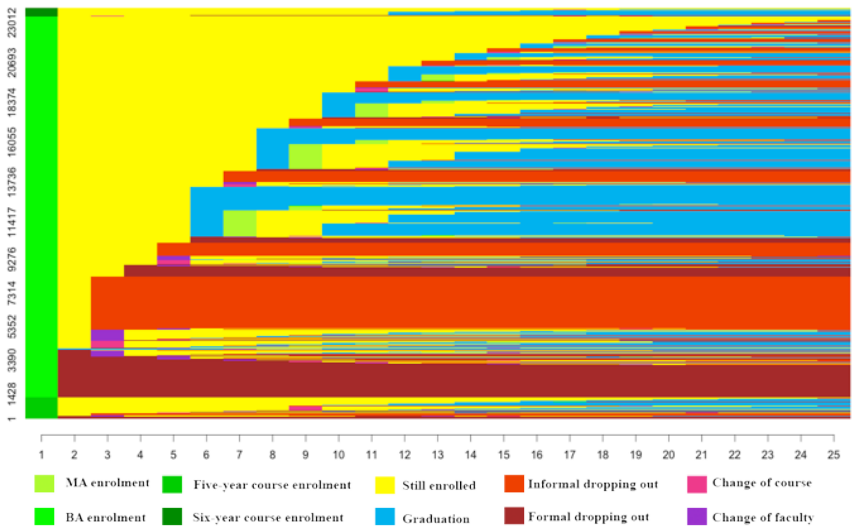
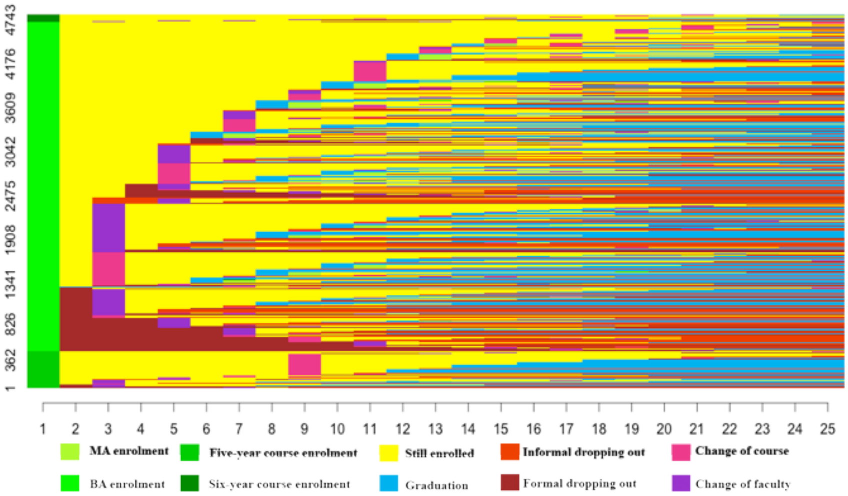
The Graph 2 represents the index-plot of the entire 2001-2002 cohort. Contrary to the ideal index plot, there is a preponderance of red color, which indicates dropping out in its two connotations (formal and informal). This outcome concerns particularly the BA students' careers. Although the majority of drop-outs are registered in the transition between the first and second year of the study course, many students experience dropping out later (even after many years).



Graph. 2. Index-plot of the entire 2001-02 cohort*
* In the Index-plot each horizontal line corresponds to one career; the events that form the career are represented through different colours (as showed in the legend)

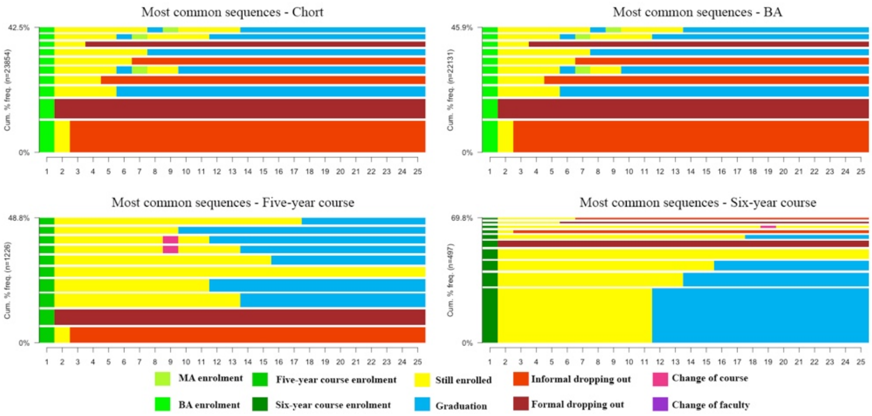
The index-plot of the careers (4,804 students, 20.1% of them enrolled in 2001-02 cohort) with one or more mobility events (Graph 3), shows a much more complex situation. The careers look even more partitioned and it is difficult to highlight trends. Anyway, the states of mobility (change of faculty, marked by purple colour, and change of the course, marked by fuchsia) frequently involve students' careers in the period immediately after enrolment.

The complexity in the right side of the graph, which refers to the end of the observation period and, therefore, to the outcomes of careers, could suggest an interesting association between the time of the change of the faculty or study course and the career outcome. Students who take a reallocation of study course in the years immediately following the enrolment are those that may stand more chances to complete successfully their career.



Graph. 3. Index-plot of the mobility students' careers

By splitting the entire cohort into groups according to the study course length (Graph 4), we can observe how the heterogeneity is different among the groups. Whereas in the entire cohort 42.5% of the career is represented by the 10 most frequent sequences (45.8% of the BA careers), for the six-year course students the homogeneity is greater: almost 70% of the careers can be expressed in terms of the 10 most frequent sequences. However, for the five-year course students, the share is close to 50% and thus the homogeneity is more in line with that registered for the BA students.



Graph. 4. Most frequent careers of the entire 2001-02 cohort

Among the 10 most frequent sequences (Graph 5) of students' careers with mobility events, the fifth is a discontinuous career (0.77%, 37 cases): this is the case of a BA student who leaves (formally) the university for one semester,

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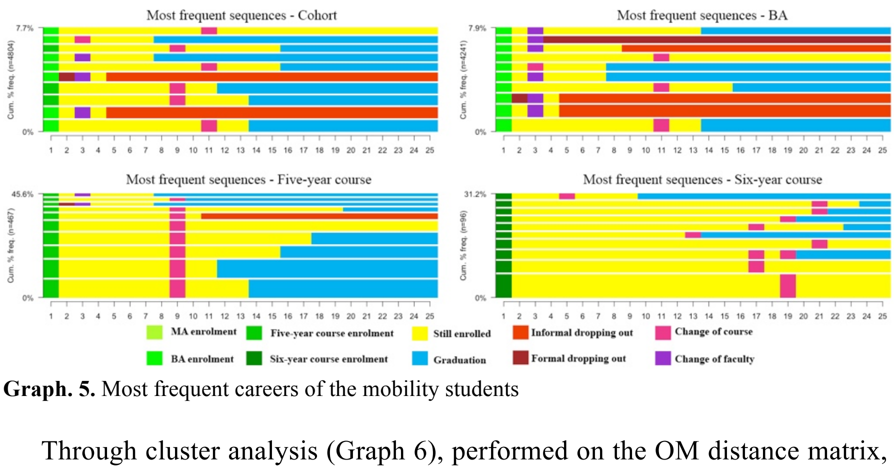
changes faculty, there remains registered only for one semester and then drops out permanently (in an informal way). This is a very complex career that might suggest the attempts implemented by the students to pass the limited enrolment course test. Furthermore, similarity of this career with the second one is rather interesting. These pathways differ only for the administrative state during the second half of observation: continuation in one case; formal dropping out in the other.

Formal dropping out is relevant in BA careers: it becomes a definitive state as a result of a change of faculty (ninth most common sequence, 26 cases, 0.61%). The direct comparison among the three subgroups allows us to highlight how the BA students have the worst performance with regard to the retention. Indeed, for these students dropping out state appears in 4 out of 10 most common sequences, while for five-year students it appears only once, and not even once for the six-year students.

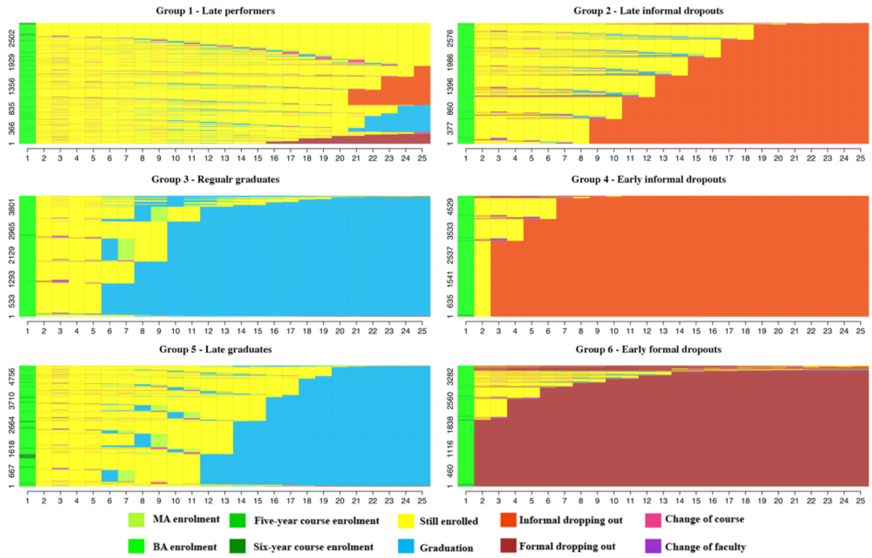
The homogeneity among subgroups is radically different. The most frequent sequence for BA students includes only 7.9% of the students; the first one of five-year course students 45.6%; the six-year course students 31.2%. This index plot shows that the courses with limited enrolment test (all the six-year and the majority of the five-year courses) could ensure a better chance for success in university career. Indeed, the students enrolled in longer study courses achieve graduation more frequently than BA students. The only exception among the 10 most frequent sequences is that the sixth career refers to five-year students: the outcome of the study course change is the informal dropping out.

Another interesting element is the consistency of delay (perpetual students) in study courses, especially for the students enrolled in the six-year study courses. Indeed, 3 out of the 10 most common sequences relate to students that are still enrolled after 25 semesters (15 cases, 15.6%). The phenomenon is more restrained for five-year course students (24 cases, 5.1%).



Graph. 5. Most frequent careers of the mobility students

Through cluster analysis (Graph 6), performed on the OM distance matrix, six well-defined groups of students were identified. The majority (35,5%) of the first group are the students that are still enrolled at the end of the observation period (25 semesters); part of them are drop outs (informal, 32,3%, and formal 8,3%) or graduates after 10 years since the enrolment (22,2%). The second and the fourth groups differ for the dropping out timing: the students of the second group keep postponing the dropping out decision until the 9th semester, whereas for the fourth group the dropping out occurs in the first half of the observation period. The second type of dropping out (the formal one) characterises the sixth group. In other words, the majority of these students drops out at the beginning of their career. The other two groups (the third and the fifth) are composed of students that end their career with graduation. Although the students of the third group graduate at the regular course length, the timing of graduation in the fifth group is slower.



Graph. 6. Index-plot for the six groups, cohort 2001-02

These six groups are used as dependent variables in a multinomial logistic regression model (ML) (Table 1). The ML includes two types of independent variables: micro-level variables [social characteristics of students (gender, age at enrolment, residence, family income), high school information (high school type and high school final mark) and first year performance indicators (credits and average mark)]; meso-level variables [university context information (length of first enrolment study course and limited enrolment course)].

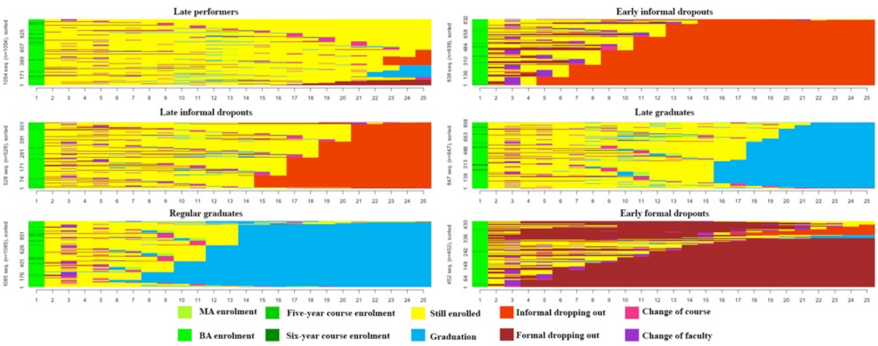
The main result shows the importance of the warming-up in determining the development of each career. The first year performance indicators are the best predictors of success. Furthermore, the university context information, especially the length of first enrolment study course, are important: students enrolled in a 5 or 6 year-course stand more chances to graduate than BA students.

Table 1. Odds ratio of ML for entire cohort 2001-2002

		Early informal dropouts		Late performers		Regular graduates		Late graduates		Early formal dropouts		Late informal dropouts	
		OR	sig.	OR	sig.	OR	sig.	OR	sig.	OR	sig.	OR	sig.
	Constant	0.673	***	0.048	***	0.014	***	0.051	***	0.497	***	0.077	***
Gender	Male	1.245	***			0.823	***					1.097	.
Age at enrolment	20-24 years	1.814	***	0.826	***			0.672	***	0.751	***	1.403	***
	25 year-courses or more	2.681	***	0.735	***	1.424	***	0.352	***	0.596	***		
High school type	Technical-Professional	1.499	***	0.845	**	1.224	***	0.773	***	0.909	.		
	Other	1.500	***			1.357	***	0.732	***				
High school final mark	Medium	0.889	*			0.895	.	1.182	***	1.183	***	0.870	*
	High	0.713	***	0.852	*	1.157	*	1.158	*	1.335	***	0.655	***
Residence	Regional	0.756	***			1.376	***						
	Out of region	0.685	***							1.627	***	0.771	***
Family income	1-10000 euro			1.305	**			0.864	.			1.195	.
	10001-20000 euro			1.337	***					0.852	.		
	20001-30000 euro			1.313	***								
	30001-40000 euro			1.189	.								
	40001 euro or more	0.836	.										
Length of study course	5 years	0.758	*	1.643	***	0.160	***	2.620	***	0.711	***		
	6 years	0.295	***	1.854	***	0.013	***	5.081	***	0.571	*	0.306	***
Limited enrolment course	Yes	0.788	***			1.239	***	0.836	***	1.255	***		
First year credits	1-15 *Ects*	0.705	.	3.184	***					0.570	*	2.588	***
	16-30 *Ects*	0.234	***	3.920	***	5.292	*	4.238	***	0.206	***	2.949	***
	31-45 *Ects*	0.067	***	2.426	***	15.837	***	6.204	***	0.083	***	1.769	.
	46 *Ects* or more	0.025	***			36.346	***	4.836	***	0.028	***		
First year average mark	Low	0.648	*					2.244	.				
	Medium	0.582	*					2.447	.				
	High	0.586	*										

*Sig. Code: 0 '***' 0,001 '**' 0,01 '*' 0,05 '.' 0,1 ' ' 1*

Through the use of the same clustering algorithm, performed on the OM distance matrix related to careers with one or more states of mobility, we obtain similar groups (Graph 7). Obviously, a greater complexity of careers, which has already been highlighted in the Graph 3, is also present in these subgroups. The discontinuity of career of the sixth group (early formal dropout) is very blatant. The index-plot for this group (Graph 7) highlights how the formal dropping out is very widespread. This phenomenon affects the students' career in a different way respect to the informal dropping out: many students, after formally dropping out, enroll again at Sapienza, maybe in a different faculty or study course.



Graph. 7. Index-plot for the six groups, mobility students' careers

Through the studying of the mobility among faculties/courses as a population migration and thinking of the institution (Sapienza) as a multitude of elements, variously connected among each other (Mohr and White 2008), the Social Network Analysis (SNA) tools are used to identify structure characteristics of the mobility (Graph 8).

In order to study the relevance of the connections among the events of each trajectory (such as within and between mobility), the OM analysis was performed on the careers with one or more mobility events. With the use of the previous clustering algorithm, we obtained similar groups. The SNA was used to identify attraction and repulsion nodes among the Sapienza study courses.
The network among study courses allows us to visually observe how the core (stronger connections) is mainly occupied by the BA courses (in purple). The MA courses (in red) are arranged radially around the central core. This position is due to the links that some of these courses have with other different duration courses, particularly five-year courses. For instance, a well-defined group is composed by the six-year courses. These nodes are only the degree programmes in Medicine, which has a six-year term. The proximity of these courses to the rest of the network is given by the relations with some Pharmacy courses and some Mathematical, Physical and Natural Sciences courses (MMPPNNSS).

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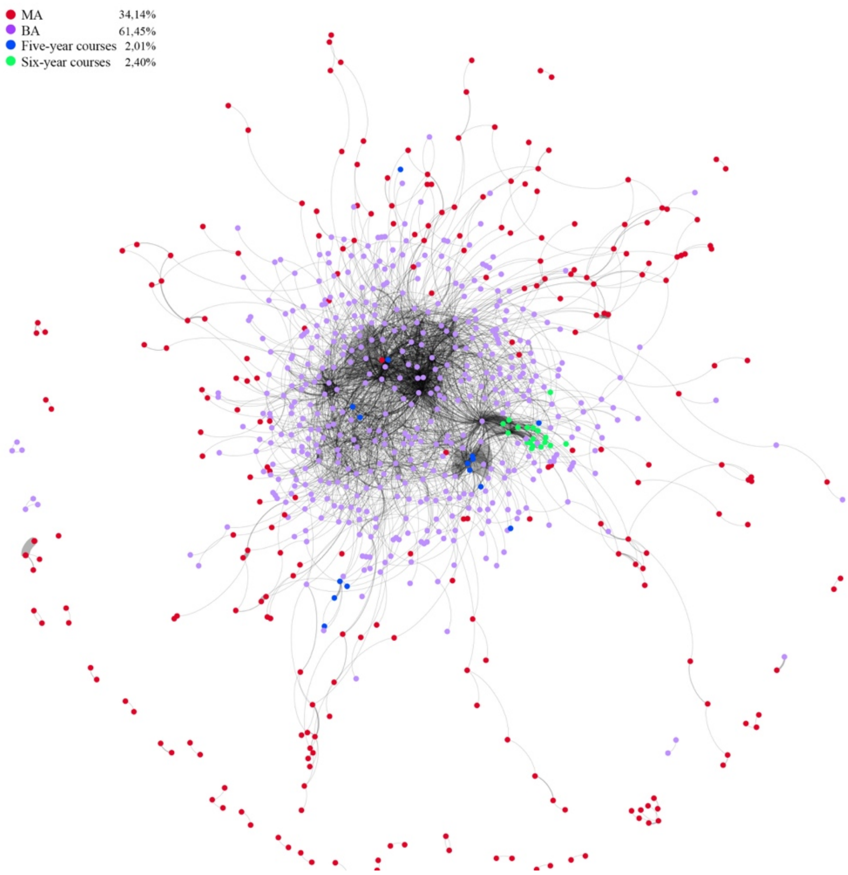
This analysis allowed us to identify specific study courses (such as Life Sciences, BA course in MMPPNNSS faculty, and Pharmacy, five-year course) used by students to circumvent the admission tests of medicine courses.

Five-year courses (15 in total) do not resemble among each other, but they appear to be divided into small groups, and they are more similar to other BA courses, which partially share educational curricula: for example, Construction Engineering (BA) is similar to Architecture course (five-year course).



Graph. 8. Change of study course according to legal course length, entire cohort 2001-2002

A second ML aims to explain the outcome through temporal and spatial information. The dependent variable in the analysis is the career outcome: still enrolled (reference category), graduate and dropout. The dependent variables are all features related to the ongoing changes: time related (timing of change; difference in course length) and context related (type of change; difference in course scientific area). The timing of change is identified as the most relevant success predictor, confirming that the warming-up period is fundamental for the career outcome.

Table 2. ML for mobile students' careers of BA*

Outcome[a]			T	Std. Err.	Wald	gl	Sign.	Exp(B)	Exp(B)-1*100
Degree		Intercept	0.3	0.566	0.28	1	0.596		
	Timing of change	2th year	3.308	0.202	266.900	1	.000	27.323	2632.303
		3th year	2.753	0.219	158.568	1	.000	15.683	1468.343
		4th year	2.487	0.269	85.537	1	.000	12.026	1102.604
		5th year	2.523	0.319	62.521	1	.000	12.468	1146.782
		6th year	2.194	0.236	86.208	1	.000	8.975	797.509
		Beyond the 6th year	0[b]			0			
	Type of change	Faculty change	-0.183	0.203	0.812	1	0.368	0.833	-16.724
		Study course change	0[b]			0			
	Difference in course length	Equal length	-0.740	0.520	2.021	1	0.155	0.477	-52.271
		Upper	-1.535	0.536	8.203	1	0.004	0.216	-78.448
		Lower	0[b]			0			
	Difference in course scientific area	Same sc. area	0.387	0.21	3.401	1	0.065	1.473	47.3
		Different sc. area	0[b]			0			
Dropout		Intercept	-0.241	0.566	0.182	1	0.67		
	Timing of change	2th year	1.813	0.194	87.591	1	.000	6.128	512.799
		3th year	1.518	0.210	52.063	1	.000	4.561	356.082
		4th year	1.764	0.260	46.060	1	.000	5.834	483.403
		5th year	1.882	0.316	35.561	1	.000	6.569	556.886
		6th year	1.683	0.243	48.163	1	.000	5.382	438.178
		Beyond the 6th year	0[b]			0			
	Type of change	Faculty change	1.059	0.199	28.178	1	.000	2.883	188.349
		Study course change	0[b]			0			
	Difference in course length	Equal length	0.007	0,521	,000	1	0,989	1.007	0.735
		Upper	-1.674	0.541	9.558	1	0.002	0.188	-81.244
		Lower	0[b]			0			
	Difference in course scientific area	Same sc. area	0.509	0.205	6.156	1	0.013	1.664	66.354
		Different sc. area	0[b]			0			

a. Reference category: Still enrolled.
b. This parameter is zero due to redundancy
* the model refers only to the BA students and at the first career.
Cox e Snell pseudo R^2 0.187; Nagelkerke pseudo R^2 0.222; -2log final model 412.917 sig. <0.001

Firstly, the model parameters show that the timing of change is crucial: the chance to graduate rather than to remain registered is higher as soon as the change occurs.

The type of change (course or faculty) is not significant with reference to the probability of graduation or to the fact of still being enrolled, but it is related to the probability of dropping out: a change of faculty nearly doubles the probability of dropping out rather than being still enrolled with respect to a change of study course (Exp (B) -1 * 100 = 188.3). Therefore, we can confirm the assumption that a strong reorientation (which determines the faculty change) requires a higher investment compared to a weak reorientation (such as a change of study course within the same faculty), exposing more students at risk of dropping out.

Mobility between equal-length courses seems not to have a significant influence neither on the probability of graduating nor dropping out, compared to the probability of persistence inside the system. On the contrary, the "upper" exchange, i.e. the course change from a shorter to a longer one, reduces both the probabilities of graduation and dropping out, rather than the continuation (respectively with Exp (B) -1 * 100 = -78.4 for the graduation and -81.2 for the dropping out. This effect could be determined simply by the increased duration of the second course of study. However, with reference to the lower probability of dropping out, this effect could hypothetically also be determined by a strong motivation of these students.

Any difference between the scientific area of the original course and the scientific area of the second one has a double effect on the outcome: students who change course or faculty within the same scientific area are more likely both to graduate or to drop out rather than to continue (Exp (B) -1 * 100 47.3 for the graduation and 66.3 for the dropping out). However, only the dropping out effect is statistically significant. This evidence shows that the mobility between different scientific areas represents a higher chance of still being enrolled than the changes within the same area.

Summary and conclusions

This paper shows the value of transforming synchronic administrative information into diachronic data vectors. Throughout this transformation, we were able to obtain a longitudinal dataset of students' careers and to investigate their dynamics by highlighting specific phenomena (dropping out, stopping out, mobility, degree attainment, etc.) and the connections among them.

The longitudinal structure allows us to study all the processes characterised by continuous changes, such as university careers. The students' careers complexity was examined in detail with the use of SA. The main results show the importance of the warming-up period (in terms of study course reorientation and first year performance) in determining the success/failure of each career.

The SA and the SNA have allowed us to look into the events related to the university dispersion. For instance, these tools have allowed us to reveal how, almost all the changes, related to the medical courses take place in the early part of the career. In most cases, these changes are strategies applied by the students who fail the first time medical limited enrolment course test, and try again in subsequent years.

All this will lead to improper management of the resources by the University: while the medical courses are becoming increasingly competitive (students who attend medical test are not high school graduates but students already included in the university context), those of Pharmacy and MMPPNNSS courses constantly lose students.

The analysis is a pilot methodological study but it can easily be used for evaluation purposes. Universities, faculties or degree programs can adopt these tools in order to monitor the career dynamics (monitoring purpose) and to promptly intervene in order to contain the dispersion phenomena (action purpose).

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