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A TIME HAZARD ANALYSIS OF STUDENT PERSISTENCE: A US UNIVERSITY UNDERGRADUATE MATHEMATICS MAJOR EXPERIENCE

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ABSTRACT. Individual level data for the entire cohort of undergraduate mathematics students of a relatively small US public university was used to estimate the risk that a student will switch major to another one before degree completion. The data set covers the period from 1999 to 2006. Survival tables and logistic models were estimated and used to discuss student's switch from their initially planned mathematics major to another. An important goal of low enrollment university departments is to increase enrollment and to attain a high retention rate. Major switching indicates a failure of these departments to retain potentially able students. Students' retention is also an important issue for university programs evaluation and funding. The goal of this work is to investigate the timing of switching major, to a different one, by mathematics students. We estimated the probability of occurrence of this event for different school terms and when this event is most likely to occur. The empirical results suggest that the probability of a mathematics student switching major varies from a high 23 % early in student's major enrollment to a low of about 6 % in later semesters. Mathematics education majors, however, showed inferior risk of switching major. Gender differences were also examined, showing no significant gender differences.

KEYWORDS: logit, major, mathematics, probability, STEM, survival table, switching risk

INTRODUCTION

Student persistence and major switching has been, for decades, the focus of considerable research activity. Researchers' attention has generally been centered on conventional student drop-out factors (e.g. student precollege characteristics, SAT scores, college GPA, gender, and ethnic background). The present study investigated the theme of the timing of mathematics students switching from their initial plan of graduating with a bachelor degree in mathematics to a different major. This is referred to, in the literature, as educational timing events (Ahlburg & McCall, 2002; Willet & Singer, 1991). Two other subthemes were studied in relation to their effect on individual staying in mathematics as follows: (1) the difference between mathematics and mathematics education students and (2) gender role in the decision to switch. To estimate the risk of changing major, survival tables were estimated using SPSS software. They revealed the number of students at risk of major switching, the number of effective major switches, and the proportion of switchers for each of first eight terms of students' enrollment. A dataset of longitudinal observations was used to estimate a logit model for undergraduate mathematics students' major change. Clearly, students' major switch is not due to a single factor and our objective was not a general multifactor study of the problem of dropout. We found that many of the studies that attempted to estimate the enrollment duration and time when science, mathematics, and engineering (S.M.E) students leave a college major were generally using simple sample descriptive statistics. Regression models were mostly applied to study the effect of individual factors on persistence and drop out but not on the duration of enrollment and time of major switch. The contribution of this work is to introduce these elements in the analysis of major switch from mathematics to other majors as experienced by undergraduate mathematics students in a US public regional university.

In literature, there are reports on the differences between universities, public, private, large and small, when studying college persistence, success, and other related problems such as the rate of departure in colleges and universities (Berger and Braxton, 1998 pp. 103 – 104; Astin, 1997). Considering these institutional differences (Tinto, 2004; Titus 2004), we favored single-institution and single major over multi-institution and multi-major analysis.

Problem Statement

Seymour and Hewitt (1997) reported that by 1989, freshmen interest in mathematics fell by four-fifth. They reported that the highest rate of major switches was in mathematics compared to all other majors in sciences, engineering, and technology (STEM fields). This is our main motivation and the rationale behind this research on mathematics major switching. Studying, specifically, undergraduate degree incompletion in mathematics and probability of students switching from mathematics major to other majors stems from our hypothesis that different higher education majors have different persistence patterns. We define persistence as a measure at student level and retention as measure at the institution level. Students persist to completion of their educational goals and institutions retain students from leaving before completion of their educational goal. All the analyses and results presented in this work are centered on student level only. There are many recurrent themes of student's attrition, in general, that include academic underpreparedness, financial difficulties, ethnicity, transition problems, and student adjustment to college life. In this case, however, we studied the duration of mathematics students' career, the risk of switching major, and the probability of occurrence of this event at any specific time during student enrollment.

Literature suggests that in general, students' withdrawal rate from their planned majors is more severe among freshman (Kalsner, 1991, Smith & Naylor, 2001). Is this true for mathematics major? What are the chances of mathematic major student staying in the major well beyond freshman year and then face risk of moving to other major? The varying switching major risk was estimated for undergraduate mathematics majors at different points in time. A first step in this direction was carried out by calculating a survival table for these mathematics majors for several school terms.

There have been some studies of similar questions for some other university majors, such as economics (Chizmar, 2000; Horvath, Beaudin & Wright, 1992), but to our knowledge, it seems that there is a lack of specific studies of this nature as they relate to mathematics majors. We do have the annual surveys of mathematical sciences by the American Mathematical Society (notices of the American Mathematical Society, 2010) that provides key information on the enrollment trends and graduation statistics in mathematics. These surveys are multi-institutional by nature. They keep track of and document the annual changes in enrollments and degrees granted by mathematics departments, from bachelor to Ph.D. granting, private and public institutions (AMS 2007 survey, AMS 2009 survey, in Notices of the American Mathematical Society 2008 and 2010).

The documented variability of student persistence across higher education institutions (Titus, 2004) and the extension of these differences to majors inside the same institution underscore the challenges of finding common solutions to the persistence problem that could work across university majors. Major switching in low enrollment mathematics departments results in loss of resources, as their allocation is based on the size of student count, and could affect, negatively, the program evaluation. This has been the case of the department we are using as a model for this work. The number of yearly graduates has fluctuated from as low as less than 10 graduates to about 30, in a university of close to 8,000 students. This clearly has adversely affected any long-term planning for the future direction of mathematics major. We postulate that there are many mathematics departments with similar experiences. Higher education programs goals frequently involve, besides quality in teaching and research, reaching a sufficient quantity level of degree completion for a major to stay viable. This is achieved by demonstrating a sufficient number of students recruited and retained. Outside large enrollment universities, mathematics departments should be concerned about ways of keeping more of their students from leaving, as they compete with other majors for their university-limited resources.

There exists a substantial amount of research on the role of gender in science, technology, engineering, or mathematics (STEM) in persistence. It is as well important to continue to explore the role of gender in student's persistence in mathematics, in particular, granted all the progress that has been made in this area. In the American Mathematical Society 2009 annual survey of the mathematical sciences in the US, the situation of women in mathematics was discussed. The report indicated that "as the data show, there are encouraging signs that the obstacles these women encountered in the past in establishing careers in mathematics are lessening." After discussing recent successes, it stated that "the solutions to the problems that remain are not simple or straightforward." It is argued that the "critical mass" of women faculty and students in the mathematics departments creates an "atmosphere in which being a woman in math is ordinary and normal." (see the notices of the AMS, 2010, p. 780). One of the ways to reach this goal is to increase the persistence rate of women students in mathematics major. Some universities have special programs to encourage women in mathematics (AMS notices, volume 51, number 7; p. 780). As more women enroll in mathematics, more research on their persistence in the major is needed.

Finally, there are mathematics departments, such as the one that is the subject of this work, that have their mathematics education program combined with mathematics program in the same major. It seemed natural to study any switching risk differences between mathematics and mathematics education students and their tendencies to stay or switch major.

The rest of this work is organized as follows: in the next sections of this paper, we start by presenting a comprehensive review of literature showing the strong interest of the research community in the subject, the progress made, and the difficulties encountered and arguing for the need of further research of the problem of student persistence in all STEM fields in general and mathematics in particular. We then present the data used and our proposed method of analysis. This is followed by a presentation of the preliminary results obtained by the calculating survival tables for mathematics and mathematics education majors including gender differences. Statistical models are then presented and estimated to determine the mathematics major switcher risk profile and the probability of switching major from mathematics to other majors. Finally, the results obtained in this analysis and the limitations of this work are discussed. An appendix showing the details of the models used and methods of estimation is also given.

Literature Review

Reason (2009) suggested that student retention has been one of the primary goals for higher education institutions for several decades, and "efforts to improve retention seem to be difficult if not ineffective" (Reason, 2009). Given the strong demand from various quarters to demonstrate an evidence of student success (Kuh, Kinzie, Buckley, & Hayek, 2006), the question has frequently been: how to measure this success? Kuh et al. argue that one of the quantifiable student attainment indicators is persistence to sophomore year and the length of time to degree and graduation.

How important are institutional differences (such as type and selectivity) regarding the levels of students' persistence in their initial major? Berger and Braxton (1998) discussed the supporting empirical evidence of the importance of organizational attributes in student persistence experiences. They reported rate differences between different type of institutions, ranging from 2 year colleges with 50 % departing rate in the first year to 4-year collegiate institutions with 28.5 % and highly selective colleges with 8 % rate of departure in the first year as well. Consequently, they argue that "there is departure puzzle related to institutions specific conditions" (Berger & Braxton, 1998). Murtaugh, Burns and Schuster (1999) used survival analysis theory to predict the retention of university students using variables such as first quarter GPA, residency, ethnicity, and other factors. They suggest the existence of "important independent association of student retention with age, high school performance, ethnicity, etc. in their quest of identifying enrolled students who are at risk of withdrawing before graduation" (Murtaugh et al., 1999, p. 369). Zwick and Sklar used regression and survival analysis to discern differences in student achievement patterns between subgroups of student population, e.g., Hispanic/English and Hispanic/Spanish groups (Zwick & Sklar 2005).

Smith and Naylor (2001) examined a sample of over 70,000 UK students in their statistical analysis of the probability of withdrawal for UK university students. They used a binomial probit model to estimate the probability that an individual withdraw from a university program before degree completion. They suggested evidence to support both the hypothesis that the completion of courses by students is influenced by prior academic preparedness and the hypothesis that social integration at university is important (Smith & Naylor, 2001). Other studies focused on increasing students' interest in STEM fields. Jensen & Sjaastad (2013) studied a Norwegian out-of-school program designed to increase students' motivation to major in a STEM area and concluded that the project enhanced reasons for choosing STEM by improving participants' skills and confidence in mathematics abilities.

The importance of issues of gender persistence and degree completion in STEM fields has drawn the attention of researchers. Many studies were dedicated solely to these issues, particularly for mathematics, science and engineering majors (Seymour & Hewitt 1997; Meadows, Nidiffer, Ball, Davis, Finelli & Schultz, 2006; Griffith, 2010; Özgür et al., 2010; Ellis, Rasmussen & Duncan, 2013). The greatest proportionate loss of women by switching occurs in mathematics/statistics and biological sciences (Seymour & Hewitt, p. 20). For other majors such as economics, the issue of gender was also investigated. Chizmar (2000) used a logit model to study the role of gender in persistence in the economics major. After controlling for different factors such as relative grades and economics credit hours, he found no difference in the hazard profile of major switchers between male and female in economics major, and noted that his conclusion differs from other studies. However, in investigating gender differences in economics courses, Horvath et al. concluded that their results suggest that female students need more validation than male students to persist in the study of economics, considering that individuals enter institutions of higher education with a variety of attributes, e.g., sex, race, and ability (Hovarth et al., 1992).

In studying persistence, Tinto proposed that researchers distinguish between dropouts who are academic failures and those who are voluntary withdrawals before degree completion. These withdrawals tend to show more sensitivity to social integration than to academic integration (Tinto, 1975, 2004; Kalsner, 1991). For example, he noted, from an earlier study by Astin in 1972, that sex of the individual appears to be related to college persistence with higher proportion of men finishing college degree programs than women. They suggested that greater proportion of women withdrawal before degree completion tends to be voluntary withdrawals than academic dismissals.

Switching from STEM to Non-STEM Fields

As a major part of the general interest in persistence in higher education, persistence and degree completion among initial science, technology, engineering, or mathematics (STEM) majors have received particular attention of researchers. Recently, a research brief, on completion rates among STEM majors, by the Higher Education Research institute at UCLA (January, 2010), reported that over “the last several decades, students’ initial academic interests have been easy to tack; however, college students’ success in their academic programs have proven more difficult to examine” (HERI, 2010). The center for data exchange and analysis followed students who entered STEM bachelor’s degree in 1993 and concluded that only 38 % of these students earned a STEM bachelor’s degree within 6 years of enrollment (HERI 2010).

Persisting in, and switching from STEM majors to non-STEM majors studies were motivated by the decline of freshmen choosing math and science since 1980s (Seymour and Hewitt 1997). What should be alarming to the mathematics community is that the largest portion of this decline was evident in mathematics. As an indication of students deciding to switch early after their initial enrollment in college STEM majors, a recent study about switcher and persister experiences in Calculus I found that of STEM intending students enrolled in this course, 12.5 % switched out of a STEM trajectory, among which 31.4 % cited their negative experience in Calculus I as contributing factor. (Ellis et al., 2013).

Mathematics Pipeline Leakage

In addition, these losses, referred to as leakage, were estimated to be around 40 % in sciences, mathematics, and engineering majors (S.M.E.). At each stage, the movement in and out of the pool resulted in a net loss for S.M.E. These losses have a cumulative impact that is substantial (Seymour & Hewitt, 1997, p. 2). Based on unpublished 1993 tabulations provided by the Higher Education Research Institute of UCLA, the most stable major in the S.M.E. fields was engineering major while the most unstable was mathematics major with about 63 % who switched to other majors compared to only about 38 % for engineering and 29.9 % for humanities (Seymour & Hewitt, p. 16). Students who enroll in college or university seeking to major in science and mathematics are unusually talented. “Planned STEM majors tend to have higher high school GPAs on average and to have taken a larger percentage of their AP courses in STEM fields than students that planned to major in non-STEM field” (Griffith, 2010). Students intending to be mathematicians and physical scientists had the highest total SAT and SATM scores of any group and earned the highest grades in high school mathematics courses. A large "proportion of them will defect from science (and mathematics) majors" (Strenta, Elliot, Adair, Matier & Scott, 1994).

Inside the S.M.E fields, there is a substantial amount of research on switching from and persisting in engineering (Eris et al., 2010; Sheppard et al., 2004; Li et al., 2009; Ohland, Sheppard, Lichtenstein, Eris, Chachra & Layton, 2008; French, Immekus & Oakes, 2003; Adelman, 1998). By contrast, mathematics major switchers and persisters' experiences have not been well documented. We argue that there is a need for more specific studies of the leakage in the higher education mathematics pipeline, as students majoring in mathematics have different learning experiences than their counterparts in the other fields of S.M.E.

Studying college major choice, Porter and Umbach reported the impact that department culture and climate have on students' learning, satisfaction, and persistence in their initial major of choice. They suggest, with other authors, that "congruence between person and environment is critical to the success of college students" (Porter & Umbach, 2006). Researchers interested in persistence and success of undergraduate students seeking a degree in mathematics should not rely solely on national or multi-institutional studies to find solutions to the loss of talented mathematics students to other majors. The 2008 senior survey by the Higher Education Research institute (HERI) at UCLA found that most seniors tended to report satisfaction with their general education (Liu, Ruiz, DeAngelo & Pryor, 2009). The question becomes: what makes a large number of mathematics students so unsatisfied that they decided to switch their major? Given the large number of switchers and the instability of mathematics major (Seymour & Hewitt, 1997), the main contribution of this paper is to estimate when does the dissatisfaction with the mathematics major takes place most? Keeping talented students in mathematics major is as important as recruiting them to the major. To understand the pattern of switching, we postulate that knowing the timing of the switching risk is of significant value to departments in their fight to keep their majors. We propose to evaluate this risk using the factor time as predictor.

Data and Method of Enquiry

The methodology adopted in this paper is based on the methods of time to event analysis, a part of more general survival analysis theory (Efron, 1998; Kiefer, 1998; Willet & Singer 1991; Ronco, 1994). At first, survival tables were estimated showing the distribution of student departure and major change (major switchers). The average undergraduate mathematics student survival time (duration of enrollment in mathematics) was also estimated. Student persistence in the mathematics major is defined by the duration of enrollment until the major switch transition has eventually occurred. The likelihood of a student switching from the mathematics major was estimated. In this context, student risk profile is defined as the conditional probability p that the event of switching will occur at time t, given that it did not occur in earlier time since enrollment. Logistic model (Mohn, 2008) was then used to estimate the conditional log-odds of student switching major.

The starting time for all the considered cases is the date of the student's enrollment in the mathematics program. The duration is the time from enrollment to departure from the major. The following questions were considered: using the terminology of the theory of survival analysis, what is the student survival (in mathematics major) duration versus the hazard of switching from mathematics major? When students are most at risk of terminating their enrollment in math major? Were there differences in survival rates among different subgroups of students, e.g., male and female? And finally, how the variable time predicts the likelihood of the event?

The data consist of all available computerized students' records of undergraduate students who enrolled in mathematics major offered by the mathematics department of a regional, public university during the period covered by this study. The records included student attributes, the date of the enrollment, the date of change to other major, if applicable, and the graduation date for those students who completed the degree. They covered a period of 7 years, starting in 1999, and the enrollment of 171 students in mathematics and mathematics education majors. The available records of all students, who were registered, with declared major in mathematics, were included in the data set. The information collected reported any individual change of major and the school term it was effective. The department under consideration offers a bachelor degree in mathematics with two emphases in mathematics and mathematics education. No college dropouts were a part of the observations. We were interested in the cases of students who have prematurely terminated their mathematics major enrollment and switched to a different university major. We specifically sought to evaluate the risk (probability of occurrence) of this switch at any given time during the period at which the student was enrolled in the major. No program re-entry was observed.

Each case recorded has either switched, graduated, or was still enrolled by the time of data collection. The data analyzed contains some features typically encountered in the analysis of survival data as follows: (1) individuals did not enter the study at the same time; (2) when the study time frame ended, some individuals were still enrolled and have not yet switched nor graduated; and (3) no individual dropped out or got lost in the middle of the study time frame. The second feature relates to censoring of the (major switching) time events (Efron, 1998). As it is well known in the case of similar data, where not everyone was followed until either graduation or switching major by the time the study ended, the problem becomes more complicated. Students who were still enrolled by the end of the study and their future status (graduating with a mathematics degree or switching major) was therefore unknown were a source of incomplete information. Rather than choosing to ignore their partial, yet valuable, information in the study, they were used and called censored cases.

Preliminary Results

The characteristics observed were age, gender, residency, marital status, transfer status, math ACT, math GPA, term GPA, financial aid, marital status, past and current enrollment semesters, and full-time enrollment status. Inclusion of these factors will be the subject of a second part of this work to appear later because of the length of the full comprehensive analysis. The following two tables describe the carrier path of the 171 cases observed and who were enrolled. They indicate whether a student has experienced the event of switching major to a different one outside mathematics field. There were 53 % men and 47 % women enrolled. The average GPA was 2.94 while for mathematics courses, the GPA was 2.16. The data revealed that the variable duration time from first enrollment to leaving the major did not show correlation with the mathematics GPA.

Table 1 shows the distribution of the math major change by school term for the entire cohort. The first column report the school terms, in the second column the calculated number of student at risk of leaving the math major, and in the last column the proportion of student who have actually switched major. After accounting for the censored cases—students that did not switch nor graduated by the time the study ended, but still were included in the calculations—as reported in column 4, we see that of the 171 declared math majors, among which 168 were at risk of major switch, a total of 40 students experienced the event after 1 term, i.e., by the end of their first school semester. There were 23 who switched after 2 consecutive terms and so on. This table was estimated

TABLE 1

Survival table showing the distribution of major change occurrences

Term	*Risk set*	*Number of major switches*	*Number of censored*	*Proportion of switchers*
1	168	40	7	0.24
2	118	23	12	0.19
3	85	12	8	0.14
4	67	11	4	0.16
5	54	7	1	0.13
6	42	3	8	0.07
7	30	3	10	0.10
8	20	1	4	0.05

For each term (column 1), the number of students at risk of withdrawing was calculated (column 2) and the proportion of students who actually switched major is shown in the last column. The calculations included ten terms (5-years period); the last two terms are not shown in the tables, since their outcomes were not significant with proportions were less than 1 %

using SPSS software for computing survival tables for population at risk of a defined event, switching major in this case.

Distinguishing by gender, there were 17 men and 23 women who switched major after their first term, 14 men and 9 women at the end of their second term as illustrated for 8 consecutive terms in Table 2.

In the first term, there were 88 men at risk of changing major, and by the end of their first term, there were 17 major switches. Similarly, there were 80 women at risk and 23 switched major by the end of their first term. Finally, column 5 of Table 1 shows the proportion of students switching major by the end of the given term: about 24 % switched major by the end of the first term (freshmen year). About 13 % of those enrolled consecutively for five terms have switched major by the end their fifth term (after sophomore year), and 7 % did the same by their sixth term. Using data from the cases that changed major, the estimated mean duration in mathematics major, of a typical switcher, was about 2.58 terms. However, if we include all cases, the estimated mean of mathematics student career is higher and estimated to be about 3.84 terms.

Statistical Modeling: Switchers Risk Profile

Students switch major from mathematics to another major at different time since their initial enrollment. They may stay in the major for a longer

TABLE 2

Survival table of the distribution of major change occurrence by semester and gender

	Men			*Women*		
Term	*Risk set*	*Switched major*	*Censored*	*Risk set*	*Switched major*	*Censored*
1	88	17	4	80	23	3
2	64	14	9	54	9	3
3	44	3	4	41	9	4
4	38	10	2	29	1	2
5	27	2	0	27	5	1
6	23	2	5	20	1	3
7	15	0	7	16	3	3
8	10	1	3	11	0	1

For each term (column 1), the number of students at risk of withdrawing was calculated (column 2 for men and column 5 for women) and major change is reported in columns 3 and 6. Only the results of eight terms are reported in the table. The results of the ninth and tenth terms were not significant

or shorter period before making the decision to switch. To derive the probabilities of switching, some assumptions needed to be made to simplify the multidimensional context of the problem. Each individual in the data was enrolled in successive terms until the event of eventually switching major took place. The other alternatives were either graduation with a mathematics degree or being still enrolled by the time of data collection. Individuals may decide to switch at any point of time after entry in the major but the transition is recorded, thus becomes effective, only by the end of a school term (discrete time). For these reasons, discrete time analysis was used to assess the risk of experiencing these single nonrecurrent events, where the independent variables represent the school semesters. Following are the estimates of the parameters of logit model (Appendix, Eq. 1) when considering in the first implementation of the model only the effect of the independent variable: time-indicator.

The results obtained from parameter estimates to evaluate the odds of a student leaving the math program at a given term are partially presented in Table 3. Ten school semesters were used as explanatory variables in this logistic regression with the independent variables D_{it}, where the index i represents the individual and the index t the time (see Appendix for formal definition).

The model was solved using ten semesters. The ninth and tenth term are not sown in the table. Their estimated probabilities were not significant. Column 5 in Table 3 shows the probabilities of switching in

TABLE 3

Model 1 parameter estimates

Semester	*β*	*p value*	*Exp β*	*Probability of switching major*
D1	−1.227	0.000 *	0.293	0.227
D2	−1.376	0.000*	0.253	0.202
D3	−1.872	0.000*	0.154	0.133
D4	−1.663	0.000*	0.190	0.159
D5	−2.079	0.000*	0.125	0.111
D6	−2.686	0.000*	0.068	0.064
D7	−2.367	0.000*	0.094	0.086
D8	−3.091	0.003	0.045	0.04

*p value <0.001; the first column indicates semesters, the second and third columns show the model parameters and the p values, and finally the estimated probability of switching major in the last column

for the first eight semesters. The cumulative probability for these semesters is surprisingly high even with the visible pattern of the diminishing estimated risk of leaving the mathematics major. There is a high probability that a typical mathematics student will switch major before even completing freshman year and even before starting the second semester. The decision of switching was made some time during the first semester with a significant likelihood. We presented in Table 3 a series of probability estimates, semester by semester of the major change decision making by students. It was estimated that the probability of a student switching major by the end of the first semester was approximately 23 % while there were, respectively, significant but lower switching risks in the subsequent semesters. This was shown by the conditional probabilities of 20 and 13 % risk of leaving mathematics major in the second and third terms, respectively. These probabilities should be interpreted in the following way: given that a student did not switch after one semester, there is a 20 % probability of switching after two semesters. There is a 13.3 % probability of switching major after the third semester given that the student did not switch in the first two semesters.

These estimated probabilities showed that the chances of a student quitting the mathematics program were substantially higher during the first four semesters. These results give some indications on the issues of keeping students in mathematics major, faced by mathematics departments, such as the one we are studying, by effectively estimating the risk level as student progresses in their mathematics career. They suggest that any remedies to loosing students to other majors must be taken very early after student initial enrollment. Measures taken after students has completed freshman year may have reduced effect on the pool of students for which the measures were designed. They may end up, at best, helping fewer students to continue pursuing mathematics degree.

These estimates suggest that once students are set on their academic goals and become more academically integrated in the program (possibly after several semesters), the probability they will leave mathematics major are much lower. One set of action should be designed to help students define clearly their academic goals and to help them academically integrate mathematics program. In discussions with students after this work was completed, we found that mathematics education students have their academic goals more clearly defined than their counterparts in mathematics.

Model Extension

Two extension models, using gender and degree emphasis, will be considered in the remaining of this paper. Do the results, discussed above, differ by gender for example? Are these results different when considering pure mathematics versus mathematics education students? We discuss now these two cases: gender effect and degree emphasis effect for mathematics education students. A binary dummy variable was introduced for gender in the model (Appendix, Eq. 2). Model 1 was reestimated after this gender variable was introduced in the model. The estimates showed no significant difference between male and female probabilities of switching major. Even after controlling for other factors, the conclusion did not change when considering gender differences. Interestingly enough, a similar conclusion was reached in (Chizmar, 2000) for economics major students. The parameter estimates for this equation are given in Table 4, model A. In the second extension of the initial model, a binary dummy variable representing students either enrolled in mathematics education or mathematics was introduced in the original model. The results are reported in Table 4, model B. The results in this case showed a significant difference in major switching patterns between these two majors. The probability of moving to other major was significantly lower for mathematics education students compared to mathematics major students.

The first column in Table 4 shows the time periods measured again in school terms, the gender binary variable (for model A, column 1 in the

TABLE 4

Model parameter estimates: Models A and B for women and math

	Model A			*Model B*		
Period	*β*	*p value*	*P (switching)*	*β*	*p value*	*P (switching)*
D1	−1.268	0.00 *	0.235	−1.147	0.00*	0.194
	(.208)**	(0.184) **				
D2	−1.415	0.00*	0.21	−1.457	0.00*	0.159
	(.243)**	(.242) **				
D3	−1.914	0.00*	0.139	−1.725	0.00*	0.131
	(.327)**	(.313) **				
D4	−1.700	0.00*	0.166	−1.477	0.00*	0.157
	(.341)**	(.334) **				
D5	−2.124	0.00*	0.115	−2.004	0.00*	0.103
	(.447)**	(.474) **				
D6	−2.726	0.00*	0.067	−2.461	0.00*	0.073
	(.605)**	(.601) **				
D7	−2.408	0.00*	0.089	−2.157	0.00*	0.094
	(.612)**	(0.609) **				
D8	−3.134	0.002	0.045	−2.884	0.005	0.050
	(1.028)**	(1.027) **				
Female	0.088	0.678	0.522			
	(.211)**					
Math education				−1.198	0.004	0.232
				(.420)**		

Note
*$p<0.001$
**Standard errors. Column 4 reports the likelihood of a female undergraduate switching major and column 7 reports the likelihood of a math education student switching major. Female *p* value is 0.678; the estimated parameter for the variable female is not significantly different from zero

Table), and the degree emphasis with math education set equal to 1 and 0 otherwise (for model B, column 1 in the Table). Only eight semesters are reported in the Table 4. The parameter estimates for the ninth and tenth semesters were not significant. For both models A and B, columns 2, 3, and 4 show the parameters estimates, the *p* values and the probability of moving to a different major, taking into account the gender and the mathematics education major emphasis factors.

Model A of Table 4 shows the effect of the independent variable gender on dependent variable switching major for a female mathematics major. The variable gender did not show a significant effect on the risk of moving to a different major. The results show that, taking the gender factor into account, the conditional probability of a woman student in mathematics switching major was estimated at 23.5 % in her first school term, then 21 % and about 14 % in her second and third school terms, respectively. This roughly coincides with our earlier all gender estimates.

Model B estimates the effect of majoring in mathematics education on the estimated probabilities. The parameters estimates show that the variable mathematics education has a significant effect on the risk of switching major, with mathematics education students more inclined to stay in their major. Column 3 of model B shows that the conditional probability of a mathematics education student leaving the major is lower at about only 19 % in the first semester and about 16 and 13 % in the second and third school terms, respectively. These probabilities for mathematics education students were significantly lower in the first four school terms. This difference decreases and almost disappears after the fourth term.

Discussion and Conclusions

The analyses presented in this work, when taken together, revealed a more comprehensive understanding of mathematics major switching timing, enrollment duration until the switch, comparison of gender switching pattern, and switching from mathematics education. For each semester, for the duration of the study, we measured the risk set that consists of those students who were at risk of switching major and the number of students who actually switched form mathematics to other majors.

We then used a binary logit model to estimate, semester by semester, the probability that an undergraduate mathematics student switch to a different major. The data used was provided by the university records system. We estimated that the probability of mathematics major students moving to different majors is high from the first semester and continues to be relatively high for several semesters.

Findings

A significant drop in these probabilities occurs only after students have stayed enrolled for about five consecutive terms. This should give institutions and departments (faculty, administrators) enough time, between student initial enrollment and the switch, to intervene to stop the leakage in the mathematics major pipeline. At the same time, the cumulative impact of these high probabilities is substantial and should constitute a source of worry to faculty and administrations. Having mathematics faculty aware of students' change of major patterns as exhibited in these analyses is the first condition to have faculty participation in finding solutions. We believe that these findings have also implications for teaching (the courses taught in the early semesters) and student advising. Being aware of how major switching process takes place should lead faculty to change the way they interact with their students in and out of the classroom. We do not claim that the solutions rest solely on the faculty shoulder, but faculty awareness of, and interest in the problem are important, if the goal is to increase the number of students staying in the major. The findings should also suggest to the department that having a system of early detection of students at risk of changing major may be one of the most important actions to take.

Gender

On the positive side, an interesting finding was revealed in the part of this work related to gender differences. The evidence suggests that the probabilities of major switch for women majoring in mathematics are not different from those of men in the same major. The analysis of gender presented could be used as an indication on the ways and actions to increase the number of women graduates in mathematics program in the case of imbalance. Potential effort toward women in mathematics needs to be at the recruitment level, and measures to decrease the rate of switching from one major to another need not have different treatment for already enrolled female mathematics students. They are doing as good as men. This contrasts with earlier reports on higher propensity to persist showed by men (58.8 %) than women (47.6 %) in S.M.E. overall majors (Seymour & Hewitt, p. 19).

A survival table was estimated. The estimated average time of student persistence as mathematics major was about 3.84 terms. However, for the cases that actually changed major, the estimated mean duration of a typical student enrollment was much lower at 2.58 terms. This confirms the conclusion that action toward at-risk students should be very early.

Strengthening orientation, student-faculty relation, and student mentoring by faculty and senior students, from the start, could have a positive impact on the problem of switching major. This may also include helping students to be well-informed about career objectives in mathematics.

Mathematics Versus Mathematics Education Major

We view this factor as one of the major differences between mathematics and mathematics educations students. The later generally do have a clearer view about their carrier objectives and path as they are trained to be teachers. Defining a career path is not as straightforward for mathematics major students as it is for other majors such as engineering, medical fields, or computer science. Not having, since initial enrollment, a clear vision of future career path after earning a mathematics degree puts mathematics students in a clear disadvantage, compared to other majors, as this weakens their goal commitment. This may explain why mathematics major was considered the most unstable major in the STEM fields with the highest rate of switchers. Switching major from mathematics to another one is probably influenced by many factors. The fact that this probability is much higher after the first two terms may indicate a significant sensitivity of switchers to the obstacles they may face in their efforts toward integration in the mathematics program. Success in retaining these early major switchers may require addressing the issue of how to quickly integrate them academically in mathematics programs and be familiar with these programs culture. The fact that the probabilities of moving out of mathematics remain high for a longer time points to the difficulties or failures of mathematics departments to fully integrate these students.

Limitations

Some limitations of this work are worth mentioning. Besides the time risk analysis, the results presented were purposely limited to the analysis of the effect of only two factors. An extension of this work will benefit from the use a multivariable model (Cabrera, Nora and Castaneda, 1993). It will have the advantage of resulting in a refinement of these findings by the inclusion of other factors, such as students' educational background in mathematics, financial aid, and other individual attributes, that may interact with any switching major decision. In our view, there is a real need for more general examination of (specifically) mathematics students changing major after they initially have planned to seek a bachelor degree in mathematics.

Appendix

Deriving the Model

Consider an individual i at a time t, where the time periods are measured in school terms. Let the dummy variable $y_{it}=1$ if the withdrawal event has occurred for individual i at time t and $y_{it}=0$ if the event has not occurred for individual i at time t. A binary variable D_{it} is used as an indicator of the school terms. It takes value 1 if a student is currently enrolled at time t.

$$D_{it} = \begin{cases} 1 & \textit{if individual i is currently enrolled at time t} \\ 0 & \textit{if individual i is not enrolled at time t} \end{cases}$$

The hazard probability of an outcome, describing the risk of its occurrence at time t, is defined by the conditional probability of not sampling a "yes" during the periods 1,…, t-1, but sampling it in period t, and is defined by (note that the event of withdrawing will only take effect according to the school term schedule)

$$h_{it} = \Pr\left\{y_{i,t} = 1 \middle| \; y_{i,t-1} = 0\right\}$$

A direct interpretation of the results of the probability model is based on the notion of log odds where the logit model is simply a linear additive model for the log odds. The odds that the event will occur, i.e., y_{it}=1, is

$$\frac{h_{it}}{1-h_{it}}$$

The following are estimates of the parameters of logit model considering, at first, only the effect of the independent variables time indicator:

$$h_{it} = \frac{1}{1 + Exp\left[-(\beta_1 D_{i_1 t} + \beta_2 D_{i_2 t} + \ldots\ldots + \beta_T D_{i_T t})\right]}$$

This is equivalent to:

$$\log\left(\frac{h_{it}}{1-h_{it}}\right) = \beta_1 D_{i_1 t} + \beta_2 D_{i_2 t} + \ldots\ldots + \beta_T D_{i_T t} \quad (1)$$

The results obtained from parameter estimates to evaluate the odds of a student leaving the math program at given term are partially presented in Table 3. Ten school terms were used as explanatory variables in this logistic regression with the independent variables D_{it}, where the index i represents the individual and the index t the time.

Extension A: a binary dummy variable was introduced for gender in the model with Female = 1 and Male = 0:

$$\log\left(\frac{h_{it}}{1-h_{it}}\right) = \beta_1 D_{i_1 t} + \beta_2 D_{i_2 t} + \ldots\ldots + \beta_T D_{i_T t} + \beta^{*} Female \quad (2)$$

Extension B: a binary dummy variable was introduced for gender in the model with mathematics education (MathEd) = 1 and mathematics = 0:

$$\log\left(\frac{h_{it}}{1-h_{it}}\right) = \beta_1 D_{i_1 t} + \beta_2 D_{i_2 t} + \ldots\ldots + \beta_T D_{i_T t} + \beta^* MathEd \quad (3)$$

We used The SPSS software to solve these models as well as to compute the survival table. Estimating the probabilities: let β_t be the estimated parameter for semester t and let the indicator variable D having value 1 for semester t and zero for all other semesters. Equation (1) becomes

$$\log\left(\frac{h_t}{1-h_t}\right) = \beta_t$$

Solving for the probability h, we get:

$$h = \frac{e^{\beta}}{1 + e^{\beta}} \quad (4)$$

With β_1=−1.227 for semester 1 in Table 3, the probability of switching is

$$h = \frac{e^{-1.227}}{1 + e^{-1.227}} = 0.22671$$

All probabilities in the Tables 3 and 4 are evaluated in the same way.

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